A STUDY TO ESTIMATE THE EFFECTIVENESS OF VISUAL TESTING TRAINING FOR AVIATION MAINTENANCE MANAGEMENT

by

Lewis Lyle Law

A Graduate Capstone Project
Submitted to the Extended Campus
in Partial Fulfillment of the Requirements of the Degree of
Master of Science in Management

Embry-Riddle Aeronautical University
Extended Campus
Space Coast Resident Center
March 2007

A STUDY TO ESTIMATE THE EFFECTIVENESS OF VISUAL TESTING TRAINING FOR AVIATION MAINTENANCE MANAGEMENT

by

Lewis Lyle Law

This Graduate Capstone Project was prepared under the direction of the candidate's Research Committee Member, Dr. Tony Delmonte, Adjunct Assistant Professor, Extended Campus, and the candidate's Research Committee Chair, Dr. James C. Dumville, Adjunct Professor, Extended Campus, and has been approved by the Project Review Committee. It was submitted to the Extended Campus in partial fulfillment of Master of Science in Management

PROJECT REVIEW COMMITTEE:

Anthony (Tony) Delmonte, D.B.A.
Committee Member

James C. Dumville , Ph.D.
Committee Chair

ACKNOWLEDGEMENTS

I would like to thank my wife Wendy and daughter Angel for… Great thanks and admiration is given to my parents Lewis and Janis Law who have supported me through my entire higher education endeavors. Recognize Committee members for their help…

ABSTRACT

Researcher: Lewis Lyle Law

Title: A STUDY TO ESTIMATE THE EFFECTIVENESS OF VISUAL TESTING TRAINING FOR AVIATION MAINTENANCE MANAGEMENT

Institution: Embry-Riddle Aeronautical University

Degree: Master of Science in Management

Year: 2007

Create abstract here...

Comment [L1]: Your in present & past tense not future.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

The Importance of the Study

The Air Commerce Act of 1926 set the beginning for standards in aviation maintenance. Even after deregulation in the late 1970s, maintenance standards and requirements still have not changed far from their initial criteria. After a potential candidate completes Federal Aviation Administration training prerequisites, they may test for their Airframe and Powerplant (A&P) certificate. Performing maintenance in the aviation industry for a minimum of three years, the technician may then test for their Inspection Authorization (IA).

After receiving their Airframe and Powerplant certificate, a technician is said to have a license to perform. At no time within the three years to eligibility for Inspection Authorization are they required to attend higher-level inspection training. What a technician learns in the aviation maintenance industry is handed down from a seasoned technician to the new hire or is developed from lessons learned on the job. Only in Europe has the Joint Aviation Authorities (JAA) required higher-level training for their aviation maintenance technicians in order to control maintenance related accidents (Lu, 2005).

Throughout the 1990s both the General Accounting Office (GAO) and the National Transportation Safety Board (NTSB) made public that the FAA is historically understaffed (GAO, 1996). In a safety recommendation the NTSB stated "The Safety Board continues to lack confidence in the FAA's commitment to provide effective quality assurance and safety oversight of the ATC system (NTSB, 1990)." The Federal Aviation Administration (FAA) has been known to be proactive in creating safer skies. With such reports you would suspect the FAA to also be proactive in developing more stringent inspection training for aviation maintenance technicians.

Statement of the Problem

The purpose of this study is to estimate the effectiveness of higher-level inspection training, such as Visual Testing (VT) for aviation maintenance technicians, to improve the safety of aircraft and to make recommendations to management with regard to the value of such training.

The Sub Problems

The first sub problem is to determine if Visual Testing Training offers a greater level of understanding for aviation maintenance and inspection.

The second sub problem is to determine if maintenance and inspection can be trained in Visual Testing in a timely manner.

The third sub problem is to determine if there is a significant difference between sub problems one and two

The fourth sub problem is to determine the significance between maintenance inspection with A&P training and maintenance inspection with Visual Testing Training.

The fifth sub problem is to determine if a quality inspector is able to retain information from training in Visual Testing after a specified amount of time.

The Assumptions

This study assumes that historical data obtained and referenced is valid and reliable to the best extent possible.

This study is based on the assumption that A&Ps and Inspectors have all had equivalent training to perform their duties.

The Delimitations

This study will utilize statistical data from a real company implementing Visual Testing training, but the company name will not be revealed due to a request by the Human Resources and Legal departments. A fictitious name Company X will be used in its place.

The findings in this study are valid only to Company X.

This study will not attempt to provide a method of implementing Visual Testing training for any company.

This study is based on statistical sampling and inference and does not include 100 percent of technicians and inspectors being trained in Visual Testing.

Definition of Terms

A Check – This is performed approximately every month. This check is usually done overnight at an airport gate. The actual occurrence of this check varies by aircraft type, cycle, or the number of hours flown since the last check. The occurrence can be delayed by the airline if certain predetermined conditions are met.

B Check – This is performed approximately every three months. This check is also usually done overnight at an airport gate.

C Check – This inspection is performed approximately every 12 to 18 months. This maintenance check takes the aircraft out of service.

Cycle – One takeoff and landing equals one cycle.

D Check – This check occurs approximately every 4 to 5 years. This is the heaviest check for the airplane. This inspectoin takes the entire airplane apart for inspection.

Inspection – An organized examination or formal evaluation exercise. It involves the measurements, tests, and gauges applied to certain characteristics in regards to an object or activity.

Ramp Check – This is a visual inspection performed before every flight sometimes called a preflight.

Visual Testing – Evaluation of surface features on articles or in materials to detect unsatisfactory conditions by use of reflected or transmitted light from a test object to the human eye.

Abbreviations and Acronyms

A&E – Airframe and Engine

A&P – Airframe and Powerplant

AD – Airworthiness Directive

AMT – Aviation Maintenance Technician

ASAP – Aviation Safety Action Programs

ASME – American Society for Mechanical Engineers

ASNT – American Society of Nondestructive Testing

ATOS – Air Transportation Oversight System

CFR – Code of Federal Regulations

COQ – Cost of Quality

CRM – Cockpit Resource Management

FAA – Federal Aviation Administration

FAR – Federal Aviation Regulation

GAO – General Accounting Office

GSE – Ground Support Equipment

IA – Inspectors Authorization

JAA – Joint Aviation Authorities

MRM – Maintenance Resources Managements

NTSB – National Transportation Safety Board

OJT – On the Job Training

SB – Service Bulletin

SWOT – Strengths, Weakness, Opportunities, and Threats

TQM – Total Quality Management

VT – Visual Testing

CHAPTER II

REVIEW OF RELEVENT LITERATURE AND RESEARCH

The Importance of Maintenance and Inspection

When the Wright Brothers built their first airplane, much effort was taken by the brothers and their mechanic, Charlie Taylor, to assure a reasonable amount of safety. As more aircraft were being produced and flying, the task of maintaining the airplane fell on the aircraft pilot.

Maintenance of the aircraft was generally performed in a barn. With just a basic knowledge of mechanics, anyone could work on the airplane. As people are different and some will take greater chances than others, many of these aircraft would take their occupants to the grave. Improper maintenance procedures coupled with needless risk would be curbed by the Air Commerce Act of 1926. This act charged the Secretary of Commerce with issuing and enforcing rules for aviation safety (Bemowski, 1997). It would soon be necessary for anyone wishing to perform maintenance on an aircraft to obtain an Airframe and Engine (A&E) certificate.

Airframe & Power Plant / Inspectors Authorization

Through many years of change, the Aeronautics branch of the Department of Commerce would become the responsibility of the Federal Aviation Administration (FAA). The requirements for applicants to pursue an Airframe and/or Powerplant (A&P) certificate must meet FAA requirements set forth within Federal Aviation Regulations (FAR) 65.71-65.77.

These regulations give a potential licensee three methods of acquiring the necessary experience needed to pass the test. The first option is to attend up to 24 months of schooling at an approved FAR Part 147 Aviation Maintenance School. Second is through work experience, otherwise known as On the Job Training (OJT) under a licensed A&P technician for up to 30 months. This method has a requirement to document work experience in a log book signed by the supervising A&P. And third, a person could enlist in the armed services to get training and experience in aviation maintenance. This method as well requires one to present an official letter from the military employer certifying the necessary experience has been obtained (Federal Aviation Administration, Department of Transportation, 2007). In all cases the applicant must have the time required for the experience in the rating for which they are testing.

After a minimum of three years, a certificated A&P may opt to acquire an Inspection Authorization (IA). Some of the skills on which the candidate will be tested are the ability to perform in-depth reviews of the Federal Aviation Administration (FAA) Regulations, FAA Orders, Advisory Circulars, and Airworthiness Directives. With this added certification, the A&P is allowed to perform annual inspections on general aviation aircraft, sign off major repairs, as well as signing off approved alterations (e-CFR, 2007, §65.91). What this certification does not do, however, is test the A&P's skills in visual inspection.

Licensed repair stations only require an A&P who is able to watch over repairman's work. These technicians are covered under the repair stations license as stated in Federal Aviation Regulation (FAR) Part 145.159 and are trained by the employer to perform their task (Federal Aviation Administration, Department of Transportation, 2007). The FAA is involved with a study that will require all repair facilities to have FAA approved training programs for their employees. This will also be accompanied by an update to the A&P

training criteria and changing the designation to the Aviation Maintenance Technician (AMT).

Repair stations employ quality inspectors in order to verify that a repairman's work has been done satisfactorily. The inspectors are also responsible for visual inspection of the flight hardware. Again, training is in-house, and the FAA inspector will randomly sample inspection points to verify the work is done satisfactorily.

Quality/Inspector Responsibilities

Out of many definitions, we can determine a Quality Inspector's responsibilities lay with the identification of anomalies that could be detrimental to the fit, form, or function of the equipment being inspected. Other responsibilities include confirming that technical work has been performed satisfactorily to company specifications and engineering requirements.

By visually inspecting the component with the use of basic tools, an Inspector is able to measure, compare, and analyze a product's characteristics to determine if they meet acceptable limitations.

Many aviation maintenance departments employ Quality Inspectors who are responsible for, not only inspecting for conformance to specification, but also for validating the aircraft documentation is kept up-to-date. These inspectors are generally FAA certified IAs, which again has only qualified that person in FAA regulations and not necessarily the materials and process's of construction and aging of aircraft.

FAA Background for Visual Inspection

Visual inspection is a primary component of aircraft maintenance. Many times the National Transportation and Safety Board has determined in their investigations that the failure to properly identify visually detectable defects, such as cracks, corrosion, and inclusions, has been to cause for aviation accidents (Good, Nichols, Subbaram,...n.d.). The FAA, however, has not responded with mandatory training; rather, studies have been performed in the area of Aviation Safety Action Programs (ASAPs) and Maintenance Resource Management (MRM). In contrast, Cockpit Resource Management (CRM) is required by the FAA for pilots, flight engineers, flight attendants, and dispatchers (Cheing-tsung, 2005).

Aviation Safety Action Program allows airline employees to report safety-related mistakes or potential problems without fear of punishment. A committee is made up of labor, management, and a representative from the FAA to review each report. This method has been used extensively by airline pilots and is spreading into the maintenance arena. MRM defines classes that are given to employees to increase their awareness of where human errors usually occur. Classes in MRM are closely related to human factors training, but organized with the problems that management has identified (Canaday, 2006).

Yet another method the FAA is adopting is the Air Transportation Oversight System (ATOS). In this system, the FAA intends to identify safety trends in order to spot and correct problems before an accident occurs. By collecting and analyzing data from airline systems, the FAA inspectors can target areas for improvement (German, 1998).

Still the obvious approach that the FAA is using to influence A&Ps and employers to participate in available recurrent maintenance and inspection training is the Aviation Maintenance Technician Awards Program (Federal Aviation Administration, 2007). Begun in 1992, this program awards technicians with tie tack/lapel pins and certificates for different phases of training hours logged in a year. Each successive phase is more demanding to the technician, which justifies the prestige of the higher award.

Aviation Maintenance Related Mishaps

The National Transportation and Safety Board (NSTB) investigates aircraft accidents and makes suggestions to the FAA to create safer skies. The FAA weighs many factors including risk and cost, when determining what suggestions from the NTSB they will implement. Currently it is not known why the FAA has not implemented more stringent training requirements, for a person who is able to inspect an aircraft for defects and return it to service. Past experience has shown a deficit in inspection training in the airlines.

Though only three accidents are being presented here in this paper, all having to do with maintenance and inspection or the lack there of, many other accidents have been due to structural failure where it is difficult to find the root cause. For the purpose of this paper, it is assumed that proper visual testing and maintenance training could have mitigated all structural failures.

United Airlines Flight 232

On July 19, 1989 a United Airlines McDonnell Douglas DC-10 heading for Chicago, Illinois experienced a catastrophic engine failure, which led ultimately to the destruction of the aircraft. The wide-body jet diverted to Sioux City Iowa for an emergency landing and, upon main gear touchdown, began to lose directional control ending in a rolling fire ball. Fatalities totaled at 111 and injuries totaled more than 170 (NTSB, 1989).

The tail mounted engine (#2) self destructed due to the separation, fragmentation, and forceful discharge of the stage 1 fan rotor assembly. Fragmented pieces, that were not contained, severed all three hydraulic lines leaving the aircraft in an uncontrollable state. The flight crew had only differential thrust to steer the large aircraft to the ground.

The National Transportation Safety Board determined the probable cause was due to the overhaul facilities inspection and quality control procedures during fan disk inspections. These procedures failed to detect a fatigue crack that had developed from a previously undetected metallurgical defect in a high stress area on the fan disk.

Alaska Air Flight 261

A flight on January 31, 2000 would prove again that not following proper maintenance and inspection procedures could lead to failure. Alaska Airlines was found responsible for 88 deaths when their McDonnell Douglas MD-83 suddenly dove 17,900 feet into the ocean only 40 miles offshore. The flight crew were preparing for an emergency landing at Los Angeles International Airport after determining the aircraft had lost pitch control.

The NTSB published findings that pointed at Alaska Airlines maintenance procedures and time lines on the MD-83 stabilizer jackscrew. First the C-check had been extended 1,800 hours past the 7,200 recommended from manufacturer. This contributed to maintenance not performing timely required measurements and servicing on the stabilizer jackscrew. Making things worse is the end-play measurements that had been made during last inspection were found to exceed 0.040 inches, but a recheck had determined the measurement to be acceptable (NTSB, 2000). This measurement was also done with an in-house fabricated bracket that was out of specification.

The NTSB also noted that the lubrication for the jackscrew gimbal nut set up a more corrosive environment leading to faster than intended wear. Maintenance at Alaska Airlines had mixed Mobilgrease 28 and Aeroshell 33 creating a corrosive copper agent. Since the gimbal nut is aluminum bronze and bronze is an alloy of copper, the maintenance department inadvertently corroded the aircraft hardware, which assisted in the part failure.

Air Midwest Flight 5481

Shortly after takeoff on January 8, 2003, a Raytheon 1900D struck a US Airways maintenance hangar. The flight crewmembers and all 19 passengers perished because of: 1) a weight and balance error and 2) a quality assurance incorrect rigging of the aircraft's elevator control system.

NTSB's accident report focused on maintenance work practices, oversight, quality assurance, maintenance training, aircraft weight and balance programs, and FAA oversight. The loss of pitch control was due to the Raytheon Aerospace quality inspector's failure to detect that the airplanes elevator control system was not rigged properly (NTSB, 2003). The FAA had to take responsibility for approving Air Midwest's maintenance program, along with the weight and balance program by which the 1900D was being maintained.

Brief History of Visual Testing Training

Visual Testing (VT) is one of the oldest means of providing information to determine the usability of used equipment. Though a relatively new designation in nondestructive testing, Visual Testing began in 1968 when the American Society of Nondestructive Testing (ASNT) issued a recommended practice SNT-TC-1A, nondestructive testing personnel qualification and certification (Everest VIT, 2003). Further quantified by the American Society for Mechanical Engineers (ASME) VT combined ASNT recommended practices with American National Standards Institute (ANSI) N45.2.6 to separate VT into three categories.

Table 1

VT-1	General condition of the part.
VT-2	Evidence of Leakage.
VT-3	General condition of mechanical and structural support components.

Certification is obtained through written and practical examinations, training and experience minimums, and an eye exam. An employer's appointed level III agent may evaluate the education, training, experience, and physical attributes of each candidate prior to testing the individual for certification.

Visual Testing Training Categories

The six primary methods of nondestructive inspection are Visual, Liquid Penetrant, Magnetic Particle, Radiographic, Ultrasonic, and Eddy Current Testing. Visual Testing training includes multiple different methods of nondestructive training each intended to build on basic knowledge. Though VT categories can be tailored to the specific company requirements, the basics are still the same.

Light and Vision

The Fundamentals of Light and Vision explains the physics of where light comes from and how it is produced along with how color is defined in the visible spectrum. Within the vision section, VT explains how the eye works to send images to the brain.

Materials and Processing / Corrosion

Materials Production expands on refining and solidification of metal, determining what constitutes primary and secondary processing, and how discontinuities are formed either in fabrication or service of the metals. Also taught is an understanding of the different types of corrosion and how they form and react with metals.

Joining Methods

In Joining process training, students will learn welding processes along with common problems associated with welding and how to read weak weld symbols. Brazing and soldering are learned with the differences between them. The four theories of adhesion are learned and followed with mechanical fastening methods such as bolting and riveting.

Table 2

Absorption Theory	Secondary or Van der Waals forces.
Mechanical Theory	Creating an increased surface area by sanding, adhesive must displace entrapped air and lock on mechanically.
Electrostatic Theory	Electrostatic forces in the form of an electrical double layer are formed at the adhesive-adherend interface.
Diffusion Theory	Adhesion arises through the inter-diffusion of molecules in the adhesive and adherend.

Micro-Measuring/Recording/Remote Visual Inspection

Inspection hand tools like flashlights, mirrors, magnifying glass, calipers, mircometers, and transfer guages, along with remote visual inspection tools such as bore scopes and video scopes are presented to students. How they work and principles behind their mechanisms are learned to support proper care of the equipment. Working experience is required for the use of each tool. Imaging, Display and Recording systems are covered due to the increased use of technology in Visual Inspection.

Again the information presented to the Visual Testing student is intended to expand on knowledge already obtained through further education such as the A&P school or college. The stress of each section is on how a human can detect defects visually and the physics behind the detection.

Quality Training Company X

Training has been performed at Company X for five years. Personnel required to take Visual Testing training have been limited to Quality Assurance, though engineers and managers have occasionally attended the course to determine its relevance. The determining factor which led to required training was the in-flight destruction of one of their aircraft and the following investigation determined one of the many causal factors was that inspectors were only required to have the same training that the technicians went through (CAIB, 2003 pg. 217). At no time was it mandatory for inspectors to expand their skills and knowledge giving them further insight into visually detectable defects.

Company X quality inspectors are responsible for performing pre and post flight airframe and systems inspections. They interpret engineering drawings to evaluate technical work has been performed to specification and standards set by the company, and at times conferring with engineering to resolve issues with documents and drawings.

Upon implementation of the Visual Testing program at Company X, a noticeable difference was noted with the level of detail the companies' inspectors began to identify. Discrepancy levels increased showing that more inspectors were finding relevant problems that had not been identified before. The belief was that the VT training created a higher level of awareness within the company quality department allowing for a more informed process of inspection.

Company X continues to train Quality Inspectors in Visual Testing and will recertify them every three years. The success of the program has also encouraged management to consider training their technicians as the first line of defense in Visual Testing.

Air Transportation Benefits through VT

The cost of maintenance and inspection can seem inordinately expensive at times, right up until that major accident that is caused by a part breaking (Dhakar, 1994). Airlines may say to the flying community that their lives are important to them, but they don't always show it in the amount of money spent on maintenance and inspection. If they are like Company X, changes will not be made until a loss has happened.

Kendrick (1986), suggests that airlines are cutting corners in maintenance to remain competitive. He lists four items that are priority to maintain airworthiness standards: 1) a dedication to quality by mechanics and their supervisors, 2) a maintenance and management team also dedicated to quality, 3) utilize best available methods to provide an awareness of a condition, and 4) timely corrective actions that insures each aircraft is operating properly (Kendrick, 1986).

The airlines are spending less to maintain their planes; reductions in safety spending are less visible to the traveling public than reductions in service quality spending (Rhoades, 1999). One of the latest trends for airlines is to outsource their maintenance to third party maintenance facilities and even other countries. Federal oversight is stretched thin trying to keep up with the outsourcing services for inspection and repair. American Airlines is said to have outsourced only 20 percent of their maintenance in a cost-cutting effort, but this is still less than the outsourcing at other airlines (Stifflemire, 2002).

If airline operators required visual testing training for their inspectors and technicians, less money would be wasted on component repairs due to age and cycles on the aircraft. Teaching workers to identify failure mechanisms of composites leads to fewer structural repairs, especially when these inspections occur in the maintenance facility. Understanding the stress points on the pressure bulkhead could help identify potential problems before they fail. The examples can get more complex, but the key idea is if the damage is detected and repaired early, the cost of repair is lower.

Quality Model

Every quality program implemented in business looks for a problem to fix, fixes it, and tests the fix. As defined by Crosby (1980), the Cost of Quality (COQ) has two main components: 1) the cost of conformance and 2) the cost of non-conformance (Mills, 2003). Cost of quality is the expense of non-conformance, or the amount of money a business loses because its product or service was not done right in the first place (Crosby, 1980).

From fixing an improperly assembled engine on the assembly line to having to deal with a lawsuit because of a malfunctioning aircraft component or a badly performed service, businesses lose money every day due to poor quality. For most businesses, this can run from 15 to 30 percent of their total costs (Mills, 2003).

Crosby, Deming, and Juran have all had significant impact on Total Quality Management (TQM) programs. The justification for TQM, other than producing a quality product that customers will value, is that quality ahead of failure is cheaper. Many tools are available to management to determine the quality and cost of quality for their organization.

The SWOT analysis is a quality developed planning tool designed to look at Strengths, Weakness, Opportunities, and Threats (Ahmed, Zairi, & Almarri, 2006). With ATOS implemented, the FAA is essentially performing a SWOT analysis. The FAA has stopped asking if there is a need for improvement and is helping companies willing to spend the money to fix their maintenance issues. Most of this assistance is in the form of studies to determine an adequate fix, employees are positively affected and company operations are improved.

Though MRM and ATOS have reduced the number of unobserved defects in maintenance, other methods of training, such as Visual Testing, can be utilized to further improve detection of anomalies. The layout of visual testing training is to teach the basics and to fine-tune training for each individual organization. By implementing a human factors segment into VT training, an organization enlightens their technicians within the human psyche, as well as, materials and processing.

Visual Testing training could offer airlines a safer and higher quality product through the education of the maintenance department. As stated earlier, some maintenance shops do not require FAA A&P certification to work on, or inspect hardware. VT training may be used to level the knowledge base of employees whether certified or not.

The Hypothesis

One aspect of certification requies the passing of a standard test in Visual Testing. This test can be used to determine if the organizations knowledge base is sufficiently alighned. The first hypothesis is that greater than 20 percent of maintenance and inspection would not support a standard 40 question test on Visual Testing before VT training.

The second hypothesis is that no more than 15 percent of quality inspectors with recent training in Visual Testing would not support a similar standard 40 question test on VT.

The third hypothesis is that there will be a significant difference between the proportions in hypothesis one and two.

The fourth hypothesis is that the proportion of quality inspectors holding A&P certificates and supporting the standard 40 question VT test will be larger than the proportion of quality inspectors not holding A&P certificates and supporting the standard 40 question VT test.

The fifth hypothesis is that no higher than 40 percent of VT certified quality inspectors will not support a standard 40 question test upon re-examination on Visual Testing after three years.

CHAPTER III

REASEARCH METHODOLOGY

Research Design

This research will utilize VT training data obtained from historical data and recent testing data at Company X gathered by the Level III Visual Testing instructors. The collected data will be used to estimate the effectiveness of the Visual Testing training program and the time required to adequately instruct the required knowledge. Data will also be collected to analyze the retention level of VT certified persons after a period of at least three years.

Sources of Data

Test data will be collected on quality inspectors who have not been trained in Visual Testing to analyze scores from a 40 question test.

Test data will be collected on quality inspectors after VT training to analyze scores from a 40 question test.

Historical data that documents past VT training scores will be analyzed to define the number of A&P versus non A&P certified quality inspectors that have supported the VT training.

Test data will be collected on quality inspectors after a period of three years has elapsed since VT training to determine retention of information.

Treatment of Data and Procedures

The first sub problem is to determine if Visual Testing training offers a greater level of understanding for aviation maintenance and inspection. The associated hypothesis is that the proportion of quality inspectors that are able to support a standard 40 question test on Visual Testing before training will be less than 20 percent.

To solve this first sub problem and test the associated hypothesis, test data will be collected by testing at least 40 quality inspectors who have not been trained in Visual Testing to analyze scores from a 40 question test. This data will be summarized in a tabular format showing the total number of quality inspectors tested, the total number of quality inspectors passing and the total number failing. Hypothesis will be quantified as:

H_o: $p \leq .20$ support $\qquad$ H_a: $p > .20$ not support

The test for single sample proportions will be conducted at the 0.05 level of significance to test the null hypothesis. Software to be used during analysis of information will be Statdisk (Triola, 2005). If the null hypothesis is rejected, the research hypothesis will have been supported. A 95% confidence interval for proportions will also be calculated as an estimate of the true proportion of quality that support, to those that do not support.

The second sub problem will estimate the number of quality inspectors that can be trained in Visual Testing in 32 hours. The associated hypothesis is that the proportion of quality inspectors that are not able to support a standard 40 question test with recent Visual Testing training after 32 hours, will be less than 15 percent.

To solve this second sub problem and test the associated hypothesis, test data will be collected on quality inspectors who have been trained in 32 hours of Visual Testing to analyze scores from a 40 question test. This data will be summarized in a tabular format as described in sub problem one above. Hypothesis two will be quantified as:

H_o: $p \leq .15$ not support H_a: $p > .15$ not support

The test for single sample proportions will be conducted at the 0.05 level of significance to test the null hypothesis. Statdisk software will be used for analysis of information (Triola, 2005). If the null hypothesis is rejected, the research hypothesis will have been supported. A 95% confidence interval for proportions will also be calculated as an estimate of the true proportion of quality that pass to those that fail.

The third sub problem will determine if a significant difference exists between sub problem one and sub problem two. The associated hypothesis is that there will be a significant difference between sub problem one and sub problem two. To solve the third sub problem and test the associated hypothesis, a test of proportions for two samples will be performed at the 0.05 level of significance between the proportion of supporting scores before training and the proportion of supporting scores after training. Hypothesis three will be quantified as:

$$H_o: p_a \geq p_b \qquad H_a: p_a < p_b$$

Where p_a is supporting scores before VT training and p_b is supporting scores after VT training

The fourth sub problem will compare the proportions of quality inspectors having A&P training and supporting a standard 40 question VT test to the proportion of quality inspectors not having A&P training and supporting a standard 40 question VT test. The associated hypothesis is that the proportion of quality inspectors with A&P training and supporting the standard 40 question VT test will be larger than the proportion of quality inspectors not having A&P training and supporting the standard 40 question VT test.

To solve the fourth sub problem and test the associated hypothesis, historical test data will be collected on quality inspectors who have been trained in Visual Testing to analyze passing scores from a 40 question test. A test of proportions for two samples will be performed at the 0.05 level of significance between the proportions of supporting scores after training. Hypothesis four will be quantified as:

$$H_o: p_a = p_b \qquad H_a: p_a > p_b$$

Where p_a is A&P trained quality inspectors and p_b is non-A&P trained quality inspectors.

The fifth sub problem will be to estimate the proportion of quality inspectors able to retain information from training after a specified amount of time. The associated hypothesis is that the proportion of VT certified quality inspectors that are able to support a standard 40 question test on Visual Testing after three years will be greater than 60 percent.

To solve the fifth sub problem and test the associated hypothesis, test data will be collected on quality inspectors who have been trained in Visual Testing prior to the year 2004 to analyze the support rate from a standard 40 question test. This data will be summarized in a tabular format as described in sub problem one above. Hypothesis five will be quantified as:

H_o: $p \geq .60$ support H_a: $p < .60$ support

The test for single sample proportions will be conducted at the 0.05 level of significance to test the null hypothesis. Statdisk software will be used for analysis of information (Triola, 2005). If the null hypothesis is rejected, the research hypothesis will have been supported. A 95% confidence interval for proportions will also be calculated as an estimate of the true proportion of quality that support to those that do not support.

CHAPTER IV

STATISTICAL RESULTS

CHAPTER V

DISCUSSION

CHAPTER VI

CONCLUSIONS

CHAPTER VII RECOMMENDZATIONS

REFERENCES

(2007, May 1). U.s. labor secretary announces $1 million grant to assist dislocated airline workers in virginia. *U.S. Newswire*, Retrieved 12-13-2007, from http://proquest.umi.com.ezproxy.libproxy.db.erau.edu/pqdweb?index=81&did=1029896331&SrchMode=3&sid=7&Fmt=3&VInst=PROD&VType=PQD&RQT=309&VName=PQD&TS=1166385079&clientId=17916&aid=9

Ahmed, A.M., Zairi, M, & Almarri, K.S. (n.d.) SWOT analysis for Air China performance and its experience with quality. *Benchmarking*, *13*, Retrieved 2006, from http://proquest.umi.com/pqdweb?did=1024051041&sid=9&Fmt=4&clientId=17916&RQT=309&VName=PQD.

Alexander, Ames, Reed, Ted, & Mellnik, (n.d.) Ted Maintenance errors linked to more airplane crashes. *Fort Worth Star-Telegram from CAMC*, Retrieved February 12, 2007, from http://www.camc.ca/en/OurProducts/SafetyManagement/ParticipantResources/SMSNewsArticles/article2.html.

ASA aviation mechanics handbook. (1989) Seattle, WA: ASA Publications.

Bemowski, Karen (January, 1997). Safety in the skies. *Quality Progress*, *30*, Retrieved February 1, 2007, from http://proquest.umi.com/pqdweb?did=10772657&sid=1&Fmt=4&clientId=17916&RQT=309&VName=PQD

Canaday, Henry (2006, November 14). Managing for safer maintenance. *Aviation Week*, Retrieved 12-30-06, from http://www.aviationweek.com/aw/generic/story_generic.jsp?channel=om&id=news/om1106cvr.xml

Crane, D (1985). *General section text book.* Riverton, WY: International Aviation Publishers, Inc.

Crosby, Philip (1980). *Quality is free: The art of making quality certain.* New York, NY: New American Library.

Dhakar, Tej S, Schmidt, Charles P, Miller, David M. (1994, April) Base stock level determination for high cost low demand critical repairable spares. *Computers and Operations Research,* Retrieved 2007 from http://proquest.umi.com/pqdweb?did=873311&Fmt=2&clientId=17916&RQT=309&VName=PQD

Federal Aviation Administration, Department of Transportation. (2007). *Part 65--certification: airmen other than flight crew members* (title 14 §65.71).

Washington D.C.: Government Printing Office. Retrieved January 2, 2007, from Electronic Code of Federal Regulations (e-CFR) Web site: http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&sid=98469608b18ee69c70edd9a64b12bc8b&rgn=div8&view=text&node=14:2.0.1.1.4.4.1.1&idno=14

Federal Aviation Administration, Department of Transportation. (2007). *Part 65--certification: airmen other than flight crew members* (title 14 §65.91). Washington D.C.: Government Printing Office. Retrieved January 2, 2007, from Electronic Code of Federal Regulations (e-CFR) Web site: http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&sid=98469608b18ee69c70edd9a64b12bc8b&rgn=div8&view=text&node=14:2.0.1.1.4.4.1.12&idno=14

Federal Aviation Administration, Department of Transportation. (2007). *Title 14: aeronautics and space* (title 14 §145.159). Washington D.C.: Government Printing Office. Retrieved January 2, 2007, from Electronic Code of Federal Regulations (e-CFR) Web site: http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&sid=17e7572d85cc6f6c76852750cb7b08ce&rgn=div5&view=text&node=14:3.0.1.1.5&idno=14

Federal Aviation Administration. (2007). *Advisory circular: aviation maintenance technician awards program* (AC 65-25D). Washington D.C.: Government Printing Office. Retrieved February 7, 2007, from FAA.gov. http://www.airweb.faa.gov/Regulatory_and_Guidance_Library/rgAdvisoryCircular.nsf/0/65d3b7bdd622752e8625727c006a1dd2/$FILE/AC%2065-25D.pdf

General Accounting Office (1996, October). *Aviation safety: new airlines illustrate long-standing problems in faa's inspection program* (GAO/RCED-97-2). Retrieved March 18, 2007, from http://www.gao.gov/archive/1997/rc97002.pdf

German, J. (1998, May 14). Sandia lends its 'accidents are unacceptable' expertise to FAA's new airliner inspection program. Retrieved February 7, 2007, from Sandia National Laboratories Web site: http://www.sandia.gov/media/faainsp.htm

Good, G, Nichols, Jason J., Subbaram, Manoj V., Nakagawara, Van B., & Montgomery, Ronald W. (n.d.). An analysis of the visual demands associated with aviation maintenance inspectors. Retrieved February 14, 2007,from http://www.hf.faa.gov/docs/508/docs/Maint%20-%20Vision%20Stds%20OSU.pdf.

Kendrick, J.J. (1986, June). Friendly skies? are commercial airline maintenance procedures up to standards?. *Quality*, *25*, Retrieved November 24, 2006, from http://proquest.umi.com.ezproxy.libproxy.db.erau.edu/pqdweb?index=3&did=7116085&SrchMode=1&sid=10&Fmt=2&VInst=PROD&VType=PQD&RQT=309&VName=PQD&TS=1164388652&clientId=17916

Levin, A. (1999, August 31). Specialist: small aviation repair shops 'unhealthy'; [First Edition]. *USA Today*, 03.A.

Lombardo, David A. (2004, July). John Goglia, a rebel with a cause, reflects on ntsb tenure. *AIN Online*, Retrieved 1-12-2007, http://www.ainonline.com/issues/07_04/07_04johngoglia.html

Lu, C (2005). Discovering the regulatory considerations of the federal aviation administration: interviewing the aviation rulemaking advisory committee. *Journal of Air Transportation.*, *10*, Retrieved January 10, 2007, from http://proquest.umi.com/pqdweb?did=1014685481&sid=6&Fmt=4&clientId=17916&RQT=309&VName=PQD

Lu, C (2005). Discovering the regulatory considerations of the federal aviation administration: interviewing the aviation rulemaking advisory committee. *Journal of Air Transportation.*, *10*, Retrieved January 10, 2007, from http://proquest.umi.com/pqdweb?did=1014685481&sid=6&Fmt=4&clientId=17916&RQT=309&VName=PQD

Mills, Don (2003, September 9). I six sigma. Retrieved February 4, 2007, from iSixSigma Web site: http://www.isixsigma.com/dictionary/Cost_Of_Quality-497.htm

National Aeronautics and Space Administration. (2003). *Columbia accident investigation board* (Chapter 10). Washington D.C.: Government Printing Office.

National Transportation and Safety Board, (1989, July 19). United airlines flight 232 McDonnell Douglas DC-10-10. Retrieved January 17, 2007, from NTSB Publications Web site: http://www.ntsb.gov/publictn/1990/AAR9006.htm

National Transportation and Safety Board, (1990, September 28). Safety Recommendation. Retrieved March 17, 2007, from: http://www.ntsb.gov/recs/letters/1990/A90_124_132.pdf

National Transportation and Safety Board, (2000, January 31). Loss of control and impact with pacific ocean Alaska airlines flight 261 McDonnell Douglas MD-83, N963AS. Retrieved January 19, 2007, from NTSB Publications Web site: http://www.ntsb.gov/publictn/2002/AAR0201.htm

National Transportation and Safety Board, (2003, January 8). Loss of pitch control during takeoff air midwest flight 5481 Raytheon (Beechcraft) 1900D, N233YV. Retrieved January 17, 2007, from NTSB Publications Web site: http://www.ntsb.gov/publictn/2004/AAR0401.htm

Phillips, D (2000, February 14). Alaska air chose not to replace worn parts. *Washington Post*, A01.

Rhoades, D.L., & Waguespack, B. (1999). Better safe than service? the relationship between service and safety quality in the us airline industry. *Bedford*, *9*, Retrieved November 24, 2006, from http://proquest.umi.com.ezproxy.libproxy.db.erau.edu/pqdweb?index=9&did=86065131&SrchMode=1&sid=11&Fmt=3&VInst=PROD&VType=PQD&RQT=309&VName=PQD&TS=1164388862&clientId=17916.

Stifflemire, P.F. (2002, June). Study of aircraft maintenance demand and supply. *Allegheny Institute for Public Policy*, *02-06*, Retrieved March 8, 2007, from http://www.alleghenyinstitute.org/reports/02_06.pdf

Triola, Mario F. (2005). *Elementary statistics*. Pearson Addison-Wesley.

Visual testing vt level II. (2003). Flanders, NJ: Everest VIT, Inc.

Waikar, A., Nichols, P. (1997). Aviation safety: a quality perspective. *Bradford*, *6*, Retrieved November 24, 2006, from http://proquest.umi.com.ezproxy.libproxy.db.erau.edu/pqdweb?index=10&did=84987303&SrchMode=1&sid=11&Fmt=3&VInst=PROD&VType=PQD&RQT=309&VName=PQD&TS=1164388998&clientId=17916

Appendix C
Beta Test

Exam: <u>VT General</u> **Date: ____________**

1. When did the American Society for Nondestructive Testing add Visual Testing to their Recommended Practice SNT-TC-1A, Nondestructive Personnel Qualifications and Certification?

(A). 1943

(B). 1965

(C). 1984

(D). 1993

2. Pulse Echo and Through Transmission are types of which NDT inspection process?

(A). Magnetic Particle

(B). Eddy Current

(C). Ultrasonic

(D). Radiographic

3. Which of the following conditions would <u>not</u> be appropriate for using Visual Testing to determine acceptability?

(A). Surface condition

(B). Evidence of leaking

(C). Internal cracks

(D). Alignment of mating surfaces

4. An example of a visual test is:

(A). Evaluation of acceptance specifications and revision dates

(B). Evaluation of surface conditions, available lighting, and general conditions

(C). Review, corrective actions, and closure of a work document

(D). None of the above

5. The first step in Liquid Penetrant testing is to what?

(A). Apply developer

(B). Thoroughly clean the surface

(C). Apply penetrant

(D). Allow penetrant to "dwell" on the surface

6. The ability to distinguish small details and separate two lines is known as:

(A). Optical resolution

(B). Eye strength

(C). Visual acuity

(D). Mental prowess

7. What characteristic of light do we ordinarily describe as color?

(A). Corona

(B). Hue

(C). Brightness

(D). Saturation

8. For the average eye, minimum angular separation of two points on an object is about:

(A). 1/32 of an inch

(B). 60 degrees

(C). One minute of arc (0.0167 degrees)

(D). None of the above

9. What condition as part of the natural aging process occurs in an inspector's eyes and affects what the inspector sees?

(A). Lens stiffens

(B). Lens softens

(C). Retina thickens

(D). Optic nerve thins

10. Light is produced when:

(A). Electrons are transmitted through a wavelike movement (comparable to ripples in water)

(B). Excited electrons revert to more stable positions in their respective atoms and release excess energy

(C). Electrons are funneled through the lens of a flashlight

(D). Electrons are repelled by atomic or molecular processes

11. Secondary Processing is also known as?

(A). Final Forming

(B). Wrought Processing

(C). Casting

(D). Secondary Finishing

12. What is the intentional or unintentional interruption in the physical structure or configuration of a part?

(A). Defect

(B). Indication

(C). Discontinuity

(D). Blemish

13. Rolling discontinuities such as seams, stringers, and cracks would these be visible where?

(A). On the edges of the rolled product

(B). Inside the rolled product

(C). At the beginning and end of the rolled product

(D). Anywhere on the rolled product

14. Indications, Discontinuities, and Defects are what type of conditions?

(A). Observed Conditions

(B). Inherent Conditions

(C). Rejectable Conditions

(D). Deficient Conditions

15. Non-metallic inclusions are inherent discontinuities that occur in metal as a result of its initial solidification.

(A). True

(B). False

16. Which type of corrosion usually forms underneath organic coatings or paints?

(A). Pitting

(B). Galvanic

(C). Galvanic

(D). Filiform

17. Which feature(s) associated with detected corrosion should be documented as "Heavy Corrosion"?

(A). Exfoliation

(B). Cracks

(C). Pitting deeper than 0.010 inch

(D). All the above

18. A decrease in toughness or ductility of high-strength steel alloys due to hydrogen is called?

(A). Hydrogen blistering

(B). Hydrogen embrittlement

(C). Hydrogen absorption

(D). None of the above

19. Which of the following is an example of "direct chemical action"?

(A). Chemical bath

(B). Chrome plating system

(C). Chemical milling

(D). Corrosion prevention compound (CPC)

20. The following definition "the deterioration of metals due to contact with some surrounding medium, i.e. liquid, gas, or some combination of the two" describes what?

(A). Erosion

(B). Corrosion

(C). Wear

(D). Fatigue

21. Which method of Arc Welding is more likely to produce a tungsten inclusion?

(A). GTAW

(B). Astro Arc

(C). SMAW

(D). GMAW

22. Which weld process consumes the electrode and uses inert gas to shield the weld?

(A). SMAW

(B). GTAW

(C). GMAW

(D). Astro Arc

23. How do orbital weld heads block out the harmful elements found in the air?

(A). By fully enclosing the tube and providing an inert atmosphere

(B). By the use of an electric flux on the weld tip

(C). By orbiting the weld head around the tube

(D). By welding with 304L CRES

24. A weld symbol that has the weld dimension written above the horizontal reference line means what?

(A). Weld on arrow side

(B). Weld on other side

(C). Weld all around

(D). Weld entire length

25. SMAW is sometimes called ------ welding?

(A). Gas

(B). Chemical

(C). Stick

(D). Electric

26. Annealing is a process of:

(A). Rapid cooling by immersing in water to preserve heat treatment properties

(B). Reheating quenched material 100-200 degrees C and cooling to improve strength

(C). Softening work hardened alloys to relieve stress and stabilize properties

(D). Cooling at room temperature for a harder, less ductile material

27. The T8 temper designation in Al 2024 T8 describes a material that has been?

(A). Solution heat treated and cold water quenched for an unstable condition

(B). Solution heat treated, and artificially overaged for a stablized condition

(C). Solution heat treated, naturally aged, and artificially aged for peak strength condition

(D). Solution heat treated, cold worked, and artificially aged for peak strength

28. The purpose of heat treating aluminum is to increase?

(A). Hardness

(B). Ductility

(C). Tensile Strength

(D). All the above

29. What is the difference between primary and recycled aluminum in terms of quality and properties?

(A). No difference

(B). More granular and less ductile

(C). More likely to have impurities

(D). None of the above

30. The major alloying element in 2024 aluminum is?

(A). Zinc

(B). Silicon

(C). Copper

(D). Magnesium

31. What is the maximum magnification for simple hand-held magnifiers?

(A). 5X

(B). 10X

(C). 20X

(D). 100X

32. One complete revolution of the thimble on a micrometer moves the spindle how far?

(A). .01 inch

(B). .015 inch

(C). .020 inch

(D). .025 inch

33. What is the magnification of a lens if image focus is achieved at 2 inches?

(A). 2X

(B). 5X

(C). 10X

(D). 25X

34. The pitch of the screw thread on the spindle of a micrometer is:

(A). 1/25th of an inch

(B). 1/1000th of an inch

(C). 1/40th of an inch

(D). 1/100th of an inch

35. Two combined lenses will have a shorter focal length than either lens used alone.

(A). True

(B). False

36. Which main section of a borescope provides the diopter correction for the observer?

(A). Distal Section

(B). Shaft (barrel)

(C). Borescope body

(D). Eye piece (Occular end)

37. Which section of a flexible borescope houses the articulating cables?

(A). Body section

(B). Insertion tube section

(C). Bending section

(D). Distal section

38. What makes a flexible borescope image bundle a coherent bundle?

(A). Same image at each end

(B). Bi-polarized view at each end

(C). Reversed view at each end

(D). Normal view at each end

39. What are the two functional systems of a rigid borescope?

(A). Imaging, distallation

(B). Imaging, illumination

(C). Illumination, oscillation

(D). Illumination, diopter

40. The borescope body is also know as the:

(A). Distal section

(B). Handpiece

(C). Shaft (or barrel)

(D). Eye piece

Appendix D
Consent to Disclosure

You are being asked to participate (participation is voluntary) in a data collection process for the Visual Testing (VT) training program. In addition to generating data for VT at United Space Alliance, this data is intended for use in the completion of a Graduate Research Project for Lewis L. Law in the Master of Science program at Embry Riddle Aeronautical University. Names and actual scores will not be used to generate the report, only raw data will be used to determine the statistics.

Required data will include the number of success or non-success of passing a standard test in visual testing before training in VT. Other data required is the number of success or non-success of passing a standard test in visual testing after training in VT. This data will be compared to one another to determine the quality of training received in VT. It is requested to know if you have received an A&P certification to compare VT training to FAA training. Data will also be collected to determine the retention of such knowledge after a period of three years has passed by comparing the success or non-success of a re-test.

By signing below and checking the appropriate boxes, you consent to the use of raw data collected in the testing process by Lewis L. Law in connection with his Graduate Research Project.

Name	Date	Pre-Training	Post Training	A&P	3-Years