FACTORS INFLUENCING CROSS UTILIZATION TRAINING IN AIRCRAFT MAINTENANCE FABRICATION

GRADUATE RESEARCH PAPER

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Abstract

Cross Utilization Training (CUT) in the Air Force is training an individual on the tasks of another individual, usually in a different specialty. There is not a standard method of selecting potential candidates for CUT and more often than not, leaders make these decisions based on "gut feeling" or at the very best, some form of arbitrary performance criteria from the current job. Performance in one specialty is not necessarily indicative of future performance in another specialty. The goal of this research was to identify areas that affect performance in CUT in order to maximize the effectiveness of CUT.

The researcher collected performance data of 25 personnel of varying demographics at 3 different locations each performing 5 different tasks from the Metals Technology and Non-Destructive Inspection career fields. Based on the type of dependent variable in the performance data, the researcher used a combination of linear, bivariate, and ordinal regression to assess relationships between demographics, confidence, experience, recency and the task performance data.

Although the data sample size was small (25), there were some statistically significant models. For three of the five tasks, confidence, experience, and recency were good indicators of performance. Future training should be focused on depth within smaller groups rather than breadth of larger groups.

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I would like to express my sincere appreciation to my faculty advisor, Lt Col Matt Roberts for his guidance and support throughout the course of this research. I would also like to thank my sponsor, Col Jonathan Bland from the Air Mobility Command Logistics, Engineering, and Force Protection Directorate (AMC/A4) for both the support and latitude provided to me in this endeavor. Furthermore, the Air Mobility Command Fabrication gurus, SMSgt Josh Huber and MSgt Sharif Abouomar were absolutely critical to this effort and I cannot thank them enough for selflessly contributing to this research. Finally, I want to thank the men and women of the 3rd Maintenance Squadron at Joint Base Elmendorf-Richardson, the 60th Maintenance Squadron at Travis Air Force Base, and the 305th Maintenance Squadron at Joint Base McGuire-Dix-Lakehurst who demonstrated their outstanding hospitality, amazing talents, and relentless professionalism while hosting me in the data collection process.

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FACTORS INFLUENCING CROSS UTILIZATION TRAINING IN AIRCRAFT MAINTENANCE FABRICATION

I. Introduction

General Issue

The purpose of this paper is to identify factors that influence task performance within the fabrication Air Force Specialties (AFSs) and assess the impact of multiskilling as it aligns with current Air Force strategy and "Fabrication Flight of the Future" initiatives. In February 2020, then Chief Master Sergeant (select) Gregory Fox, the Air Mobility Command functional manager for the fabrication AFSs released a paper outlining the vision of the Fabrication of the Future (Fox, 2020). He assessed an imbalance in the 2A7X1 (Metals Technology) and 2A7X2 (Non-Destructive Inspection) manning levels. Occupational Analysis Reports for each of the career fields identified a disproportionately high manning to task ratio in some areas and disproportionately low in other areas. With support from a team of functional Subject Matter Experts (SMEs) in the fabrication community, he proposed a multi-faceted approach to the future of the fabrication community that includes the addition of new technologies, merger of the 2A7X1 and 2A7X2 AFSs, creation of fabrication hubs, and the creation of a Superintendent position at the Rapid Sustainment Office to act as a single point of contact for future technological advances.

Six months later, the newly appointed Air Force Chief of Staff, General Charles Q. Brown, Jr. released his strategy document titled *Accelerate Change or Lose*. Simply stated, *Accelerate Change or Lose* implores leaders to think of new, innovative ways of doing things; accelerating the change to a rapidly growing and complex environment (Brown, Jr., 2020). Enemy capability is growing faster than the current way of doing business and if the Air Force doesn't change the way we fight, the luxury of being largely uncontested in any domain may come under attack. Naturally, this strategy falls in line with the 2018 National Defense Strategy (NDS). A core component of the NDS, *modernizing key capabilities,* outlines the departure from large, centralized main operating locations in favor of small, agile, dispersed operating locations that are difficult to detect and defeat (Mattis, 2018).

The present day construct of the fabrication community does not lend itself particularly well in support of small, agile combat teams. For mobility units, there are few daily operations that require the expertise of a 2A7XX Airman, but many deployment packages still require a small footprint of fabricators as a risk mitigation in the event their experience is needed. When a small deployment footprint is desired, most often the 2A7XX Airmen are the first to get left behind. Not only does this increase the operational risk of longer non-mission capable (NMC) times -- time spent waiting for repair, but it eliminates valuable opportunities for operational experience for 2A7XX Airmen. Cross Utilization Training (CUT) is often used as a flexible solution to improve combat capability by reducing the deployed manpower footprint by developing a pool of qualified personnel (Department of the Air Force, 2019). CUT is defined as training Airmen from one AFSC on tasks from another AFSC, also known as multi-skilling.

Research Proposal

The Fabrication Flight of the Future is a necessary change in the 2A7XX community and comes at a particularly ideal time because there is an appetite for sweeping changes throughout a community that hasn't had a significant change since the creation of the 2A7X5 Low Observable Aircraft Structural Maintenance over a decade ago. As the Air Force shifts strategy to smaller multi-skilled teams, coupled with implementation of the "Fabrication Flight of the Future", choosing the right Airmen to multi-skill is imperative. Although CUT has been widely promoted for decades, the only guidance in selecting candidates states one should complete upgrade training in one's primary AFSC prior to beginning CUT (Department of the Air Force, 2019). This research will attempt to identify factors that could be better predictors of performance in the 2A7X1 Metals Technology and 2A7X2 Non-Destructive Inspection communities.

Problem Statement

With the emphasis on small tailorable teams built with multi-capable Airmen, there is a renewed energy for Cross Utilization Training as a way to bolster combat capability within smaller teams. However, the Air Force does not currently have a process to help identify ideal CUT candidates. To help address this issue, it would be beneficial to have a better understanding of which factors influence performance in CUT in order to more effectively choose CUT candidates.

Research Hypotheses

Hypothesis 1: Confidence will be positively related to performance.

Hypothesis 2: Experience will be positively related to performance.

Hypothesis 3: More recent task completion will be positively related to performance.

Hypothesis 4: Primary AFSC Airmen will have higher task performance scores than CUT Airmen.

Hypothesis 5: Time in Service (TIS) will be positively related to performance.

Hypothesis 6: Time in Grade (TIG) will be positively related to performance.

Hypothesis 7: Age will be positively related to performance.

Hypothesis 8: Gender will not be related to performance.

Hypothesis 9: Rank will be positively related to performance.

Hypothesis 10: Skill level will be positively related to performance.

Methodology

The researcher selected specific tasks to measure based on recommendations from subject matter experts from the Metals Technology and Non-Destructive Inspection career fields. The researcher selected four locations to conduct an in-person human subjects experiment in order to measure performance in the specified tasks against various factors. The researcher conducted various regression analyses using IBM SPSS statistical software to identify relationships between certain factors and task performance.

Assumptions/Limitations

There are a few assumptions made by the researcher. First, the researcher assumes that training prior to the experiment is consistent. As a limitation, there is no way to control the type or quality of all training for each subject. In the real world there are good trainers and bad trainers. Some students acquire knowledge very quickly and others take more time. There are many factors that influence the quality of one's training so for the purposes of this research, the researcher elected to normalize all training prior to the experiment. Another assumption made is that the performance metrics gathered by the researcher during the experiment are consistent with future performance. In other words, the performance data gathered would be identical to another researcher's data should the same people be tested again in the future on the same tasks. Naturally, human factors make this difficult and are included in the list of limitations. There are many external and internal factors that affect one's performance at any given time. Stress at home, stress at work, performance anxiety, quality of sleep, weather conditions, and overall mood are all factors that could influence performance and are uncontrollable limitations to the accuracy of the data collected. Furthermore, the Hawthorne effect is a phenomenon wherein people will perform differently when they know they are being observed (Merrett, 2006). This does not necessarily change one's performance, but it does induce additional variability. The researcher made efforts to standardize evaluation processes as much as possible, but these experiments are purposely observed in a real-world setting, not a laboratory environment. Another limitation the researcher faced when choosing the tasks to observe included time limitations. The researcher's request to supporting units to informally CUT technicians from NDI to Metals Tech tasks and technicians from Metals Tech to NDI tasks comes with a significant training burden with very little, if any operational value to the unit. In order to improve the chances of a sufficient sample size, the researcher eliminated tasks that had a high training burden from consideration. Also eliminated from consideration were tasks that would take a large time commitment to observe. Assuming a sufficient sample size, five tasks for each technician, and a limited amount of time available to conduct observations, the researcher chose tasks that were reasonably quick to complete, ideally with a combined time commitment for each technician of approximately 1 hour. The last limitation came as a result of a smaller that desired sample size. For various reasons, the researcher was only able to observe 25 technicians. The spread within the sample group was very good; however, because the overall sample size was small, there is an increased possibility that the sample size is not necessarily indicative of the population.

II. Literature Review

Chapter Overview

The purpose of this chapter is to provide an overview on the background and historical perspective of former and current restructuring efforts in the Aircraft Maintenance Fabrication community as well as provide an overview on how this research aligns with current Air Force strategy.

Fabrication of the Future

The fabrication of the future concept was created by a small team of fabrication senior enlisted maintainers with more than 75 years of experience combined in Aircraft Structures, Metals Technology, and Non-Destructive Inspection. The underlying problem driving the proposed change is the perceived misbalance in utilization of the Metals Technology and Non-Destructive Inspection career fields. Additionally, the expense of duplicating machines in every maintenance group across the globe drives units to compete for resources. Those units are at the mercy of local leadership to prioritize funding for necessary equipment. If a unit does not receive the funding necessary to purchase hundreds of thousands of dollars in equipment, there could be degradation to the unit's mission and the training of the Airmen in the unit who don't get the opportunity to build on their skillsets. The recommendation to merge and institute fabrication hubs comes with the assumption of new technologies coming online in the near future. Advanced manufacturing techniques such as 3D printing with polymers and metals as well as cold spray are already being tested in some units today. Within the Non-Destructive Inspection community, Computed Tomography is a technology that uses

3D x-ray and imaging software to detect and measure defects without a hazardous waste stream in a fraction of the time using legacy methods like Liquid Penetrant Inspection (Fox, 2020). The Metals Technology and Non-Destructive Inspection career fields have gone largely unchanged in terms of responsibilities and techniques for several decades. The world today is much different than it was 30-40 years ago. Militarily, the missions are different and the technology is significantly different. Failure to adapt to evolving technologies will result in further underutilization of personnel at best, and at worst, will render the skillsets of our maintainers ineffective as the skills they have will become more and more obsolete.

Advanced Manufacturing Concepts

The Fabrication of the Future concept is driven in part by the increasing rate of technological growth. From the earliest examples of recorded history, subtractive manufacturing was all that existed. Subtractive manufacturing is the process of creating an object by removing materials. Common examples include lathes, drilling, cutting, and more recently Computer Numerical Control (CNC) and Waterjet machining. Following World War I, the industrial age brought on a rapid improvement in machine technology wherein machines and automation rapidly increased the ability and speed in manufacturing (Ristuccia, 2013). Additive manufacturing is a much newer manufacturing process where material is added and bonded to create an object. The most popular form of additive manufacturing is three-dimensional (3D) printing. 3D printing technology started with plastics and polymers and has since advanced into metal. The uses for additive manufacturing and 3D printing are seemingly endless. One of the biggest advantages to additive manufacturing is the virtually eliminated waste stream left over after manufacturing. As is to be expected with emerging technology, 3D printing is not without challenges, especially in the field of aviation. Although it is possible to print some complex, multi-component aircraft parts and structures, many of the components are not yet certified or tested for use because of the changing dynamics in the solidification process in metal 3D printing. The end result is a component that looks visually strong, but may contain micro-cracks or deficiencies in the material left over from inconsistencies in the print (Chen, 2016). As the results of a structural failure in an aircraft would likely be catastrophic, there is still much to be learned in this area as the technology improves. However, there are many other non-airworthy areas where 3D manufacturing is a superior alternative to subtractive manufacturing due to reduced cost and waste material (Fox, 2020).

Cold Spray is another new alternative in manufacturing that negates the disadvantage of inconsistencies in the material as a result of thermal bonding. Cold spray is a process where media particulates are accelerated above a critical velocity, pass through a divergent or convergent nozzle, and kinetically bond to the target surface. The media is accelerated just below the point where thermal deformation happens so there is no risk of increased stress or fracture due to thermal variances on the affected component. Unlike other forms of thermal bonding such as flame, arc, or plasma, the media in cold spray bonds only through kinetic adhesion (Assadi, 2003).

Computed Tomography

Whereas 3D printing and Cold Spray are two forms of advanced manufacturing, computed tomography is an advanced form of inspection post-manufacturing. Under the current process, once a fabricator completes a weld, for example, the weld must be inspected by a 2A7X2 Non-Destructive Inspection technician through one of five available inspection methods. Computed Tomography (CT) in the industrial application is “a newly established, non-destructive X-ray computerized method for studying multicomponent materials and constructions in a 3D regime. It is currently the only method that allows the observation and analysis of internal and external microstructures of objects without sample preparation and without strong limitations on the size and shape of the objects studied. CT can also reveal volume, shape, grain size distribution and connectivity of pores, present phases and cracks. Unlike 2D imaging, CT 3D imaging can confirm not only the presence of these parameters, but CT can usually quantify them” (Krebbers, et al, 2021).

In the 2018 National Defense Strategy, Secretary Mattis said, “Modernization is not defined solely by hardware; it requires change in the ways we organize and employ forces” (Mattis, 2018). Gathering new equipment and strengthening capabilities does not make the Air Force more able to fight against a near-peer. In order to optimize the successes that could come with advanced technologies, the Air Force must adjust its force presentation model.

Historical Perspective

Reshaping the aircraft maintenance force structure to keep up with emerging trends is not a new idea. On April 30, 1987, the Air Force implemented Project RIVET WORKFORCE, a wholesale restructure of aircraft maintenance career field specialties that are known today as Air Force Specialties (AFSs) and more specifically, adding an alphanumeric designator known as the Air Force Specialty Code (AFSC) by which all

Airmen are known (Boyle, et al, 1985). Two decades earlier, the Air Force had 47 unique maintenance specialties. As new technologies came online, rather than add skillsets to the existing specialties, the Air Force added additional specialties, valuing specialization over generalization. By the mid-1980s, the number of specialties ballooned to 134 (Elliott, 1988). Rivet Workforce sought to reduce the amount of specialization in an effort to increase utilization and decrease deployed manpower requirements driven by changing doctrine and strategy, now focused on smaller, more agile teams. 135,000 maintainers were divided back down into 43 distinct AFSs with an additional 60 “shreds”, defined as an historical event that paved the way for the Unit Type Code (UTC) development by which deployment packages are modeled (Christensen, 2017). The principle purposes of Rivet Workforce included (1) an effort to streamline maintainers to a particular weapon system (a shift toward specialization vs generalization), (2) the combination of similar task groups into a single AFS, when possible, (3) development of mixed-method training (in-residence technical schools, on-the-job training, professional military education, recurring task training, etc) at specific points throughout the Airman’s career, and (4) reevaluation of manpower standards over the course of time to ensure requirements were still being met. Maintenance AFSs were organized into two groupings, “on-equipment” and “off-equipment” maintenance, as is the current construct (Boyle, et al, 1985, Christensen, 2017).

Current Doctrine/Strategy

Air Force Doctrine Publication (AFDP-1) outlines the Air Force’s responsibilities to the Nation in three key areas of Global Vigilance, Global Reach, and Global Power.

Aircraft maintenance directly ties to Global Reach and Global Power which are defined as "the ability to project military capability responsively–with unsurpassed velocity and precision–anywhere, and provide mobility to rapidly supply, position, or reposition joint forces" and "the ability to hold at risk or strike any target anywhere, assert national sovereignty, safeguard joint freedom of action, and create swift, decisive, precise effects", respectively (Department of the Air Force, 2021). Airpower is not bound by geographical limitations. The structure, policies, and capabilities of the Air Force stem from this doctrine in the form of strategy, operations, and tactics. While effects are based on a top-down approach wherein the strategy defines operations and operations define tactics, the smallest pieces of the puzzle in the tactical realm affect overall capability much like links in a chain. All chain links must work toward the overall strategy for the desired effect to be achieved.

Agile Combat Employment (ACE) is a term born from Adaptive Basing in the INDOPACOM area, championed by General Charles Q. Brown, formerly the Commander of Pacific Air Forces and currently the Air Force Chief of Staff. The term ACE is relatively new, but comes from a much older strategy under many previous names (i.e. adaptive basing). AFDP 3-99 defines it as a scheme of maneuver (maneuver being a key tenant of air power) used to increase survivability in high-threat environments. There are significant drawbacks to ACE, namely the increased risk acceptance required from all levels of leadership, the reliance on host-nations and allies, the dramatically increased strain on the logistics network, and the reduced mission assurance driven by smaller units of manpower and equipment (Department of the Air Force, 2020). It is not intended to be a "competition" or "below armed conflict" posture

(Department of the Air Force, 2021). ACE is intended for a high-end conflict with a peer or near-peer and although there is a revitalized priority and new naming, ACE is not a new concept. In 1982, *Air Force 2000* explained the future strategy of the Air Force and the departure from large, unhardened, centralized structures to multiple smaller dispersed, tailorable, flexible teams (U.S. Dept of the Air Force, 1982). Despite the emphasis on this new strategy, there was little change to the overall structure of the Air Force and implementation remained in the strategy environment. Once the Air Force began operations in the Middle East, efforts went towards another single conflict in a permissive environment rather than reorganizing and restructuring to prepare for dispersed operations referred to in *Air Force* 2000. Despite multiple iterations of strategy describing the Air Force's planned departure from moving in heavy, large, centralized teams toward smaller, adaptable, dispersed teams. In a 2020 study, RAND identified some of the challenges with ACE and the small dispersed team concept. The Air Force cannot simply apply ACE as an additional model under the current force employment construct. The wholesale changes required to effectively operate under the ACE concept are significant and cover the entire spectrum of doctrine (Mills, et al, 2020).

For nearly 40 years, the doctrine of the Air Force has remained largely unchanged. The Air Force has enjoyed relatively uncontested air dominance that results in "away games" and keep the homeland safe using the most advanced weapon systems paid for by American wealth and taxpayer dollars (Brown, Jr., 2020). As the threat of near-peer and peer aggression continues to grow, it is now more likely than ever that the United States will face conflict in a contested or degraded environment. The Air Force must rapidly adapt the way it fights. The Air Force makes changes every few years as senior leaders come and go, but the changes are relatively minor. They may alter the focus of a particular area, but so far have not been so drastic as to change the fundamental operating concepts. For the past few decades, the Air Force sought gains in the expeditionary environment. The nature of the expeditionary model is to be lighter, leaner, and faster in response to a changing environment. When the Air Force became an "Expeditionary Force", it simply changed the face of the model by slimming down the footprint of the force to only be as large as the desired effect required, but didn't make much headway on the logistics tail. Quite the opposite is true, the logistics tail grew. In a 2000 Rand study, Paul Killingsworth summed up the greatest challenge of an expeditionary model by highlighting the enormous logistics requirement of support processes and equipment and argued that the biggest improvement in the expeditionary realm is made strategically long before the deployment takes place (Killingsworth, 2000).

Multiskilling

The Air Force must adopt multiskilling to win in a contested environment. Agility is critical and multiskilling is the method necessary to achieve the same capability with a smaller force. Multiskilling is a strategy where workers are trained in multiple skills, usually outside their normal scope of expertise to enable a smaller group to have a broader skillset. Studies have shown multiskilling to be very effective in improving job satisfaction and employability but does require additional training burden and changes to the management structure to be most effective (Haas, et al, 2001).

In 2016, Air Force Captain Jessica Salgado performed research on the effectiveness of skill retention through multiskilling at Air Logistics Complexes (ALC).

Her research sought a quantitative explanation of the link between multiskilling and retention. In other words, if the Air Force ALCs adopt multiskilling, will there be an impact on proficiency or job quality (Salgado, 2016). Her research was a continuation of Capt Wesley Sheppard's 2014 research that identified potential AFSCs that would see the most benefit from multiskilling at the F-22 depot facilities. He concluded that Low Observable (2A7X5) and Aircraft Structural Maintenance (2A7X3) were great candidates for multiskilling (Sheppard Jr., et al, 2014). Low Observable (LO) and Aircraft Structural Maintenance (ASM) are the other two AFSCs other than Metals Tech and NDI that make up the fabrication career fields. Many of the skills used in LO and ASM are the same skills required for MT and NDI, so Salgado's and Sheppard's research is very relevant to the discussion of multiskilling in MT and NDI.

There are three types of multiskilling: Vertical, Horizontal, and Depth. Vertical is when one learns their supervisors duties. Horizontal is learning skills from other disciplines (i.e. another AFSC). Depth is learning more complex skills (i.e. a 5-level learning 7-level tasks prior to formal upgrade) (Horbury & Wright, 2001). The Salgado research suggested there was evidence to support the hypothesis that multiskilling between LO and ASM resulted in less than 5% reduction in skill retention for a multiskilled Airman versus those that were not multiskilled (Salgado, 2016).

Summary

In conclusion, although everyone has different preferred learning methods, aptitudes, and abilities (Stothard & Nicholson, 2001), and although the length of required training, the methods, and the content may change, once a technician passes the desired learning objective threshold, there is very little difference in output between different technicians (Salgado, 2016). Multiskilling is an effective way to increase the skills across a broader range of personnel, increasing the flexibility of a unit.

III. Methodology

Chapter Overview

This research is focused on identifying factors that affect performance in multiskilling. The researcher conducted a Human Subject Experiment to gather data on specified 2A7X1 Metals Technology and 2A7X2 Non-Destructive Inspection tasks, then performed three separate types of regression analysis depending on the type of dependent variable in order to determine relationships between a series of different variables. For scale dependent variables, the researcher performed linear regression, also known as Ordinary Least Squares method. For bi-variate dependent variables (result was one of two variables, in this case Pass or Fail), the researcher performed bi-variate logistics regression. For results with multiple ordinal variables, the researcher performed ordinal logistics regression.

Task Selection

Task selection is an important component in the human subject experiment because the results of the data could be heavily affected by task choice. Tasks too easy or difficult do not give an accurate depiction of ability. Moreover, tasks that are performed infrequently are not necessarily useful for the purposes of multi-skilling in an Agile Combat Employment scenario. The goal of task selection was to select tasks that were relevant, meaningful, and able to be taught in a reasonable period of time while meeting certain criteria with regards to experimental observation.

To determine task relevance and meaningfulness, the researcher consulted the 2021 Occupational Analysis Report (OAR) for each career field. The OAR is an assessment of a career field under the direction of Air Force Manual (AFMAN) 36-2664, Personnel Assessment Program, Chapter 6, Occupational Analysis. OA data is used by decision makers to make informed and objective personnel, training, and education decisions based not on opinion or conjecture, but on empirical, quantitative data. The OAR contains information for every task in the Career Field Education and Training Plan (CFETP) including frequency of task completion, training effort required, amount of time spent completing the task, the difficulty of the task, and more. In addition to the OAR, the researcher consulted the 2A7XX Fabrication functional managers for Air Mobility Command at AMC/A4MR for their opinions on relevant, meaningful tasks.

From Metals Technology, the researcher selected CFETP Task A2.9.3.1.2, Remove/Install Heli-coil inserts, CFETP Task A2.10.4.1, Operate Hardness Tester, and CFETP Task A2.11.1.2, Use precision measuring devices. From Non-Destructive Inspection, the researcher selected CFETP Task 2.12, 2.12.1, and 2.12.1.3, Liquid Penetrant Inspection Method C, and CFETP Task 2.13, Magnetic Particle Inspection Method.

There are many suitable alternatives in task selection. The researcher selected these tasks based on a balance of frequency of use, burden of training, and burden of experimental observation.

Experimental Design

Since the purpose of this experiment was to identify factors influencing performance, consistency and repeatability was very important between the different experiment locations. The researcher gave instructions to each participating unit that defined whom and how subjects should be trained. In terms of operational realism, there are numerous internal and external variables and influences. The goals of an operationally realistic experiment are nearly opposite of a controlled laboratory experiment because the purpose of a laboratory experiment is to reduce or eliminate variance and inconsistency. Focusing the experimental design too heavily on realism will result in data that is virtually impossible from which to extract meaningful information. Conversely, focusing the experimental design too heavily on a laboratory environment with strong efforts to remove variables and inconsistency results in data that is virtually useless in the operational environment. Taking this into account, the researcher made decisions about the experimental design that allowed natural variability prior to the experiment, but removed as much variability as possible during the actual observation.

Units were tasked to provide no fewer than 10x each 2A7X1 Metals Technology and 2A7X2 Non-Destructive Inspection personnel of mixed skill level, rank, and experience who received on-the-job training for all five previously identified tasks. All training was to take place in-house by experienced/qualified personnel. Trainees were to become proficient on tasks, but would not be certified for operational use on any tasks beyond the purpose of this experiment. See Appendix A, “MXS Support Request Memo”. It was important to the researcher to have the units use their own standards for on-the-job training to make the training as realistic as possible. All technicians, regardless of primary AFSC completed all five tasks.

For CFETP Task A2.9.3.1.2, Remove/Install Heli-coil inserts, technicians were provided an aluminum block with a pre-installed helical coil insert (heli-coil) and the associated fastener. Technicians were briefed “you have been dispatched to an aircraft to remove and replace a bad heli-coil. This is the associated faster. I will provide any additional tools you need once you verbalize your request for a specific tool." The technician was expected to measure the hardware to determine the appropriate heli-coil size. When prompted by the technician, the observer offered calipers and a thread pitch gauge to measure the hardware. Upon successfully identifying the correct size heli-coil and upon request of the technician, the observer provided the appropriate sized pre-built heli-coil insert/extraction kit found standard in all tool rooms, known as Composite Tool Kits (CTKs) as well as a hammer, and the appropriate sized heli-coil insert (see Figure 1).

Figure 1. Tools required for "Remove/Install Heli-coil inserts"

This was a timed event in order to ascertain any correlation between speed and other factors. The technicians were graded according to local Quality Assurance (QA) Maintenance Standardization and Evaluation Plan (MSEP) Personnel Evaluation (PE) standards, as required by Air Force Instruction 21-101, Aircraft and Equipment

Maintenance Management. See Appendix D for PE grading criteria example from Joint Base McGuire-Dix-Lakehurst; however, all maintenance units use the same grading criteria.

For CFETP Task A2.10.4.1, “Operate Hardness Tester,” technicians were given a piece of 6061 T6 scrap aluminum and briefed “this piece of 6061 T6 was just heat treated and needs hardness tested.” This was a pass/fail experiment testing the technician’s ability to properly set up the hardness testing machine, identify correct calibration using standardized “coupon”, perform hardness testing, and interpret results. See Figure 2 for Hardness Tester setup.

Figure 2. Hardness Tester operation

For CFETP Task A2.11.1.2, “Use precision measuring devices,” technicians were given a pre-manufactured object with height, exterior width, and interior diameter width. This was a pass/fail experiment testing the technician’s ability to accurately measure the object as compared to a known calibrated value (if available) or subject matter expert's measurement within allowable tolerances for each measuring device. The technician was instructed to provide three measurements: height using a height gauge (+/- .002"), outside diameter using calipers (+/- .001") and inside diameter using a T-gauge and micrometer (+/- .0002"). See Figure 3 for precision measurement devices setup.

Figure 3. Precision Measuring Devices

For CFETP Task 2.12, 2.12.1, and 2.12.1.3, Liquid Penetrant Inspection Method C, technicians were given a test part with a known number of cracks. They were instructed to perform Liquid Penetrant Inspection Method C and identify any cracks. Technicians were evaluated on knowledge, process, technique, and interpretation using established 2A7X2 PE guidelines (Appendix E). See Figure 4 for Liquid Penetrant Inspection Method C example at Joint Base Elmendorf-Richardson, Alaska.

Figure 4. Liquid Penetrant Inspection Method C

For CFETP Task 2.13, Magnetic Particle Inspection Method, technicians were given a test part with a known number of cracks. They were instructed to perform Magnetic Particle Inspection Method and identify any cracks. Technicians were evaluated on knowledge, process, technique, and interpretation using established 2A7X2 PE guidelines (Appendix E). See Figure 5 for Magnetic Particle Inspection Method example at Joint Base Elmendorf-Richardson, Alaska.

Figure 5. Magnetic Particle Inspection Method

All tasks were evaluated by a Subject Matter Expert and were given a Pass/Fail grade using established discrepancy categories and findings as outlined in Air Mobility Command's AFI 21-101 supplement. According to the Air Mobility Command's AFI 21-101 supplement, a Category I discrepancy is assessed when a required inspection/TO/AFI procedural item is missed or improperly completed. A Category II discrepancy is assessed when an obvious defect which could have been readily detected by a technician or supervisor but is not part of a particular task's work card, warning, caution, note, or other AFI requirement and is missed. Findings are assessed as major or minor error depending on severity. Major errors are significant safety concerns, specifically any condition that presents a danger to personnel, equipment, or system reliability and could impact safety of flight or warrant discontinuing the process or equipment operation. Minor errors are all other unsatisfactory conditions that do not meet the threshold of a major error. Major errors constitute an automatic failure of the task evaluation. Minor errors do not constitute an automatic failure, but could collectively result in an overall failure if there are more errors than allowed in the pre-determined Acceptable Quality Level (AQL) for the specific task.

Site Selection

Joint Base Elmendorf-Richardson, Alaska (JBER) and Travis AFB, California (TAFB) are two of the test bed locations for the fabrication of the future. This made them ideal choices for this research as they have already established a normalized process for cross-utilization training between Metals Tech and NDI. Additionally, these locations are ideal because of their multi-airframe Wings, connections to other MAJCOMs (as this research translates far beyond the fabrication career fields), and perhaps most importantly a willingness to devote many hours to this research for potentially very limited return on investment. JBER is home to the F-22, C-17, and E-3. The Wing is aligned under Pacific Air Forces, but has operational ties to Air Mobility Command with the C-17 and Air Combat Command with the F-22 and E-3. Geographically, there are challenges to the supply chain because of the distance from the mainland United States. However, the location serves as a strategic hub servicing much of the INDOPACOM AOR.

TAFB is part of Air Mobility Command and is home to the KC-10 (transitioning to the KC-46 over the next few years), C-17, and C-5M. Aside from the multi-platform mission support, JBER and TAFB are ideal because of the push toward additive manufacturing and advanced fabrication concepts, potentially in the form of fabrication hubs in the future. JBER and TAFB are leading the way at the field level and provide very valuable inputs to shaping the future of fabrication.

The third location for this research is Joint Base McGuire-Dix-Lakehurst (JBMDL), New Jersey. JBMDL is home to the KC-10, KC-46, and C-17. Unlike JBER or TAFB who already have cross-utilization training plans in motion, the 305th Maintenance Squadron at JBMDL does not have a formalized plan to cross-train all Metals Tech and NDI personnel. Despite being a smaller unit than the 3rd Maintenance Squadron at JBER or the 60th Maintenance Squadron at TAFB as well as the immense training burden solely for this research, the 305 MXS at JBMDL provided more personnel than the other units combined. The researcher requested support from Dover Air Force Base, Delaware for the final testing location; however, the 436th Maintenance Squadron was not able to get the necessary training complete in the given timeframe. As a result, they were excluded from participation and the experiment population was only 25 personnel, far short of the desired goal and failing to reach the 30-person minimum sample size required to be statistically significant.

Demographic/Questionnaire Data Collection

Prior to starting the experiment, all technicians were asked to fill out a consent form (Appendix B) as well as a questionnaire addressing demographic and task-specific information (Appendix C). Demographics included Rank, Date of Enlistment (to calculate Time in Service), Date of promotion (to calculate Time in Grade), Age, Background (Metals Tech or Non-Destructive Inspection), Skill level, and ASVAB/AFQT score. The task-specific questionnaire included three identical questions about each specific task. The first question was "Concerning the task "(name of each task)", how many hours of experience (including training) do you have completing the task?" This question identifies experience. The second question was "Concerning the task “(name of each task)”, what is your confidence level that you are able to successfully complete the task as instructed with an acceptable passing score as determined by a Subject Matter Expert?” This question identifies confidence level. The third question was, “Concerning the task “(name of each task)”, how long has it been since you last accomplished this task (training or operationally)?” This question identifies recency. Experience and recency choices were time values not equally sized or distributed in order to identify a higher level of fidelity on the effect of early experience/recency under the assumption that at higher levels of experience/recency, there is a decreasing influence on performance. Responses were categorized as ordinal since there is increasing scale value between each selection. Confidence choices were also categorized as ordinal, but the choices were more categorical (subjective) than time-related (objective).

IV. Analysis and Results

Data Gathering/Preparation

All data was gathered on-site during the visits to each of the three experiment locations. The researcher transferred all information from the demographic and task-specific questionnaires as well as scores from the in-person experiments into Excel and later copied into IBM SPSS statistical software to run regression analyses. The researcher replaced names with numbers in order to protect the individual's identities. Time in Service (TIS) and Time in Grade (TIG) were calculated using the excel formula "=(Days(Date of experiment, Date of Enlistment/Promotion))/365" which displays TIS and TIG in years. The researcher attached a numerical value to each response for ease of analysis. Experience and recency responses were assigned 1-5 and confidence responses were assigned 1-3. The following figures illustrate the different demographics represented in this experiment.

Rank Distribution	
A1C	7
SrA	7
SSgt	6
TSgt	3
WG11	1
WG12	1
Total	25

Base Distribution	
JBER	7
Travis	5
JBMDL	13
Total	25

Skill Level Dist	
3	4
5	10
7	11
Total	25

Gender Distribution	
Male	22
Female	3
Total	25

Background Dist	
MT	16
NDI	9
Total	25

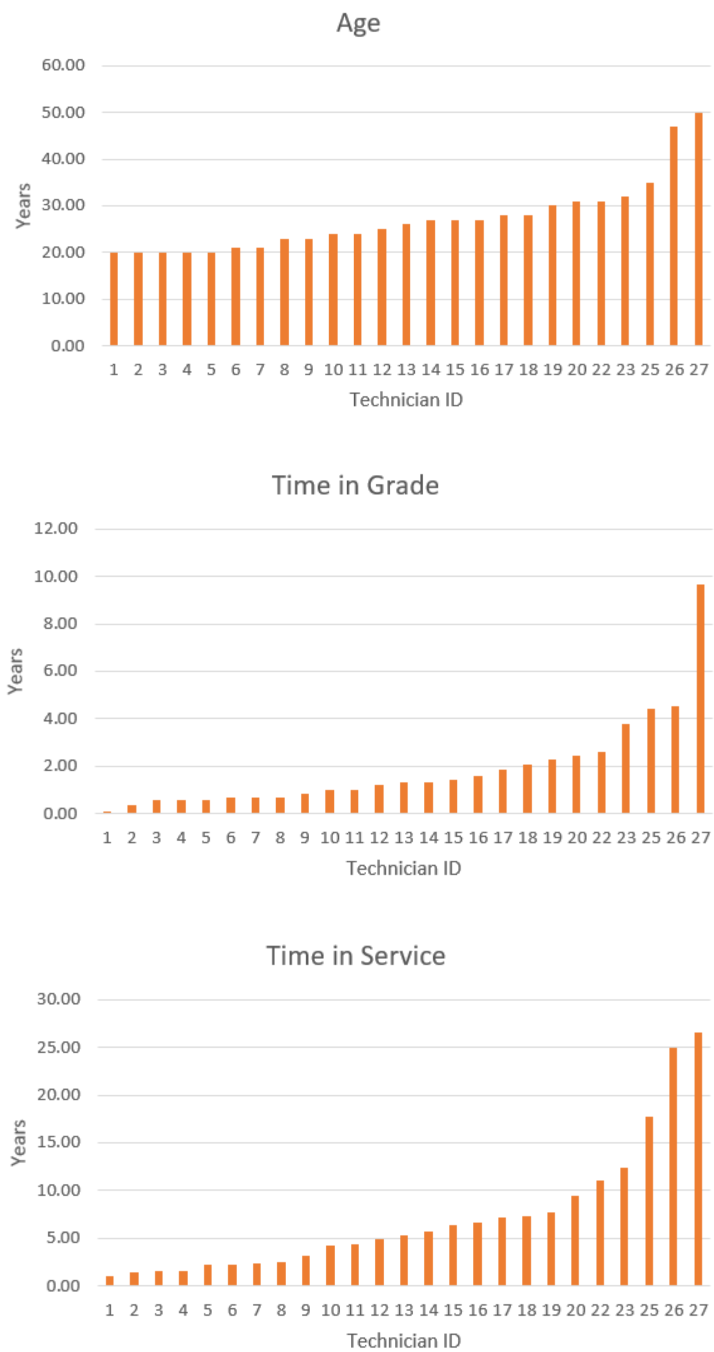

Figure 6. Demographic Distribution

With the exception of gender, the demographic spread was broad. Even though the number of participating females was very low, it is somewhat representative of the male-dominated career fields of Metals Technology and Non-Destructive Inspection as is the case with the broader Aircraft Maintenance category. Since some regression models are easier to run if strings (regular text) are converted to numerical data, the researcher changed rank to the corresponding enlisted grade (A1C/E-2 is 2, SrA/E-3 is 3, etc.), gender to 1 (male) and 2 (female), Background to 1 (MT) and 2 (NDI) and any Pass/Fail became 0 (Fail) and 1 (Pass). Only 65% of respondents knew their ASVAB/AFQT score, so non-respondents were removed. The only potential relationship of interest to the researcher was the relationship between background and ASVAB/AFQT score. The general consensus among Senior Non-Commissioned Officers from the Metals Tech and NDI communities is that NDI personnel tend to have a higher ASVAB/AFQT score. The linear regression analysis did not indicate a significant relationship; however, among the 16 respondents that posted scores on the demographic questionnaire (8 from each career field), Metals Tech had an average score 5 points higher than the NDI. Although interesting that this particular data set did not seem to support the common belief in the field that NDI technicians score higher on the ASVAB/AFQT, it was not statistically significant. Due to the insignificance and extremely small data set, ASVAB/AFQT was removed from further testing. Overall, the results of this experiment identified statistical significance between some variables. The following is a presentation of findings broken down by task.

Remove/Install Helical Coil (Helicoil) Insert (Metals Technology task)

Demographics vs Time

Time in service and age had a high level of covariance so in order to improve the model accuracy, the researcher removed age as a variable for all regression models. The researcher created dummy variables for the gender, rank, background, and skill level variables. Linear regressions were set with the dependent variable as time (in seconds) and the independent variables as TIS, TIG, gender, rank, background, and skill level.

Correlations

		Helicoil Time (sec)	TIS (yrs)	TIG (yrs)
Pearson Correlation	Helicoil Time (sec)	1.000	.015	.365
	TIS (yrs)	.015	1.000	.293
	TIG (yrs)	.365	.293	1.000
Sig. (1-tailed)	Helicoil Time (sec)	.	.472	.037
	TIS (yrs)	.472	.	.078
	TIG (yrs)	.037	.078	.
N	Helicoil Time (sec)	25	25	25
	TIS (yrs)	25	25	25
	TIG (yrs)	25	25	25

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.377[a]	.142	.064	477.00451

a. Predictors: (Constant), TIG (yrs), TIS (yrs)

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	829603.431	2	414801.716	1.823	.185[b]
	Residual	5005732.569	22	227533.299		
	Total	5835336.000	24			

a. Dependent Variable: Helicoil Time (sec)

b. Predictors: (Constant), TIG (yrs), TIS (yrs)

Coefficients[a]

Model		Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	634.448	154.295		4.112	<.001
	TIS (yrs)	-7.356	15.107	-.101	-.487	.631
	TIG (yrs)	96.193	50.416	.394	1.908	.070

a. Dependent Variable: Helicoil Time (sec)

Figure 7. Helicoil - TIS/TIG vs Time (seconds)

Correlations

		Helicoil Time (sec)	M
Pearson Correlation	Helicoil Time (sec)	1.000	-.346
	M	-.346	1.000
Sig. (1-tailed)	Helicoil Time (sec)	.	.045
	M	.045	.
N	Helicoil Time (sec)	25	25
	M	25	25

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.346[a]	.120	.082	472.56826

a. Predictors: (Constant), M

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	698958.545	1	698958.545	3.130	.090[b]
	Residual	5136377.455	23	223320.759		
	Total	5835336.000	24			

a. Dependent Variable: Helicoil Time (sec)

b. Predictors: (Constant), M

Coefficients[a]

Model		Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	1216.000	272.837		4.457	<.001
	M	-514.545	290.846	-.346	-1.769	.090

a. Dependent Variable: Helicoil Time (sec)

Figure 8. Helicoil - Gender vs Time (seconds)

Correlations

		Helicoil Time (sec)	SSgt	SrA	A1C
Pearson Correlation	Helicoil Time (sec)	1.000	.190	-.240	.181
	SSgt	.190	1.000	-.350	-.350
	SrA	-.240	-.350	1.000	-.389
	A1C	.181	-.350	-.389	1.000
Sig. (1-tailed)	Helicoil Time (sec)	.	.182	.124	.193
	SSgt	.182	.	.043	.043
	SrA	.124	.043	.	.027
	A1C	.193	.043	.027	.
N	Helicoil Time (sec)	25	25	25	25
	SSgt	25	25	25	25
	SrA	25	25	25	25
	A1C	25	25	25	25

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.328[a]	.107	-.020	498.03064

a. Predictors: (Constant), A1C, SSgt, SrA

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	626611.071	3	208870.357	.842	.486[b]
	Residual	5208724.929	21	248034.520		
	Total	5835336.000	24			

a. Dependent Variable: Helicoil Time (sec)

b. Predictors: (Constant), A1C, SSgt, SrA

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	631.000	222.726		2.833	.010
	SSgt	295.500	301.573	.261	.980	.338
	SrA	-53.571	291.617	-.050	-.184	.856
	A1C	272.429	291.617	.253	.934	.361

a. Dependent Variable: Helicoil Time (sec)

Figure 9. Helicoil - Rank vs Time (seconds)

Correlations

		Helicoil Time (sec)	Skill5	Skill3
Pearson Correlation	Helicoil Time (sec)	1.000	.042	-.128
	Skill5	.042	1.000	-.356
	Skill3	-.128	-.356	1.000
Sig. (1-tailed)	Helicoil Time (sec)	.	.421	.270
	Skill5	.421	.	.040
	Skill3	.270	.040	.
N	Helicoil Time (sec)	25	25	25
	Skill5	25	25	25
	Skill3	25	25	25

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.129[a]	.017	-.073	510.74648

a. Predictors: (Constant), Skill3, Skill5

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	96372.764	2	48186.382	.185	.833[b]
	Residual	5738963.236	22	260861.965		
	Total	5835336.000	24			

a. Dependent Variable: Helicoil Time (sec)

b. Predictors: (Constant), Skill3, Skill5

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	792.182	153.996		5.144	<.001
	Skill5	-3.982	223.161	-.004	-.018	.986
	Skill3	-171.182	298.212	-.130	-.574	.572

a. Dependent Variable: Helicoil Time (sec)

Figure 10. Helicoil - Skill Level vs Time (seconds)

These models were all insignificant (p-values >.05). Based on this data set, there is no evidence to suggest TIS, TIG, gender, rank, or skill level are suitable determinants of the speed with which an individual can perform this task. However, there is a statistically significant relationship between background and the speed with which an individual performs this task.

Correlations

		Helicoil Time (sec)	NDI
Pearson Correlation	Helicoil Time (sec)	1.000	.548
	NDI	.548	1.000
Sig. (1-tailed)	Helicoil Time (sec)	.	.002
	NDI	.002	.
N	Helicoil Time (sec)	25	25
	NDI	25	25

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.548[a]	.300	.270	421.43683

a. Predictors: (Constant), NDI

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1750329.000	1	1750329.000	9.855	.005[b]
	Residual	4085007.000	23	177609.000		
	Total	5835336.000	24			

a. Dependent Variable: Helicoil Time (sec)

b. Predictors: (Constant), NDI

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	564.750	105.359		5.360	<.001
	NDI	551.250	175.599	.548	3.139	.005

a. Dependent Variable: Helicoil Time (sec)

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means				
						Significance		
		F	Sig.	t	df	One-Sided p	Two-Sided p	Mean Difference
Helicoil Time (sec)	Equal variances assumed	4.023	.057	-3.139	23	.002	.005	-551.25000
	Equal variances not assumed			-2.709	11.094	.010	.020	-551.25000

Figure 11. Helicoil - Background vs Time (seconds)

This model showed high significance (*p*-value = .005) but an adjusted R square of only .27 which means the model could only account for 27% of the variance in this data set. Based on an ANOVA with Least Significant Difference (LSD) selected, the average time for all NDI technicians was statistically different and twice as long as Metals Tech, 564 seconds vs 1116 seconds.

With a low R square, there are definitely more factors that influence the speed with which one completes this task, but based solely on this data set, background is a factor that influences the speed with which a technician completes this task.

Demographics vs. Success (Pass/Fail)

The researcher performed a bivariate logistics regression with the dependent variable set as Pass/Fail which was previously converted to a numerical value of 1 and 0, respectively. The independent variables were TIS, TIG, gender, rank, background, and skill level. Within the sample size of 25, there were 7 failures and 18 passes. The 7 failures included an even variety of demographics with no correlation between any single or group of variables. The regression model showed no significance (*p*-value = .197); therefore, within this data set, demographics are not necessarily factors that influence the ability to successfully complete this task.

Demographics vs. Quality (# errors)

Ideally, with a dependent variable like the number of errors committed, an ordinal regression is the best model. However, due to such a small data size with many "single instance" variables, the researcher performed individual linear regressions with the dependent variable set as the number of errors assessed on the tasks. The independent variables were set as TIS, TIG, gender, rank, background, and skill level. The regression models showed no significance for TIS (*p*-value = .661), TIG (*p*-value = .534), rank (*p*-value = .072), gender (*p*-value = .056), or skill level (*p*-value = .749). However, there was a statistically significant relationship between background and the number of errors committed.

Correlations

		Helicoil Errors	MT
Pearson Correlation	Helicoil Errors	1.000	-.414
	MT	-.414	1.000
Sig. (1-tailed)	Helicoil Errors	.	.020
	MT	.020	.
N	Helicoil Errors	25	25
	MT	25	25

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.414[a]	.171	.135	1.06308

a. Predictors: (Constant), MT

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	5.367	1	5.367	4.749	.040[b]
	Residual	25.993	23	1.130		
	Total	31.360	24			

a. Dependent Variable: Helicoil Errors

b. Predictors: (Constant), MT

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	1.778	.354		5.017	<.001
	MT	-.965	.443	-.414	-2.179	.040

a. Dependent Variable: Helicoil Errors

Figure 12. Helicoil - Background vs Quality (# errors)

Based on this data set, Metals Tech personnel complete this Metals Tech task with an average of one fewer errors than NDI personnel. With the exception of background, demographics are not necessarily factors that influence the quality with which this task is completed.

Experience/Confidence/Recency vs. Time

The researcher performed a linear regression with the dependent variable set as time (in seconds) and the independent variables set as the numerical values assigned to represent experience, confidence, and recency.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.643[a]	.413	.321	414.28096

a. Predictors: (Constant), Heli Recency, Heli Confidence, Heli Hrs Experience

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2298976.811	3	766325.604	4.465	.016[b]
	Residual	3260945.624	19	171628.717		
	Total	5559922.435	22			

a. Dependent Variable: Helicoil Time (sec)

b. Predictors: (Constant), Heli Recency, Heli Confidence, Heli Hrs Experience

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1741.697	313.997		5.547	<.001
	Heli Hrs Experience	-101.034	77.114	-.328	-1.310	.206
	Heli Confidence	-180.582	157.577	-.281	-1.146	.266
	Heli Recency	-123.620	56.643	-.395	-2.182	.042

a. Dependent Variable: Helicoil Time (sec)

Figure 13. Helicoil - Experience/Confidence/Recency vs Time (seconds)

The model is significant (*p*-value =.016) but the data only accounts for 32% of the variance in the model. Since experience and confidence have been shown to be highly correlated in previous research (Morgan & Cleave-Hogg, 2002), the researcher conducted a correlation analysis to determine the relationship between experience and confidence (see Figure 14).

Correlations

Variable	Variable2	Correlation	Count	Lower C.I.	Upper C.I.	Notes
		Statistic				
HeliConfidence	HeliHrsExperience	.689	23	.387	.858	

Missing value handling: PAIRWISE, EXCLUDE. C.I. Level: 95.0

Figure 14. Helicoil - Confidence vs Experience Correlations

As expected, there is a strong positive correlation between confidence and experience. As experience increases, so does confidence. Taking this into account, the researcher performed additional models comparing various iterations of recency, confidence, and experience individually and when combined.

The model comparing only recency against time was not significant (*p*-value = .117). Therefore, confidence and/or experience must provide some relationship. Confidence (*p*-value = .016) and experience (*p*-value = .032) individually are potentially identifying factors of performance. When combined, confidence and recency (*p*-value = .011) and experience and recency (*p*-value = .008) are even stronger models. In other words, confidence and experience are each adequate indicators of how quickly one will perform this task, but the strongest results are achieved when either of them is combined with recency.

Experience/Confidence/Recency vs. Success (Pass/Fail)

The researcher performed a bivariate logistics regression with the dependent variable set as Pass/Fail which was previously converted to a numerical value of 1 and 0, respectively. The independent variables were set as the numerical values assigned to represent experience, confidence, and recency. There were a total of 7 failures out of the 25 attempts. Of the seven failures, only four rated themselves low in experience and/or confidence. The regression model showed no significance within this data set indicating experience (*p*-value = .339), confidence (*p*-value = .670), and recency (*p*-value = .124) are not necessarily factors that influence the ability to successfully perform this task. Of note, no model with alternate combinations of experience, confidence, or recency resulted in a statistically significant results.

Experience/Confidence/Recency vs. Quality (# errors)

The researcher performed an ordinal regression with the dependent variable set as an ordinal scale representing the number of errors assessed on the tasks. The independent variables were individually set as the numerical values assigned to represent experience, confidence, and recency. A combined model indicated low significance (*p*-value = .075). Individually, experience (*p*-value = .276) and recency (*p*-value = .868) were not significant. Confidence alone vs quality is a significant model (*p*-value = .020). Based on the ANOVA with Least Significant Difference (LSD) in Figure 15, there is a negative relationship between confidence level and the number of errors. Those that rated themselves "Not Confident" (confidence level 1) committed more errors than those than had a confidence level of 2 or 3.

Multiple Comparisons

Dependent Variable: Helicoil Errors
LSD

(I) Heli Confidence	(J) Heli Confidence	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
1.00	2.00	1.66667*	.64777	.018	.3154	3.0179
	3.00	1.73077*	.57378	.007	.5339	2.9277
2.00	1.00	-1.66667*	.64777	.018	-3.0179	-.3154
	3.00	.06410	.49529	.898	-.9690	1.0972
3.00	1.00	-1.73077*	.57378	.007	-2.9277	-.5339
	2.00	-.06410	.49529	.898	-1.0972	.9690

*. The mean difference is significant at the 0.05 level.

ANOVA

Helicoil Errors

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	9.685	2	4.843	4.809	.020
Within Groups	20.141	20	1.007		
Total	29.826	22			

Descriptives

Helicoil Errors

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1.00	4	2.5000	1.00000	.50000	.9088	4.0912	2.00	4.00
2.00	6	.8333	1.16905	.47726	-.3935	2.0602	.00	3.00
3.00	13	.7692	.92681	.25705	.2092	1.3293	.00	2.00
Total	23	1.0870	1.16436	.24279	.5835	1.5905	.00	4.00

Figure 15. Helicoil Confidence vs Quality (# Errors)

For this data set, confidence is a potential identifying factor in the quality of completion on this particular task.

<u>Operate Hardness Tester (Metals Tech task)</u>

Demographics vs. Success (Pass/Fail)

The researcher performed bivariate logistics regressions with the dependent variable set as Pass/Fail which was previously converted to a numerical value of 1 and 0, respectively. The independent variables set individually for each regression were TIS, TIG, gender, rank, background, and skill level. Within the sample size of 25, there were only 2 failures and 23 passes. The regression models showed no significance within this data set between TIS (*p*-value = .517), TIG (*p*-value = .538), gender (*p*-value = .141), rank (*p*-value = 1.000), background (*p*-value = .998), and skill level (*p*-value = .657) indicating demographics are not necessarily factors that influence the ability to achieve a passing score on this task.

Experience/Confidence/Recency vs. Success (Pass/Fail)

The researcher performed a bivariate logistics regression with the dependent variable set as Pass/Fail which was previously converted to a numerical value of 1 and 0, respectively. The independent variables were set as the numerical values assigned to represent experience, confidence, and recency. There were a total of 2 failures out of the 25 attempts. Of the two failures, both technicians rated themselves low in experience, confidence, and recency. This indicates the members had not yet been fully trained. The regression models showed no significance within this data set indicating experience (*p*-value = .997), confidence (*p*-value = .181), and recency (*p*-value = .998) are not necessarily factors that influence the ability to successfully complete this task.

Operate Precision Measurement Devices (Metals Tech task)

Demographics vs. Success (Pass/Fail)

The researcher performed a bivariate logistics regression with the dependent variable set as Pass/Fail which was previously converted to a numerical value of 1 and 0, respectively. The independent variables were TIS, TIG, gender, rank, background, and skill level. Within the sample size of 25, there were only 2 failures and 23 passes. The regression models showed no significance within this data set between TIS (*p*-value = .711), TIG (*p*-value = .589), gender (*p*-value = .999), rank (*p*-value = 1.000), background (*p*-value = .998), and skill level (*p*-value = .657) indicating demographics are not necessarily factors that influence the ability to achieve a passing score on this task.

Experience/Confidence/Recency vs. Success (Pass/Fail)

The researcher performed a bivariate logistics regression with the dependent variable set as Pass/Fail which was previously converted to a numerical value of 1 and 0, respectively. The independent variables were set as the numerical values assigned to represent experience, confidence, and recency. There were a total of 2 failures out of the 25 attempts. Of the two failures, both technicians rated themselves low in experience, confidence, and recency. This indicates the members had not yet been fully trained. The regression models showed no significance within this data set indicating experience (p-value = .998), confidence (p-value = .188), and recency (p-value = .999) are not necessarily factors that influence the ability to successfully complete this task.

Perform Liquid Penetration Inspection Method C (NDI task)

Demographics vs. Success (Pass/Fail)

The researcher performed a bivariate logistics regression with the dependent variable set as Pass/Fail which was previously converted to a numerical value of 1 and 0, respectively. The independent variables were TIS, TIG, gender, rank, background, and skill level. Within the sample size of 25, there were 10 failures and 15 passes. The regression models showed no significance within this data set between TIS (p-value = .835), TIG (p-value = .798), gender (p-value = .999), rank (p-value = .835), background (p-value = .185), and skill level (p-value = .316) indicating demographics are not necessarily factors that influence the ability to achieve a passing score on this task.

Demographics vs. Quality (# errors)

The researcher performed an ordinal regression with the dependent variable set as an ordinal scale representing the number of errors assessed on the tasks. The independent variables were set as TIS, TIG, gender, rank, background, and skill level. The regression models showed no significance within this data set between TIS (*p*-value = .332), TIG (*p*-value = .708), gender (*p*-value = .187), rank (*p*-value = .129), background (*p*-value = .060), and skill level (*p*-value = .082) indicating demographics are not necessarily factors that influence the quality with which an individual completes this task.

Experience/Confidence/Recency vs. Success (Pass/Fail)

The researcher performed a bivariate logistics regression with the dependent variable set as Pass/Fail which was previously converted to a numerical value of 1 and 0, respectively. The independent variables were set as the numerical values assigned to represent experience, confidence, and recency. There were a total of 10 failures out of the 25 attempts. Of the 10 failures, 8 rated themselves low in experience and confidence. The regression models showed no significance within this data set indicating experience (*p*-value = .090), confidence (*p*-value = .361), and recency (*p*-value = .580) are not necessarily factors that influence the ability to successfully complete this task.

Experience/Confidence/Recency vs. Quality (# errors)

The researcher performed an ordinal regression with the dependent variable set as an ordinal scale representing the number of errors assessed on the tasks. The independent variables were set as the numerical values assigned to represent experience, confidence, and recency. The combined model of experience, confidence, and recency vs # errors was significant (*p*-value = .028) indicating a statistically relevant relationship between experience, confidence, and recency with regards to the quality of performance.

Model Fitting Information

Model	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	49.605			
Final	30.971	18.634	9	.028

Link function: Logit.

Goodness-of-Fit

	Chi-Square	df	Sig.
Pearson	23.060	33	.901
Deviance	22.078	33	.926

Link function: Logit.

Pseudo R-Square

Cox and Snell	.525
Nagelkerke	.578
McFadden	.310

Link function: Logit.

Figure 16. Liquid Penetration Inspection - Experience/Confidence/Recency vs Quality

Individually, Confidence was not a significant indicator of quality (*p*-value = .063), nor was recency (*p*-value = .92). However, experience was statistically significant (*p*-value = .006) individually, and also scored well when combined with confidence (*p*-value = .015). As experience increases, confidence is also likely to increase. When experience and confidence increase, the number of errors committed decreases.

<u>Perform Magnetic Particle Inspection (NDI task)</u>

Demographics vs. Success (Pass/Fail)

The researcher performed a bivariate logistics regression with the dependent variable set as Pass/Fail which was previously converted to a numerical value of 1 and 0, respectively. The independent variables were TIS, TIG, gender, rank, background, and skill level. Within the sample size of 25, there were 11 failures and 14 passes. The regression model showed no significance; however, 8 of the 11 failures were Metals Tech personnel, exactly half of the total Metals Tech personnel in this data set (16). Additionally, 10 of the 11 failures were the same technicians that failed the Liquid Penetrant Inspection Method C, potentially indicating inadequate training within the NDI tasks. Despite this apparent correlation, the regression models showed no significance within this data set between TIS (*p*-value = .611), TIG (*p*-value = .867), gender (*p*-value = .999), rank (*p*-value = .607), background (*p*-value = .423), and skill level (*p*-value = .255) indicating demographics are not necessarily factors that influence one's ability to successfully complete this task.

Demographics vs. Quality (# errors)

The researcher performed an ordinal regression with the dependent variable set as an ordinal scale representing the number of errors assessed on the tasks. The independent variables were set as TIS, TIG, gender, rank, background, and skill level. The regression models showed no significance within this data set between TIS (*p*-value = .966), TIG (*p*-value = .734), gender (*p*-value = .403), rank (*p*-value = .502), background (*p*-value = .769), and skill level (*p*-value = .324) indicating demographics are not necessarily factors that influence the quality with which an individual completes this task.

Experience/Confidence/Recency vs. Success (Pass/Fail)

The researcher performed a bivariate logistics regression with the dependent variable set as Pass/Fail which was previously converted to a numerical value of 1 and 0, respectively. The independent variables were set as the numerical values assigned to represent experience, confidence, and recency. There were a total of 10 failures out of the 25 attempts. Of the 10 failures, 8 rated themselves low in experience and confidence. The regression model showed no significance within this data set indicating experience (*p*-value = .342), confidence (*p*-value = .592), and recency (*p*-value = .893) are not necessarily factors that influence the ability to successfully complete this task.

Experience/Confidence/Recency vs. Quality (# errors)

The researcher performed an ordinal regression with the dependent variable set as an ordinal scale representing the number of errors assessed on the tasks. The independent variables were set as the numerical values assigned to represent experience, confidence, and recency. When experience, confidence, and recency are combined, the result is a statistically significant model in determining quality of the task performance (*p*-value = .014).

Model Fitting Information

Model	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	40.911			
Final	20.099	20.812	9	.014

Link function: Logit.

Goodness-of-Fit

	Chi-Square	df	Sig.
Pearson	6.129	18	.996
Deviance	7.697	18	.983

Link function: Logit.

Pseudo R-Square

Cox and Snell	.469
Nagelkerke	.515
McFadden	.263

Link function: Logit.

Figure 17. Magnetic Particle - Experience/Confidence/Recency vs Quality (# errors)

When performed individually, only recency had a statistically significant model (*p*-value = .021. Experience (*p*-value = .335) and Confidence (*p*-value = .501) were not individually statistically significant.   Although recency alone is a statistically significant model in predicting the quality of performance, the combined model is preferred because it takes into account more than a single factor.

Hypotheses Conclusions

Based on the observed data set, there are statistically significant relationships between certain factors and performance. The following (Figure 18) is a summary of results followed by an explanation as stated by the research hypotheses.

	Helicoil			Hardness	Measure	Penetrant Meth C		Magnetic Particle	
	Time	Success (P/F)	Quality (Errors)	Success (P/F)	Success (P/F)	Success (P/F)	Quality (Errors)	Success (P/F)	Quality (Errors)
TIS	x	x	x	x	x	x	x	x	x
TIG	x	x	x	x	x	x	x	x	x
Age									
Gender	x	x	x	x	x	x	x	x	x
Rank	x	x	x	x	x	x	x	x	x
Background		x		x	x	x	x	x	x
Skill Level	x	x	x	x	x	x	x	x	x
Confidence		x		x	x	x		x	
Experience		x	x	x	x	x		x	
Recency		x	x	x	x	x		x	

Figure 18. Significance of Factors by Task

Hypothesis 1: Confidence will be positively related to performance.

Within this data set, confidence is a statistically significant indicator of quality when evaluated individually or when combined with experience and/or recency on three of the five tasks evaluated: Remove/Install Helical Coil Insert, Perform Liquid Penetration Inspection Method C, and Perform Magnetic Particle Inspection. It is also individually statistically significant as an indicator of speed in removing/installing helical coil inserts. Based on this data set, there is evidence to support this hypothesis.

Hypothesis 2: Experience will be positively related to performance.

Within this data set, experience is a statistically significant indicator of quality when evaluated individually or when combined with confidence and/or recency on three of the five tasks evaluated: Remove/Install Helical Coil Insert, Perform Liquid Penetration Inspection Method C, and Perform Magnetic Particle Inspection. Based on this data set, there is evidence to support this hypothesis.

Hypothesis 3: More recent task completion will be positively related to performance.

Within this data set, recency is a statistically significant indicator of quality when evaluated individually or when combined with confidence and/or experience on three of the five tasks evaluated: Remove/Install Helical Coil Insert, Perform Liquid Penetration Inspection Method C, and Perform Magnetic Particle Inspection. Based on this data set, there is evidence to support this hypothesis.

Hypothesis 4: Primary AFSC Airmen will have higher task performance scores than CUT Airmen.

The only task where background was a significant factor was "Remove/Install Helicoil Insert". In this task, Metals Tech personnel (Primary AFSC) performed the task twice as fast as NDI personnel (CUT personnel) and committed an average of one fewer errors. Based on this data set, there is only enough evidence to partially support this hypothesis.

Hypothesis 5: Time in Service (TIS) will be positively related to performance.

None of the five tasks showed any statistically significant relationship between TIS and performance. Based on this data set there is not enough evidence to support this hypothesis.

Hypothesis 6: Time in Grade (TIG) will be positively related to performance.

None of the five tasks showed any statistically significant relationship between TIG and performance. Based on this data set there is not enough evidence to support this hypothesis.

Hypothesis 7: Age will be positively related to performance.

Age was not tested due to multicollinearity issues with TIS and was therefore excluded from all models. This hypothesis was not tested.

Hypothesis 8: Gender will not be related to performance.

None of the five tasks showed any statistically significant relationship between gender and performance. Based on this data set there is not enough evidence to support this hypothesis.

Hypothesis 9: Rank will be positively related to performance.

None of the five tasks showed any statistically significant relationship between rank and performance. Based on this data set there is not enough evidence to support this hypothesis.

Hypothesis 10: Skill level will be positively related to performance

None of the five tasks showed any statistically significant relationship between skill level and performance. Based on this data set there is not enough evidence to support this hypothesis.

V. Conclusions and Recommendations

Conclusions of Research

Largely in part due to a small sample size, large-scale analysis is potentially wildly inaccurate. However, there is at least one key point that is likely to transcend this narrow scope of research. The researcher concludes that when attempting to identify factors that influence performance, the best place to look is the individuals' own perception of their ability. The most important result in any of these tasks is a passing score (i.e. the ability to complete the task successfully). In order to trust an Airman to contribute to the mission effectively, one must have confidence that they are able to perform the desired task at any given time. None of the independent variables considered had a statistically significant impact on the ability of a technician to successfully complete the task. The technician's personal assessment on their confidence level, experience level, and how recent they performed the task had a statistically significant positive relationship with quality (the number of errors committed). Technicians that had higher confidence levels, more experience, and completed a particular task more recently were more likely to complete the task with fewer errors. Therefore, within the confines of this research, the most effective way to improve performance on a given task is to identify how to improve one's confidence, experience, and recency.

Recommendations for Action

Regarding the fabrication flight of the future initiative, this researcher's recommendation to the field is to emphasize training tailored to the individual that improves confidence, experience, and recency. With limited resources available, training large groups in small amounts will not have the same value as training small groups in large amounts.

Recommendations for Future Research

This research did not identify factors that affect the ability to successfully complete a task. Future research could be aimed at identifying these factors. As CUT/multiskilling is widely used across Aircraft Maintenance and many other AFSCs, future research could apply these concepts to other specialties.

Appendix A: Support Request Memo

DEPARTMENT OF THE AIR FORCE
USAF EXPEDITIONARY CENTER (AMC)
JOINT BASE MCGUIRE-DIX-LAKEHURST, NEW JERSEY

21 Dec 2021

MEMORANDUM FOR 3 MXS/CC
60 MXS/CC
305 MXS/CC
436 MXS/CC

FROM: USAF EC/ASAM

SUBJECT: 2A7X1 Aircraft Metals Technology (AMT) & 2A7X2 Nondestructive Inspection (NDI) Cross-Utilization Training (CUT) Research

1. As part of my graduate thesis through the Air Force Institute of Technology and USAF Expeditionary Center, I will be conducting CUT research explicitly focused on Mobility Air Force (MAF) Fabrication Flights. The purpose of this study is to identify correlations amongst demographics, methods of training, and work quality that best aligns the Fabrication of the Future concept with Air Force doctrine and strategy. This research proposal has received support from HAF/A4LM and AMC/A4 with the knowledge that your units were selected to partake in the study.

2. The purpose of this memo is to request the support of your fabrication flights to assist in the study. Each of your Squadrons was selected based on your unique mission set. The experiments will begin on February 21, 2022, requesting the following requirements:

a. No less than 10x (the more, the better) AMT personnel of mixed skill level, rank, and experience will receive on-the-job training for the following NDI tasks:

(1) IAW TO 33B-1-1, 33B-1-2, and CFETP Task 2.12, 2.12.1, and 2.12.1.3, Liquid Penetrant Inspection Method C. Focus on portable inspection procedures.

(2) IAW TO 33B-1-1, 33B-1-2, and CFETP Task 2.13, Magnetic Particle Inspection Method. Focus on portable inspection procedures.

b. No less than 10x (the more, the better) NDI personnel of mixed skill level, rank, and experience will receive on-the-job training for the following Metals Technology tasks:

(1) IAW CFETP Task A2.9.3.1.2, Remove/Install Heli-coil inserts

(2) IAW CFETP Task A2.10.4.1, Operate Hardness Tester

(3) IAW CFETP Task A2.11.1.2, Use precision measuring devices

c. Provide one SNCO functional expert, preferably the Fabrication Flight Superintendent, to facilitate the training and function as the liaison between the unit and myself.

3. All training must take place in-house using experienced/qualified personnel. Trainees must be proficient on the tasks, but will not be certified for operational use on any of the tasks beyond the scope of this experiment. Task training is only authorized under the scope of this experiment.

4. Please complete training NLT February 21, 2022.

5. If you have any additional questions or concerns, please contact me by phone at 412-496-8284 or email aaron.vogeler@us.af.mil.

VOGELER.AARON.L.1287046185 Digitally signed by VOGELER.AARON.L.1287046185 Date: 2021.12.22 10:27:53 -05'00'

AARON L. VOGELER, Maj, USAF

Appendix B: Informed Consent Form

Informed Consent Document For
Factors Influencing Cross Utilization Training in Aircraft Maintenance Fabrication

Principal Investigator: Major Aaron L. Vogeler, DSN 650-7320
Advanced Study of Air Mobility, USAF EC
aaron.vogeler@us.af.mil

1. **Nature and purpose:** You are invited to participate in this research study concerning factors influencing Cross Utilization Training in Aircraft Maintenance Fabrication. The purpose of this research is to determine if relationships exist between demographic qualities and task performance. The time requirement for each volunteer is anticipated to be a total of one visit of approximately 2 hours in addition to any training requirements in advance of the study. A total of more than 40 anonymous participants across 4 separate locations are expected to participate.

2. **Experimental procedures:** If you decide to participate, you will be given five maintenance tasks to complete in which you will be timed. Your performance will be evaluated only for the purposes of quantifying data. Your individual performance will be anonymous and not documented outside the scope of the experiment.

3. **Discomfort and risks:** There are inherent risks associated with any maintenance task. Discomforts may consist of normal risks associated with current job performance such as fatigue and minor stress. There are not any known additional risks associated with this research beyond the expected risk associated with the nature of maintenance tasks.

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

5. **Compensation:** There is no compensation for participation beyond normal pay for Active Duty.

6. **Alternatives:** You may choose to *not* participate in this study. Declining to participate will not result in any penalty or loss of benefits to which you are otherwise entitled. Notify the investigator immediately should you choose to not participate.

Your signature indicates your acknowledgement and understanding of the previous information and indicates your voluntary decision to participate in this research study.

Printed Name: ______________________________

Signature: __________________________________ Date: ______________

Appendix C: Experiment Questionnaire

Technician #

1. What is your Rank? __________
2. What month/year did you enlist? __________/________
3. What month/year did you promote to your current rank? _________/_________
4. What is your gender? ___________
5. What is your Age? _______
6. What is your background? (circle)
   a. NDI
   b. Metals Tech
7. What is your highest earned skill-level
   a. 3-level
   b. 5-level
   c. 7-level
8. What was your composite ASVAB/AFQT score? ________

---

9. Concerning the task **"Liquid Penetration Inspection Method C"**, how many hours of experience (including training) do you have completing the task? (circle one)

   < 5 hours   5-10 hours   11-20 hours   20-50 hours   > 50 hours

10. Concerning the task **"Liquid Penetration Inspection Method C"**, what is your confidence level that you are able to successfully complete the task as instructed with an acceptable passing score as determined by a Subject Matter Expert? (circle one)

    Not Confident   Somewhat Confident   Very Confident

11. Concerning the task **"Liquid Penetration Inspection Method C"**, how long has it been since you last accomplished this task (training or operationally)? (circle one)

    < 2 weeks   2-4 weeks   1-3 months   4-6 months   > 6 months

---

12. Concerning the task **"Magnetic Particle Inspection Method"**, how many hours of experience (including training) do you have completing the task? (circle one)

    < 5 hours   5-10 hours   11-20 hours   20-50 hours   > 50 hours

13. Concerning the task **"Magnetic Particle Inspection Method"**, what is your confidence level that you are able to successfully complete the task as instructed with an acceptable passing score as determined by a Subject Matter Expert? (circle one)

    Not Confident   Somewhat Confident   Very Confident

14. Concerning the task **"Magnetic Particle Inspection Method"**, how long has it been since you last accomplished this task (training or operationally)? (circle one)

    < 2 weeks   2-4 weeks   1-3 months   4-6 months   > 6 months

---

15. Concerning the task **"Remove/Install Heli-coil Inserts"**, how many hours of experience (including training) do you have completing the task? (circle one)

    < 5 hours   5-10 hours   11-20 hours   20-50 hours   > 50 hours

16. Concerning the task **"Remove/Install Heli-coil Inserts"**, what is your confidence level that you are able to successfully complete the task as instructed with an acceptable passing score as determined by a Subject Matter Expert? (circle one)

    Not Confident   Somewhat Confident   Very Confident

17. Concerning the task **"Remove/Install Heli-coil Inserts"**, how long has it been since you last accomplished this task (training or operationally)? (circle one)

    < 2 weeks   2-4 weeks   1-3 months   4-6 months   > 6 months

---

18. Concerning the task **"Operate Hardness Tester"**, how many hours of experience (including training) do you have completing the task? (circle one)

    < 5 hours   5-10 hours   11-20 hours   20-50 hours   > 50 hours

19. Concerning the task **"Operate Hardness Tester"**, what is your confidence level that you are able to successfully complete the task as instructed with an acceptable passing score as determined by a Subject Matter Expert? (circle one)

    Not Confident   Somewhat Confident   Very Confident

20. Concerning the task **"Operate Hardness Tester"**, how long has it been since you last accomplished this task (training or operationally)? (circle one)

< 2 weeks 2-4 weeks 1-3 months 4-6 months > 6 months

---

21. Concerning the task **"Use Precision Measuring Device"**, how many hours of experience (including training) do you have completing the task? (circle one)

< 5 hours 5-10 hours 11-20 hours 20-50 hours > 50 hours

22. Concerning the task **"Use Precision Measuring Device"**, what is your confidence level that you are able to successfully complete the task as instructed with an acceptable passing score as determined by a Subject Matter Expert? (circle one)

Not Confident Somewhat Confident Very Confident

23. Concerning the task **"Use Precision Measuring Device"**, how long has it been since you last accomplished this task (training or operationally)? (circle one)

< 2 weeks 2-4 weeks 1-3 months 4-6 months > 6 months

Appendix D: Grading Criteria Example

evaluations to complete during the month. Types of inspections must be separated and shall not be combined (such as, PE/QVI). **(T-1)**.

6.7.3. **(AMC)** Inspections that are not scheduled or occur on a regular basis can be tracked on quarterly and annual E&I plans.

6.7.3.1. The E&I Plan, and changes to it, will be coordinated through each squadron Operations Officer/MX SUPT and approved by the MXG/CC. **(T-1)**.

6.7.3.2. The E&I Plan will be reviewed and updated monthly based on trends in the maintenance complex and will be adjusted to meet the MXG/CC's focus areas. **(T-2)**.

6.7.3.2. **(AMC)** The E&I Plan will be reviewed and updated quarterly **(T-2)**.

6.7.3.2.1. **(Added-AMC)** The quarterly plan must show inspections accomplished during each month within the quarter **(T-2)**.

6.7.3.3. When developing the E&I Plan, the QA SUPT will:

6.7.3.3.1. Address areas of concern identified by maintenance managers and the WWM. **(T-1)**.

6.7.3.3.2. Tailor the plan for each squadron, flight and section. **(T-1)**.

6.7.3.3.3. Coordinate and distribute the E&I Plan. **(T-1)**.

6.7.4. Evaluation Criteria.

6.7.4.1. Acceptable Quality Levels (AQL). AQLs denotes the maximum allowable number of minor findings that a process or product may be charged for the task to be rated "Pass" and are used to minimize subjectivity in assessing tasks identified by the MSEP.

6.7.4.1.1. MAJCOMs may develop standardized AQLs by weapon system and establish procedures to review at least annually.

6.7.4.1.1. **(AMC)** The WSL QA and the En Route lead QA will review AQL data during annual RIL coordination and adjust command standard AQLs accordingly **(T-2)**.

6.7.4.1.1.1. **(Added-AMC)** Local RIL AQLs will not be less stringent than AMC RIL AQLs **(T-2)**.

6.7.4.1.2. MXG/CCs will establish AQLs for tasks/inspections not included on the MAJCOM AQL listing. **(T-2)**.

6.7.4.1.2.1. AQLs need to be derived/revised from QA performance-based data.

6.7.4.1.3. AQLs/baselines for nuclear maintenance, cruise missile maintenance and nuclear weapons handling tasks are defined in AFMAN 21-200.

6.7.4.2. Discrepancy Categories.

6.7.4.2.1. Category I (CAT I). A required inspection/TO/AFI procedural item missed or improperly completed. This category is a specific AFI requirement, work card item or TO step, warning, caution, or note for a specific condition or action. Use sub-classifications of major or minor to indicate the discrepancy's relative severity.

6.7.4.2.1.1. **(Added-AMC)** Category I discrepancies/findings may be used to identify requirements that are specific to the evaluated task, process, or program and are found in the guidance required to be present and used in order to complete the task.

6.7.4.2.2. Category II (CAT II). An obvious defect, which could have been readily detected by a technician or supervisor, but is not a specific AFI requirement, work card item or TO step, warning, caution, or note for that specific evaluated task. Use sub-classification of major or minor to indicate the discrepancy's relative severity.

6.7.4.2.2.1. (Added-AMC) Discrepancies/findings identified during zonal inspections will be CAT II **(T-2).**

6.7.4.2.2.2. **(Added-AMC)** Category II discrepancies/findings may be used to identify requirements that are general guidance and may apply to multiple tasks, processes, and programs.

6.7.4.3. Findings.

6.7.4.3.1. A major finding is defined as a condition that may endanger personnel, jeopardize equipment or system reliability, impact safety of flight or warrant discontinuing the process or equipment operation.

6.7.4.3.2. Any major discrepancy will result in an automatic inspection failure. **(T-1)**.

6.7.4.3.3. The QA Inspector will intercede and declare a major finding when one additional action will result in one of the following; endanger personnel, jeopardize equipment or system reliability, impact safety of flight or warrant discontinuing the process or equipment operation. **(T-1)**.

6.7.4.3.3.1. The QA Inspector will write up the major finding even though the jeopardizing action was never taken due to their intercession. **(T-1)**.

6.7.4.4. A minor finding is defined as an unsatisfactory condition that requires repair or correction, but does not endanger personnel, impact safety of flight, jeopardize equipment reliability or warrant discontinuing a process or equipment operation.

6.7.4.4.1. CAT II minors shall be documented for trends, but must not be counted against the AQL. **(T-1)**.

6.7.4.4.2. Soft FO contained in tool kits or found in cargo areas of aircraft which pose no FOD threat are classified as a minor finding since it will require more than one additional action to meet the definition of a major finding.

6.7.5. Observations. This category represents observed events or conditions with safety implications or technical violations not related to an evaluation or inspection, are considered unsafe, in violation of established procedures, or in the case of equipment, unfit for operations. Observations include: DSVs, TDVs and UCRs. The LEAP QA database is used to document any of the following conditions:

6.7.5.1. DSV. An observed unsafe act by an individual.

6.7.5.1.1. The QA Inspector must stop the unsafe act immediately. **(T-1)**.

Appendix E: NDI Personnel Evaluation Guidance

Task Evaluation Guidance for Quality Assurance Personnel Evaluations on NDI Personnel

Based On Skill Level/Upgrade Training

This document's task evaluation guidance expands on Quality Assurance (QA) requirements outlined in TO 33B-1-1, paragraph 1.2.7.1. The following tasks are appropriate for the identified skill level and experience of the technician. NDI Lab Chiefs and QA personnel should use their discretion to select tasks that best fit the NDI methods and techniques performed within the work center. The task listing is a starting point (minimum) to meet QA Personnel Evaluation (PE) task requirements but may be expanded on.

For this guidance, a 3-Level is a Technician in 5-Level upgrade training with the appropriate tasks signed off. A 7-Level is a Technician in 7-Level upgrade training with the appropriate tasks signed off or an already qualified 7-Level. **NOTE:** The 3-Level PE is to be accomplished following task sign-off and third-party certification. IAW TO 33B-1-1, paragraph 1.2.7.1, "NDI personnel without a current PE documented SHALL NOT perform tasks associated with the NDI method." A NAS 410 Level 2 is equivalent to a 7-Level.

A red asterisk (*) indicates a task that may be chosen for a QA PE at the NDI Lab Chief and QA discretion.

Penetrant Testing (PT)			
Task	**3-Level**	**5-Level**	**7-Level**
Method A - Perform Part Processing & Inspection (TO 33B-1-2, WP 202 00 or applicable Weapon System or component TO)	X	X	X
Method C - Perform Part Processing & Inspection (TO 33B-1-2, WP 201 00 or applicable Weapon System or component TO)	X	X	X
Method D - Perform Part Processing & Inspection (TO 33B-1-2, WP 200 00 or applicable Weapon System or component TO)	X	X	X
Magnetic Particle Testing (MT)			
Task	**3-Level**	**5-Level**	**7-Level**
Stationary Magnetic Particle - Perform Part Processing (Circular/Longitudinal) & Inspection (TO 33B-1-2, WP 300 00 or applicable Weapon System or component TO)	X	X	*
Stationary Magnetic Particle - Perform Amperage Determination (QQI/Gauss Meter & Hall Effect Probe) w/Stationary Mag Bench (TO 33B-1-2, SWP 300 01/300 02)	X	X	
Portable Magnetic Particle - Perform Part Processing (No QQI) & Inspection (TO 33B-1-2, WP 301 00 or applicable Weapon System or component TO)	X	X	
Portable Magnetic Particle - Perform Magnetic Field Strength Determination (QQI), Part Processing, & Inspection w/Yoke (TO 33B-1-2, WP 301 00 or applicable Weapon System or component TO)	*	X	X
Stationary Magnetic Particle - Perform Amperage Determination (QQI/Gauss Meter & Hall Effect Probe), Part Processing (Circular/Longitudinal), & Inspection w/Stationary Mag Bench (TO 33B-1-2, WP 300 00/01/02 or applicable Weapon System or component TO)	*	X	X

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14. ABSTRACT
The goal of this research was to identify areas that affect performance in Cross Utilization Training (CUT) in order to maximize its effectiveness. The researcher collected performance data of 25 personnel of varying demographics at 3 different locations each performing 5 different tasks from the Metals Technology and Non-Destructive Inspection career fields. The researcher used a combination of linear, bivariate, and ordinal regression to assess relationships between demographics, confidence, experience, recency and the task performance data. For three of the five tasks, confidence, experience, and recency were good indicators of performance.

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Cross Utilization Training, Fabrication, Aircraft Maintenance, Multiskilling

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