THE EFFECT OF A SINGLE STANDARD OF ENGINEERING SAFETY (S3E) ON THE AIRWORTHINESS OF MILITARY DERIVATIVE AIRCRAFT

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FOR MY PARENTS AND FAMILY

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What we do in life echoes for an eternity but nothing good is possible without God. I hope to ever more faithfully do His will.

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NOMENCLATURE

AD	- Airworthiness Directive
DOD	- Department of Defense
EO	- Engineering Order
FAA	- Federal Aviation Administration
FAR	- Federal Aviation Regulation
FOD	- Foreign Object Damage
FOM	- Fleet Operations Maintenance or Facilitate Other Maintenance
GSE	- Ground Servicing Equipment
IG	- Inspector General
MEL	- Minimum Equipment List
MIL STD	- Military Standard
MRSI	- Master Rescheduling Item Control (Maintenance)
NDT	- Non-Destructive Testing
NIST	- National Institute of Standards and Technology
OSU	- Oklahoma State University
QA	- Quality Assurance
Rotable	- Refurbish able
SAE	- The Engineering Society for Advanced Mobility on Land, Sea, Air and Space (Originally the "Society of Automotive Engineers")
S3E	- The Single Standard of Engineering Safety
T.O.	- Technical Order
V_1	- Decision speed before which you abort the take-off and after which you continue.
V_2	- The minimum take-off safety speed or engine-out climb speed
V_r	- The calculated rotation speed
V_{zrc}	- The zero rate of climb speed for a particular weight and condition

CHAPTER I

INTRODUCTION

The United States Department of Defense (DOD) is able to perform many of its passenger carrying and cargo missions with modified commercial aircraft. As a group, these aircraft are called military derivative aircraft because they are military weapon systems that were derived from commercial aircraft (DOD Directive 5000.2-R, 1996). These are aircraft originally designed, built, and certified to commercial airworthiness standards by the Federal Aviation Administration (FAA) for civilian use (FAR Part 21, 2000).

The April 3, 1996 tragic and untimely death of cabinet member, Secretary of Commerce, Ron Brown and his very high profile entourage of influential businessmen on one of these military derivative aircraft has refocused attention on the safety of DOD military derivative aircraft and procedures. As cited by Congressman Robert Menendez in the introduction to his April 1997 Single Standard of Aviation Safety legislation, this accident is merely one of many mishaps that may have been prevented by the use of a single standard of engineering safety combining the very best of the military and commercial worlds (Menendez, 1997). Unfortunately, the legislation did not pass and a single standard for engineering safety was never defined or established.

Due to the very nature of the unique military mission, the Federal Aviation Administration (FAA), under the Department of Transportation (DOT), whose rules and oversight originally provided the basis for the engineering design of these military derivative aircraft, has no jurisdiction over the military assets (DOD Directive 4151.18, 1992) (DOD Regulation 4140.1-R, 1993). Indeed, the Pentagon contends that with its enviable overall safety record and venerable hierarchy of command and control, that no oversight on their conduct pertaining to any aspect of engineering, operations, or maintenance is needed, nor is it appropriate (DOD 4140.1-R, 1993). Further, due to the very nature of the DOD's mission for these aircraft with regard to national security and defense posture, FAA oversight would at the very least encumber and in some cases prevent the effective carrying out of the mission. Yet, whether or not DOD voluntarily complies with the aircraft's original airworthiness standards, the issue remains and as such, formulates this study's problem statement.

To be clear, the intent of this study is not to turn military flying units into commercial airline operations. The objective is to merge the very best of both the military and commercial engineering safety standards into one set of functional airworthiness criteria and follow up with training. This is to be accomplished by the DOD achieving *full* cognizance, knowledge and adoption of the commercial safety standards as mission parameters allow.

These formerly commercial aircraft now used by the military were commercially designed, built and FAA certified *with the assumption that they will be kept airworthy under that same commercial system with FAA oversight* (FAR Part 21, 2000). It is arguable that in spite of the unique DOD mission and the acknowledged inbred professionalism of the military members, the very nature of using civilian assets for military purposes without the benefit or knowledge of *all* of the time-tested airworthiness rules and practices is, at best, an unwise policy.

Statement of the Problem

Are military (DOD) units that operate military derivative aircraft maintaining the vehicles airworthiness using standards that achieve an equivalent level of safety with their commercial counterparts? If not, what instrument can be used to determine this as well as assess their level of compliance to the original certified airworthiness standards? Armed with an accurate compliance assessment, could the units then target appropriate corrective measures using a single standard of engineering safety (S3E) for airworthiness?

For the purpose of this study, S3E is the use of commercial standards for airworthiness embodied in FAR 121 and FAA Order 8300.10, then tailored and applied to the DOD. This is the source of the research questions and audit instrument.

Hypothesis

There is a significant difference in airworthiness compliance with the original commercial design standards in DOD units operating military derivative aircraft that receive instruction in the single standard of engineering safety (S3E) and those who do not.

For this study, an important portion of instruction is the auditing process. The testing audit in this study is based upon S3E criteria.

Need and Significance of the Study

During the drafting of the Congressional legislation citing troubling incidents and mishaps including, most notably, the accident that resulted in Secretary Ron Brown's death, it came to light that there exists a lack and / or inconsistent compliance to airworthiness standards within DOD units operating military derivative aircraft (The Single Standard of Aviation Safety Act, 1997). After over four years of research by this investigator, the discovery is that there is still a need for a *single standard for engineering safety (S3E) in airworthiness* between the DOD and DOT to reconcile the gaps in airworthiness criteria. It would be significant if S3E were shown to provide an increased level of compliance to airworthiness criteria.

Objectives of the Study

The objective of this study is to:

1. Determine if the military (DOD) units that operate military derivative aircraft are maintaining the vehicles airworthiness using standards that achieve an equivalent level of safety with their commercial counterparts.
2. Develop an instrument that can be used to assess the DOD units' level of compliance to the original certified airworthiness standards.

3. Determine if, once armed with an accurate compliance assessment, the DOD units could then target appropriate corrective measures using a single standard of engineering safety (S3E) for airworthiness.

To accomplish this, the study applied the S3E to randomly selected military maintenance units operating military derivative aircraft to see what effect if any it had on airworthiness within that unit. The S3E treatment was tested with one control and one experimental military unit. The random selection was also blind to the study.

As stated earlier, S3E is the use of commercial standards for airworthiness embodied in FAR 121 and FAA Order 8300.10, then tailored and applied to the DOD. This is the source of the research questions and audit instrument. This study applied S3E based on FAA regulated commercial criteria used daily on commercial airlines onto military derivative aircraft. The study's audit instrument was also based upon S3E. Since these military derivative aircraft were originally commercial aircraft, a standard, time-tested FAA airline audit was used with some variation to account for DOD nomenclature etc. DOD airworthiness standards *were* considered to ensure S3E completeness but not directly applied. The DOD standards were not directly applied because:

1. There is no single military airworthiness standard (DOD Directive 5000.1, 1996).

2. There *is* a single standard for airworthiness for these commercial aircraft, which is the basis from which these aircraft were designed, built and certified (FAR Part 21, 2000).

3. The engineering baseline of the military derivative aircraft is commercial standards not military standards. That is, as previously observed, these aircraft began their existence designed, built and FAA approved as commercial aircraft (FAR Part 21, 2000).

4. Commercial S3E criteria are used because the DOD units already comply with DOD airworthiness standards. This is evinced by the fact that they remain operational and mission ready although challenged with continuous scrutiny from DOD higher headquarters.

5. Commercial aircraft fly more sorties and experience more flight cycles on these same aircraft than their military counterparts and thus have a greater experience base from which to draw (Aviation Week and Space Technology, July 2000) (FAA, Airline Utilization Report, 2001).

The population examined was military units whose mission was similar to their commercial counterparts. Further, the military units were randomly selected from the very numerous choices of DOD organizations that operate the same *basic* type aircraft.

What is meant by basic type aircraft is that, whatever the military designates the aircraft under the DOD weapon system program, the basic commercial airframe will be the same type. For instance, the U.S. Navy designates its commercially built Boeing 737 the C-40 while the U.S. Air Force designates that type aircraft as the T-43. Yet, the basic aircraft as designed, built, and FAA certified remains a commercial Boeing 737.

Assumptions

1. Assume that the military units were in a roughly equivalent airworthiness status.
2. Assume that the S3E guidance given to the treated unit was, with Subject Matter Experts (SME) assistance, fully understood by the unit.
3. Assume that the audit was sufficiently general to the S3E concept so as to eliminate or mitigate the effects of purely military mission aspects such as air-to-air refueling, paratroop drops, radar evasive low level missions, etc.
4. Assume equivalency in the military missions and personnel skills.

Limitations

1. The study does not consider purely military functions such as air refueling, air drop etc.
2. The study does not examine humans although individuals obviously play a vital role in the ultimate S3E airworthiness.
3. The study does not examine the operational or aircrew side of the units.
4. The study considers only military derivative aircraft in its random sampling although the experiment could be applied to purely military designed, built and approved aircraft.

Roots of Safety

The fundamental parameters that allow the infrastructure of the aviation transportation system to operate safely is what this study calls the roots of aviation safety. The roots of aviation safety can be found in engineering experience and strict discipline of maintaining aircraft airworthiness. Indeed, the Federal Aviation Administration (FAA) Aircraft Certification Service states that aviation safety begins with safe aircraft (FAA Academy, Part 21: Origin, Concepts, Philosophy, 1994). This is because any aircraft can be designed such that it is unsafe to operate due to its inherent undesirable characteristics. It can also be designed such that it is fairly safe to operate but is unsafe to perform its mission, whether it be a transport aircraft, helicopter, fighter jet, agricultural "crop-duster" etc. That is, one can fly the craft but it will not safely perform its intended mission due to design flaws. This may include an unacceptable rate of climb or other undesirable performance parameter, unsuitable cabin environment due to noise, temperature, smoke, lack of stable pressurization, unacceptably short range; etc. Either one of these major factors makes the vehicle not airworthy and thus not certifiable (approval) by the FAA (FAR Part 23, 2000) (FAR Part 25, 2000).

To maintain and update the airworthiness of their aircraft, manufacturers and users conduct constant audits in an attempt to mitigate the occurrence of defects, oversights or malpractice. Cross talk, both formal and informal, among the members of the transportation system feeds into the process in order to make the best utilization of the information.

Definition of Terms

The following terms and definition will be used in this study.

Airworthiness – The condition of an aircraft, aircraft system or aircraft part in which that item operates in a safe manner to accomplish its intended function.

Basic "Type" Aircraft – The assigned designation identifying all aircraft within the commercial system by FAA certified design.

Certify – The legal, governmental recognition that the aircraft, aircraft system or aircraft part complies with all of the applicable Federal Regulatory requirements.

MACH – The ratio of a given velocity to the speed of sound.

Military Derivative Aircraft – Military aircraft that are *derived* from originally designed, built and FAA certified commercial aircraft.

Ovigal Wing – Arched and tapered wing.

Pedigree – The lineage of an aircraft, aircraft system or aircraft part can be directly traced to a FAA approved airworthiness source.

Roots of Aviation Safety – The engineering and experiential basis from which commercial airworthiness standards emanate and evolve.

Shop Chief – Common term for the individual in charge of a particular military sub-entity.

Single Standard of Engineering Safety – Commercial Standards for airworthiness embodied in FAR Part 121 and FAA Order 8300.10, tailored and applied to the DOD.

Weapon System – The assigned designation identifying all aircraft by type and mission within the DOD system.

CHAPTER II

REVIEW OF LITERATURE

Chapter Overview

This review of literature begins with introduction and historical background sections that set the stage and then discusses the basis for the study's problem statement. Next, there is a review of the critical topics of this study. Since the subject of airworthiness is the basis of the chapter as well as the study, the following section is a discussion of airworthiness itself as well as the basis of the debate concerning airworthiness between DOT and DOD standards.

Next is an overview of airworthiness standards of the DOD. This is only an overview even though it touches upon more than fifty DOD documents. It is considered an overview because this investigator encountered literally hundreds of pertinent documents among all of the military services that use military derivative aircraft. Most of these DOD documents overlapped and some even contradicted each other concerning airworthiness standards.

The next topic covered is the process and logic flow of the FAA certification. The FAA is the ultimate and sole entity that can invoke a commercial certification as formal approval for any aircraft. FAA aircraft certification process and standards application for any given type aircraft is criteria upon which the commercial airworthiness standards, which are also enforced by the FAA, are based. Lastly a case study on the 2000 Concorde accident is presented so as to place this chapter's information in context.

Introduction

Commercial aircraft in the United States are certified, that is, formally approved for service by the FAA. This approval action is taken with the assumption that these aircraft will maintain their airworthiness under a system overseen by the original approval authority, that is, the FAA (FAR Part 21, 2000). The DOD acquires and uses commercial aircraft for military purposes (DOD Directive 5000.2-R, 1996; AFPD 62-5, 1998; T.O. 00-25-115, 1989). They are called military derivative aircraft. The DOD system of operations, maintenance and training is fundamentally autonomous, that is, not under FAA oversight and geared toward the wartime mission (CNETINST 1510.1E, 1998; DOD Directive 4151.18, 1992; AFI 11-218, 1994).

This leads again to the study's problem statement as follows. Are military (DOD) units that operate military derivative aircraft maintaining the vehicle's airworthiness using standards that achieve an equivalent level of safety with their commercial counterparts? If not, what instrument can be used to determine this as well as assess their level of compliance to the original certified airworthiness standards? Armed with an accurate compliance assessment, could the units then target appropriate corrective measures using a single standard of engineering safety (S3E) for airworthiness?

Historical Background

A question always arises when there are different standards of safety for the same operation in spite of the fact that the ultimate objectives are identical " . . . And to which of the holy ones will you turn? For wrath kills a foolish man and envy slays a simple one. I have seen the foolish taking root, . . . his sons are far from safety, . . ." Job 5: 1-4 (New King James Version). Commercial standards are controlled and enforced by the Federal Aviation Administration (FAR Part 21, 2000). The FAA commercial standards exist for only one global purpose, to ensure the highest level of safety or *airworthiness* obtainable for commercial aircraft (FAR Part 21, 2000).

As a separate and autonomous governmental agency, the DOD never has come under the purview of the FAA for establishing airworthiness, but rather, has self certified its aircraft as airworthy (GAO / NSIAD-96-5, 1996; DOD Directive 5000.2-R, 1996; AFPD 62-5, 1998). This is even true for the commercially designed, built and FAA certified aircraft that the DOD uses. The combination of DOD regulations that the military uses to determine airworthiness are understandably biased toward the military wartime mission requirements. As such, they do not compel the military units to follow *all* of the commercial standards from which these aircraft were designed, built, certified, operated and maintained (MIL-STD 2173 AS, 1995; DOD Directive 4151.18, 1992; AFI 21-103, 1998).

But why does the DOD acquire and utilize commercially designed and certified aircraft in the first place? Development and production costs of purely military aircraft are such that, whenever possible, the DOD is motivated by budget and schedule constraints to purchase commercial aircraft and modify them into military weapons systems (DOD Directive 5000.1, 1996). As stated earlier, these aerospace vehicles as a class are called "military derivative aircraft." They are military weapon systems "derived" from commercial aircraft.

There is a long history of using military derivative aircraft going back to World War I when civilian aircraft were converted by the Army and Navy into war machines (FAA Academy, Part 21: Origin, Concepts, Philosophy, 1994). Indeed, the original commercial airworthiness standards as depicted in 1926 Air Commerce Act established the Aeronautics Branch of the Department of Commerce. Bulletin 7 is the predecessor to the Federal Aviation Administration and the FARs. Figure 1 depicts the historical background of aircraft airworthiness regulations as they apply to military derivative aircraft (FAA Order 8110.4B, 2000).

As the commercial regulations became more specialized and military missions sharpened their focus on containing the Communist Nuclear threat in the Cold War, the DOD concentrated on their own airworthiness standards, apart from the commercial sector.

As such, these FAA certified aircraft play a vital role in our Nation's overall defense mission (DOD Directive 5000.2-R,1996; FASOINST 4790.15, 1997; NAVAVNDEPOTOPSCENINST 5451.2, 1998; T.O. 00-20-1, 1988). Furthermore, their role in the DOD is due to expand and not contract (DOD 4100.9-R, 1996).

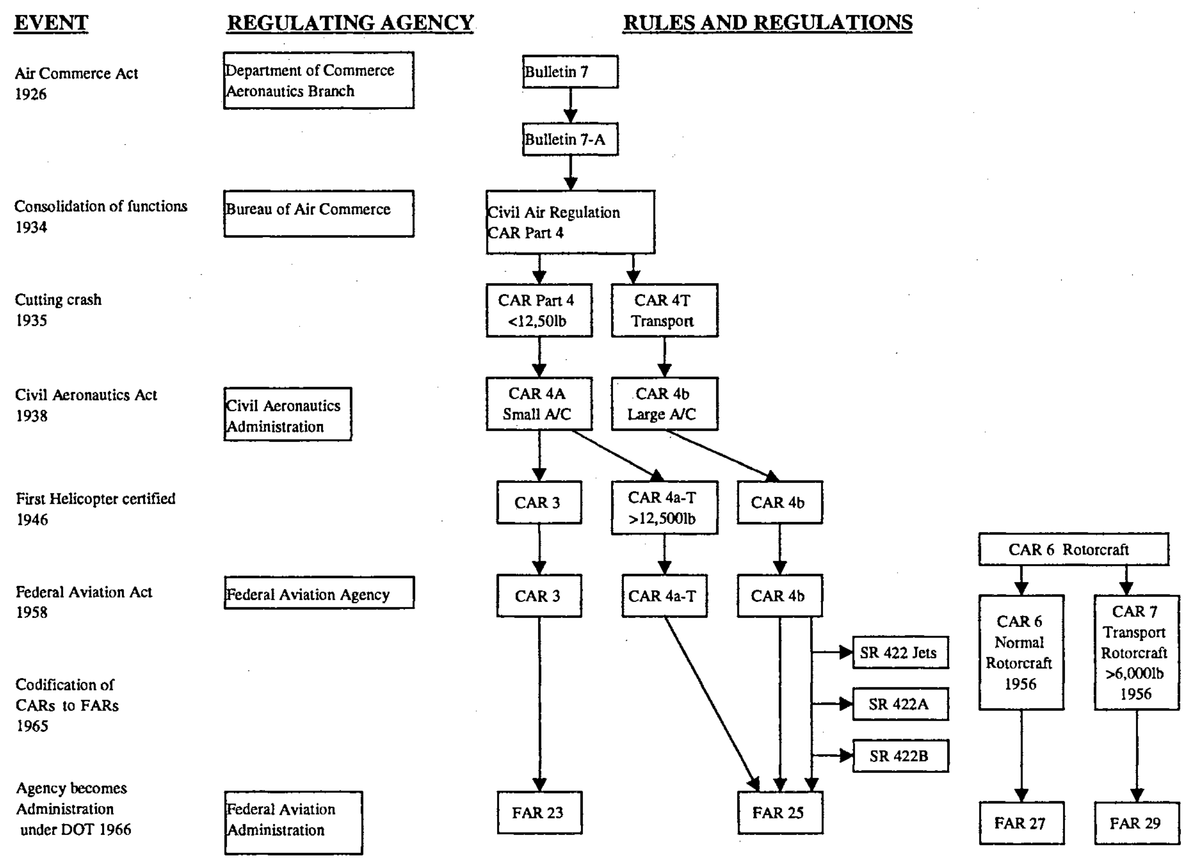


Figure 1. FAA Regulations History.

Airworthiness

What exactly is "airworthiness" and what is its significance? Let us approach this in a fundamental manner. An "aircraft" is defined as any craft or vehicle designed for the function of flight through or navigation in the air (Funk & Wagnalls Standard World Language Dictionary Vol. I, 1962). "Operate" is a verb meaning "to bring about or produce the proper effect" (Funk & Wagnalls Standard World Language Dictionary Vol. I, 1962). The word "safe," as an adjective, is defined as "free from hurt, injury, danger or risk" (Funk & Wagnalls Standard World Language Dictionary Vol. I, 1962). A "function," as a noun, is defined as "proper employment of assigned task or mission" (Funk & Wagnalls Standard World Language Dictionary Vol. I, 1962). "Airworthiness" then is defined as the condition of an aircraft, aircraft system or aircraft part in which that item *operates in a safe manner to accomplish its intended function* (SAE, ARP 4754. 1996). For a pilot it means that maintenance and engineering have done their jobs correctly and it is now safe to fly the aircraft.

Commercial engineering standards for airworthiness are embodied in Federal Aviation Regulation Part 121, FAA Order 8300.10 Airworthiness Inspectors Handbook and FAA Order 8400.10 Aviation Safety Inspectors Handbook. These documents encompass the criteria for using *all* of the original *and* follow-on commercial engineering requirements from which the aircraft was certified. The single standard of engineering safety (S3E) is *this same criterion for airworthiness* but directed and applied specifically to the DODs military derivative aircraft. S3E is a unique product of this study for the purpose of testing the hypothesis.

Basis of the Airworthiness Debate

But why devote so much deference to commercial airworthiness standards? The United States commercial track record for safety is a venerable one. Indeed, in the banner year of 1998, after logging many thousand of hours, there were *zero* fatalities for the US carriers. Much more importantly, the aircraft involved in this admirable safety record were commercially designed, built and FAA certified *with the assumption that they will be kept airworthy under that same commercial system with FAA oversight* (FAR Part 21, 2000).

Again, not only does the DOD not mandate the use of all commercial standards at all times but also the military does not voluntarily maintain the airworthiness of its aircraft by using these standards (DOD Directive 4151.18, 1992; DOD Directive 5000.2-R, 1996; AFPD-62-5, 1998; AFPD-62-4, 1998; DOD Regulation 4140.1-R, 1993). This is so even though all of the same proven and successful processes and standards are in concert with the original design criteria.

The DOD does however acknowledge the importance of the data available in the original and follow-on engineering airworthiness criteria even though it does not fully access them. This is indicated in military documents such as the Defense Transportation Regulation, DOD 4100.9R (1996), Maintenance of Military Material, DOD Directive 4151.18 (1992), Defense Acquisition, DOD Directive 5000.1 (1996); Naval Air Systems Command System Safety Program 5100.3C (1991); Air Force Instruction 21-107 (1994); Air Force Policy Directive 62-5 (1998) and Air Force Policy Directive 62-4 (1998). The intent of these policies is to *move toward* an equivalent level of continued operational safety for these commercially designed, built and certified military aircraft with their private sector counterparts (NAVAIRINST 4350.2C, 1989). As expected, however, the DOD mission always supersedes this effort in priority (DOD, RDT&E Budget Item-0604805F, 2000). There have, however, been minor efforts to organize units and policy and educate a very few select individuals in the acquisition of aircraft portion of the DOD on the correct implementation of commercial standards (DOD 4151.18, 1992; DOD Directive 5000.2-R, 1996).

DOD Airworthiness Overview

According to the Defense Logistics Agency (DLA) for all branches of the military, the entities responsible for maintaining airworthiness are the "Chief Engineer" and "Lead Engineer" for the weapon system (DOD RDT&E Budget Item 0604805F, 2000; AFMCI 63-1201, 2000). Placing the heavy burden of finding airworthiness of a fleet of new or modified aircraft on just a few individuals that have to rely on a non-coherent system of regulations and guidance is not considered prudent or wise in the commercial world, and is, therefore, by regulation, not done (FAR Part 121, 2000). Essentially, the DOD allows airworthiness authorities, such as they are, to "pick and choose" what criteria to follow depending on the expediency of the military task at hand or mission requirements (DOD Directive 5000.2-R, 1996; MIL-STD-410E, 1998; ASO Field Instruction 4700.31, 1998).

In the DOD, the dedication to the safety mission is evident when one examines the massive and precise guidance orders and policies, *some* originating from the rigorous commercial engineering standards. Just one example is the DOD metrology and calibration programs based upon commercial standards (NAVAIRINST 13640.1A, 1990; AFI-21-113, 1994). The plethora of DOD and Military Service specific orders, regulations and instructions, many of which overlap as will be evident in the following portion of this review of literature which only covers a relatively small number of them.

The DOD is aware that the key element in the safety program is to begin with operating aircraft engineered with safety built in and then keep them in that safe condition. Everything from the maintenance of the aircraft engines, personnel safety and overall training are geared to the airworthiness mission (AMCI 21-104, 1998; NAVAIRINST 13700.15A, 1994; NAVAIRNOTE 4700, 1994; AMCI 21-107, 1998; AFI 91-301, 1996; AFI 36-2201, 1997; Occupational Competencies, 1991).This is the responsibility of the engineering arm, the operational aircrews as well as the maintenance personnel and the managing relationship between these entities (MCO P4400.177, 1998; USAF, AFI 21-107, 1994; USAF, AFI 21-101, 1998).

There is a constant line of tension between the mission requirements and urgency and the engineering requirement of maintaining aircraft system integrity which affects the parts used on the aircraft as well as engineering repair functions and documentation (ASO Field Instruction 4861.1, 1998; USAF TO 00-25-107, 1998). Policies to ensure that engineering system integrity functions are performed in the highest quality fashion is essential to the safe operation and maintenance of the aircraft (ASO/ NATSF 4200.1D, 1989; USAF AFPD 21-1, 1993). Just as essential is that the systems of logistics ensure the highest "pedigree," that is, traceable lineage to an authorized approval source, to the parts and components and that the pedigree is traceable back to the basic aircraft engineering design (COMNAVAIRRESFORINST 1500.5D, 1997; USAF TO 00-25-115, 1989; USAF TO 00-20-1, 1998).

Day to day operations in ensuring the aircraft airworthiness includes the use of preventive processes, operational test and evaluation and monitoring/ management of repair cycle again to ensure strict adherence to the aircraft's engineering design and ultimate airworthiness (NAVAIRINST 13650.1C, 1998; NAVAIRINST 13680.1, 1989; NAVAIRINST 4790.20, 1990; USAF TO 00-20-3, 1989; USAF AMCI 99-101, 1997; USAF TO 00-20-1, 1988). In the DOD as in the commercial sector, component time change requirements as well as major aerospace vehicle integrity review are also essential to the engineering airworthiness of that aircraft (NAVAIRINST 4790.3B, 1992; NAVAIRINST 5100.3C, 1991; USAF TO 00-20-9, 1997; USAF TO 00-25-4, 1995; USAF AFI 21-102, 1994).

The DOD is aware that keeping complex safety engineering necessary to establish as well as maintain aircraft airworthiness requires the development and training of specialists and specialized equipment as well as the audible documentation that ensures accountability to adhering to the engineering airworthiness standards (MIL-STD-882C, 1998; NAVAIRINST 5215.10D, 1998; NAVAIRINST 1500.2C, 1991; USAF TO 00-20-5, 1996; USAF AFI 36-2201, 1997). Everything from sophisticated communications equipment to servicing the aircraft must be accounted for (DOD INST 6050.5, 1990;

FASOINST 4440.6N, 1998; MCO P4790.12, 1990; USAF AFI 21-116, 1997; USAF TO 00-25-172, 1987; NAVAIRINST 4720.2A, 1998). All of the engineering and maintenance specialties must be included in a reliability and maintainability program (FASOINST 4861.1H, 1998; NAVAIRINST 13610.2, 1989; USAF AFI 21-118, 1994).

Reliability, maintainability, inspection, malfunction detection analysis, and rigorous documentation are but a few of the activities and programs used to maintain the engineering integrity and thus the airworthiness of the aircraft (MIL-STD-2173 AS, 1995; NAVAIRINST 13120.1C, 1990; NAVAIRINST 13070.1B, 1998; NAVAIRINST 4790.21, 1995; USAF AMCPAM 21-115, 1997; USAF TO 00-20-7, 1989; USAF AMCI 21-109, 1995; AFI 21-105, 1994). Airworthiness tracking techniques using documentation takes many forms from engineering data, engineering technical manuals, technical orders, safety reporting and many more safety related matters directly dealing with airworthiness (NAVAIRINST 5215.12A, 1995; NAVAIR00-500C.24, 1991; NAVAIR00-80T-96, 1998; USAF TO 00-20-2, 1998; USAF AFPD 21-3, 1993; USAF AFI 91-204, 1998). All of these are done to ensure a high standard of safety and thus prevent aircraft mishaps and personal injury (FASOINST 4441.15G, 1996; MIL-STD-882C, 1998; NAVAIRINST 13680.1, 1989; USAF AFOSH 91-31, 1997; USAF AFI 91-202, 1998; USAF AFOSH 91-100, 1998).

The Role of FAA Certification

The commercial fleet and the military derivative fleet were both designed, built and approved off of the same approval system that culminates with certification by the

FAA. Indeed, most of the aircraft came off of the same commercial assembly line. How they are maintained airworthy is directly related to how they were certified by the FAA (FAR Part 21, 2000).

There is the principle, within the FAA, that aviation safety begins with safe aircraft and that this is most effectively achieved with the general compliance with time tested engineering standards (FAA Academy, Part 21: Origin, Concepts, Philosophy, 1994). This principle is one that begins with the design of the aircraft, the certification and tracking of the aircraft components and those manufacturing the components, the facilities used to produce then to subsequently modify the aircraft, as well as the qualifications of the individuals doing the work (FAR Part 21, 2000). All of these entities must be FAA approved in order for the aircraft to be FAA certified (FAR Part 21, 2000).

When an aircraft is "certified," this means the *legal, governmental recognition* that the aircraft, aircraft system or aircraft part complies with all of the applicable Federal Regulatory requirements (SAE, ARP 4754. 1996). The formal recognition is achieved by the FAA issuing an aircraft type certificate (TC) for the original design or a supplemental type certificate (STC) for follow-on approved modifications (FAR Part 21, 2000).

In contrast to the DOD system of regulations and specifications, the FAA's role is one of oversight of the design and construction of commercial aircraft. Assuming that the aircraft will continue under the same system of FAA oversight of its airworthiness, the end product is the aircraft certification by type granted by the FAA. The "type" (as in particular vehicle) certification (TC) process is depicted in Figure 2 (FAA Order 8110.4B, 2000).

When a major modification is made to the original certified type or model aircraft, that legal recognition by the FAA is called a *supplemental* type certification (STC). The reason for this nomenclature is that the baseline engineering design remains intact but is supplemented, that is, "*added on to*" by this modification. The modification can be as relatively small as a change or addition to the navigation equipment or a large as actually redesigning major portions of the aircraft's flying surface or power plant (engine type) replacement. The logic flow chart to *both* the TC and STC are essentially the same and is depicted in Figure 3 (FAA/AIR Southwest Region Guide, 1994).

It follows therefore, that an aircraft's state of airworthiness, that is, its ability to safely perform its intended function consistently and reliably, hinges upon maintaining the integrity of the aircraft's certification status, both original and supplemental (FAR Part 25, 2000) (FAR Part 121, 2000). This integrity includes warranted (for safety reasons) and appropriate (for airworthiness update) engineering and design updates. The commercial aviation system members are greatly motivated to ensure the highest level of actual and perceived safety since this has a *direct bearing on their commercial viability* (FAA Academy, Part 21: Origin, Concepts, Philosophy, 1994). As a result, in sharp contrast to the DOD, there has evolved a robust yet efficient infrastructure of checks and balances between the FAA and Industry, with some input from other outside sources, to make the airworthiness determination (FAA Order 8300.10, 1998).

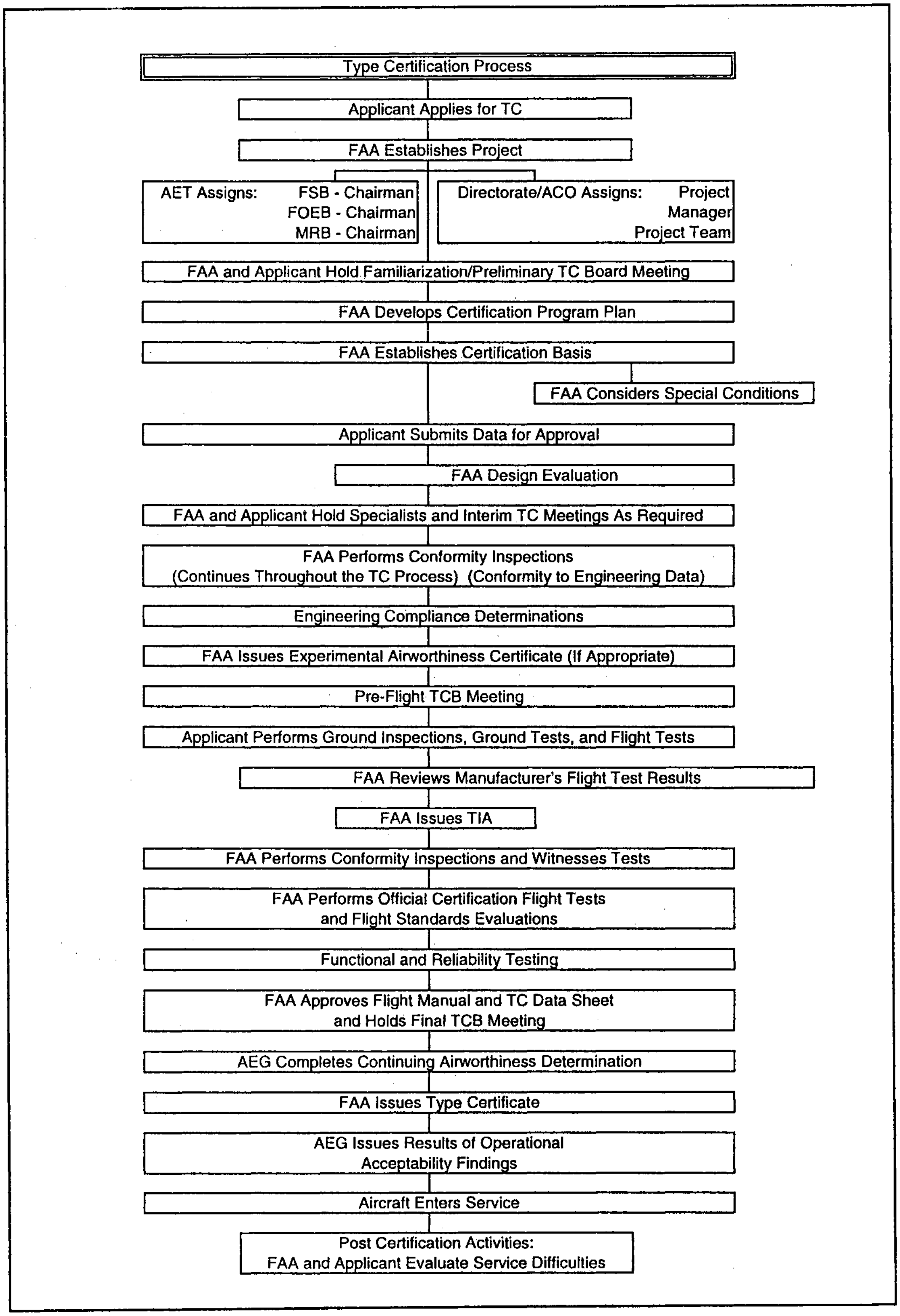


Figure 2. Aircraft Type Certification Process.

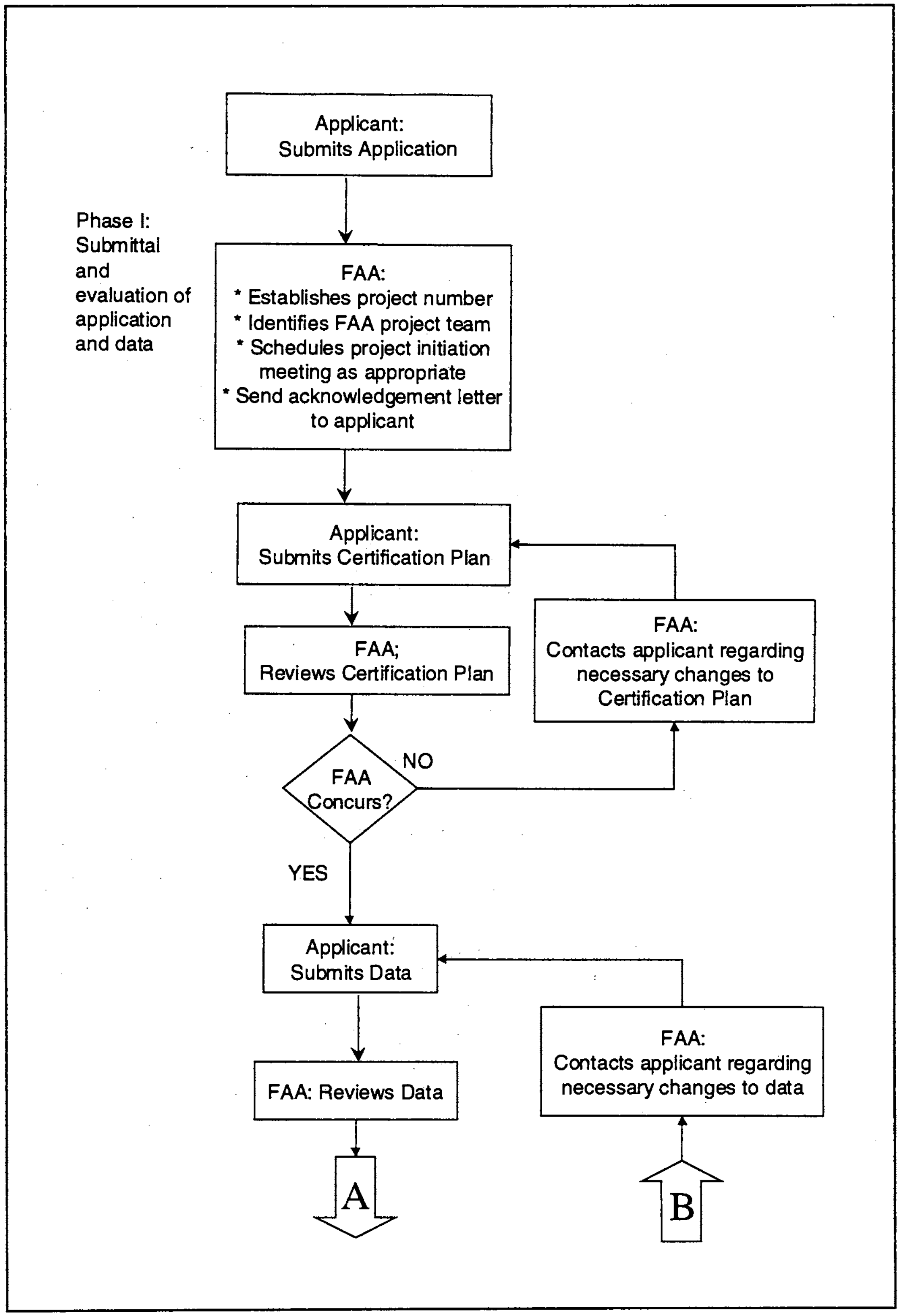


Figure 3. TC & STC Flow Diagram.

Figure 3. TC & STC Flow Diagram (continued).

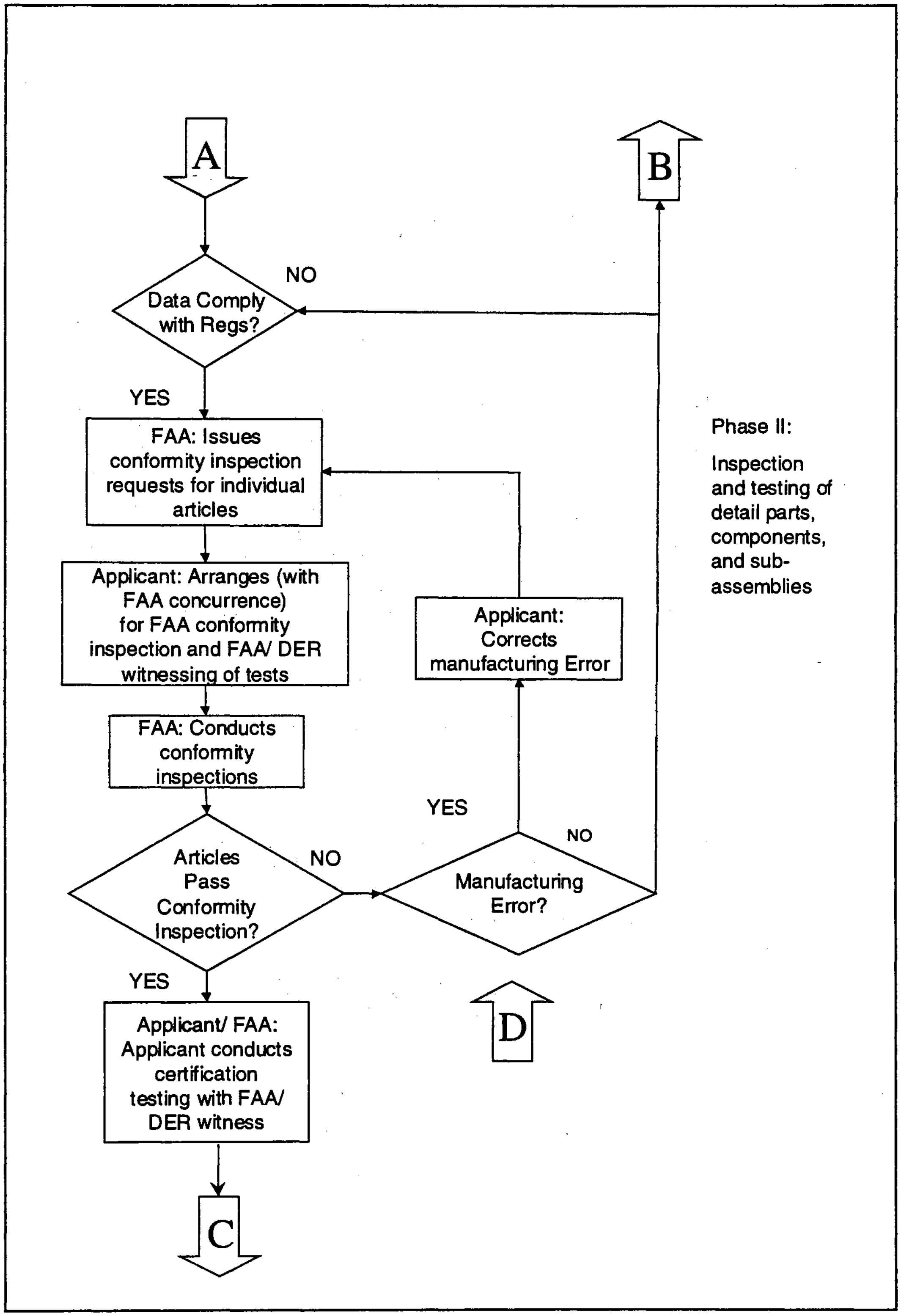


Figure 3. TC & STC Flow Diagram (continued).

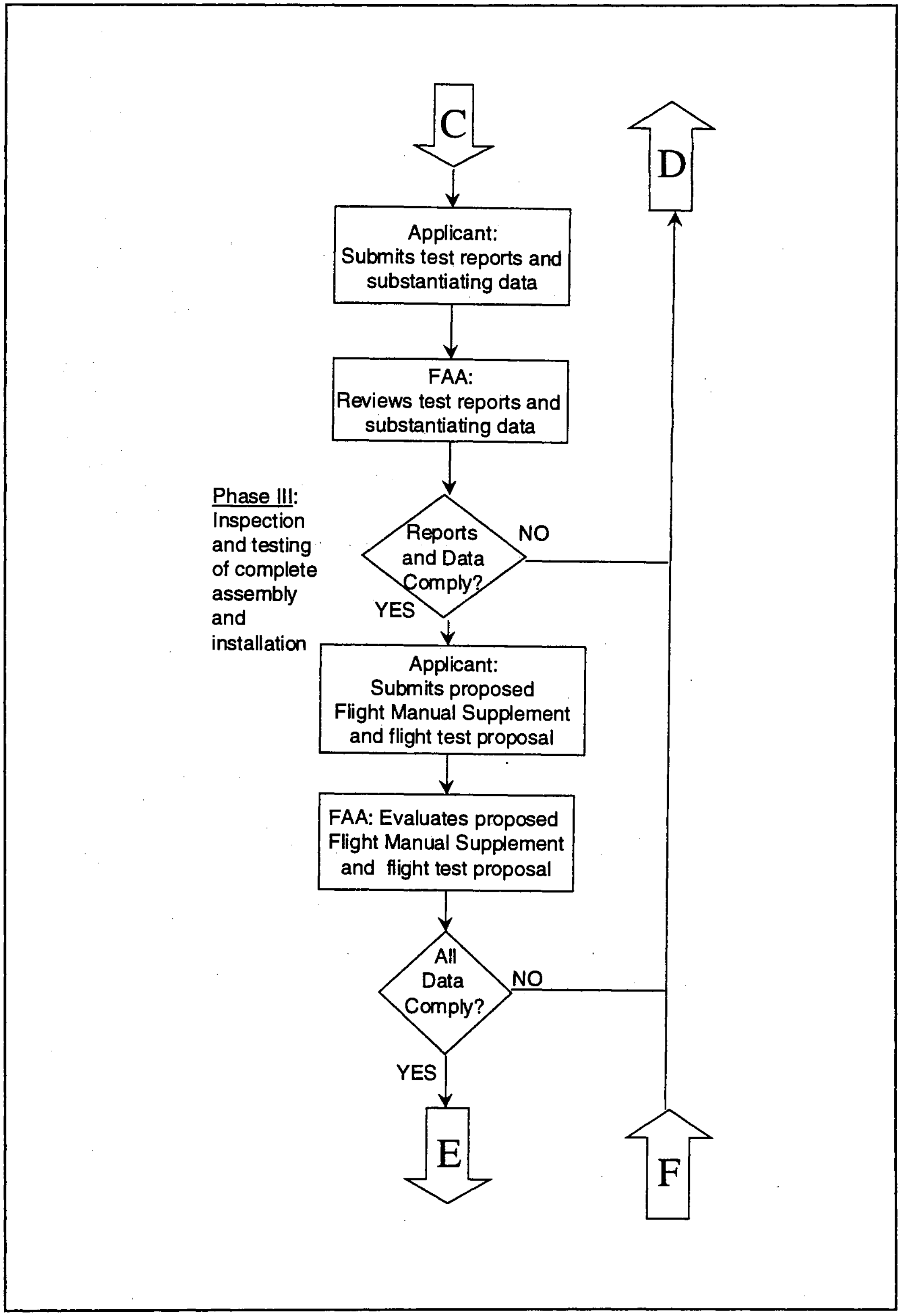


Figure 3. TC & STC Flow Diagram (continued).

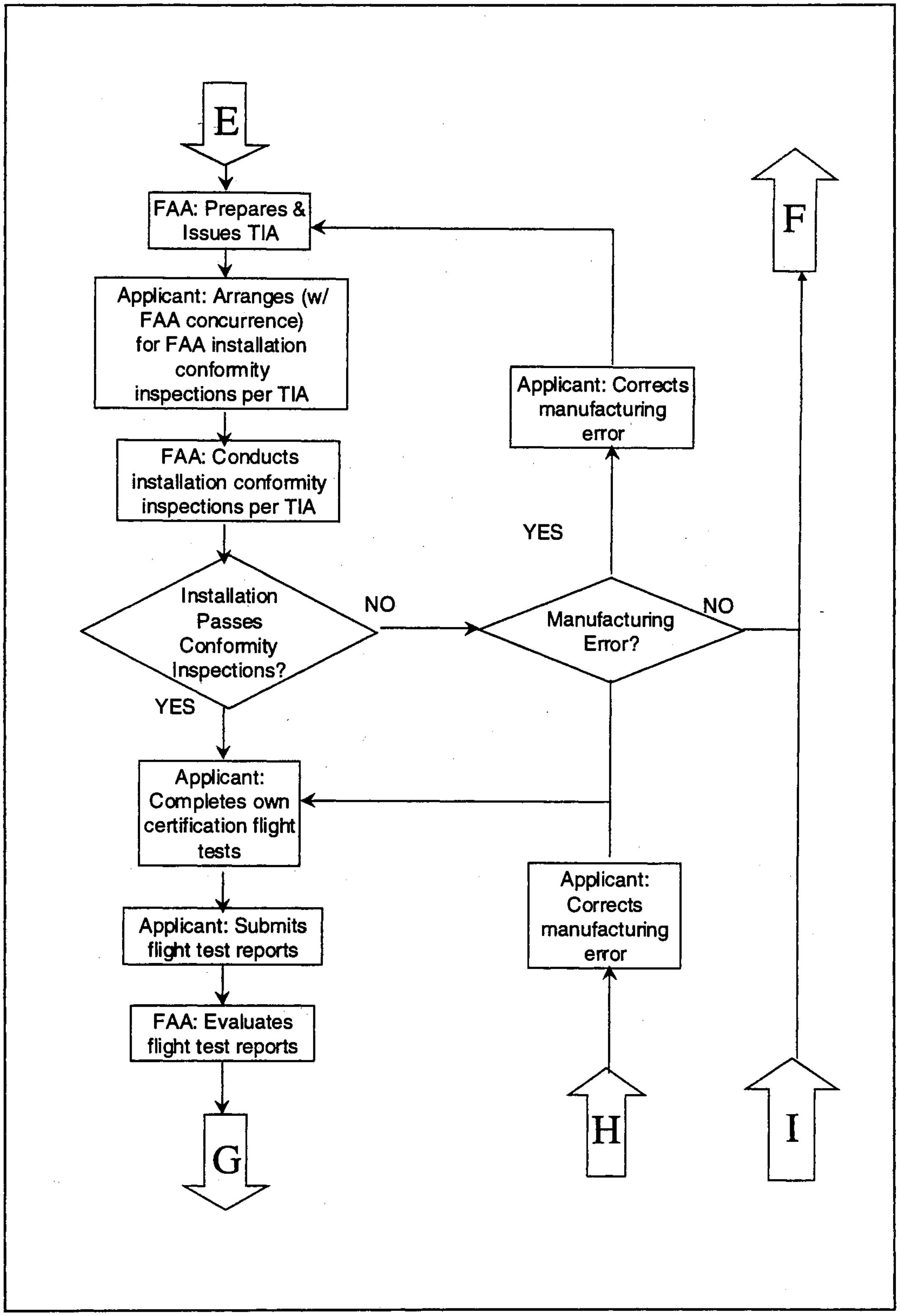
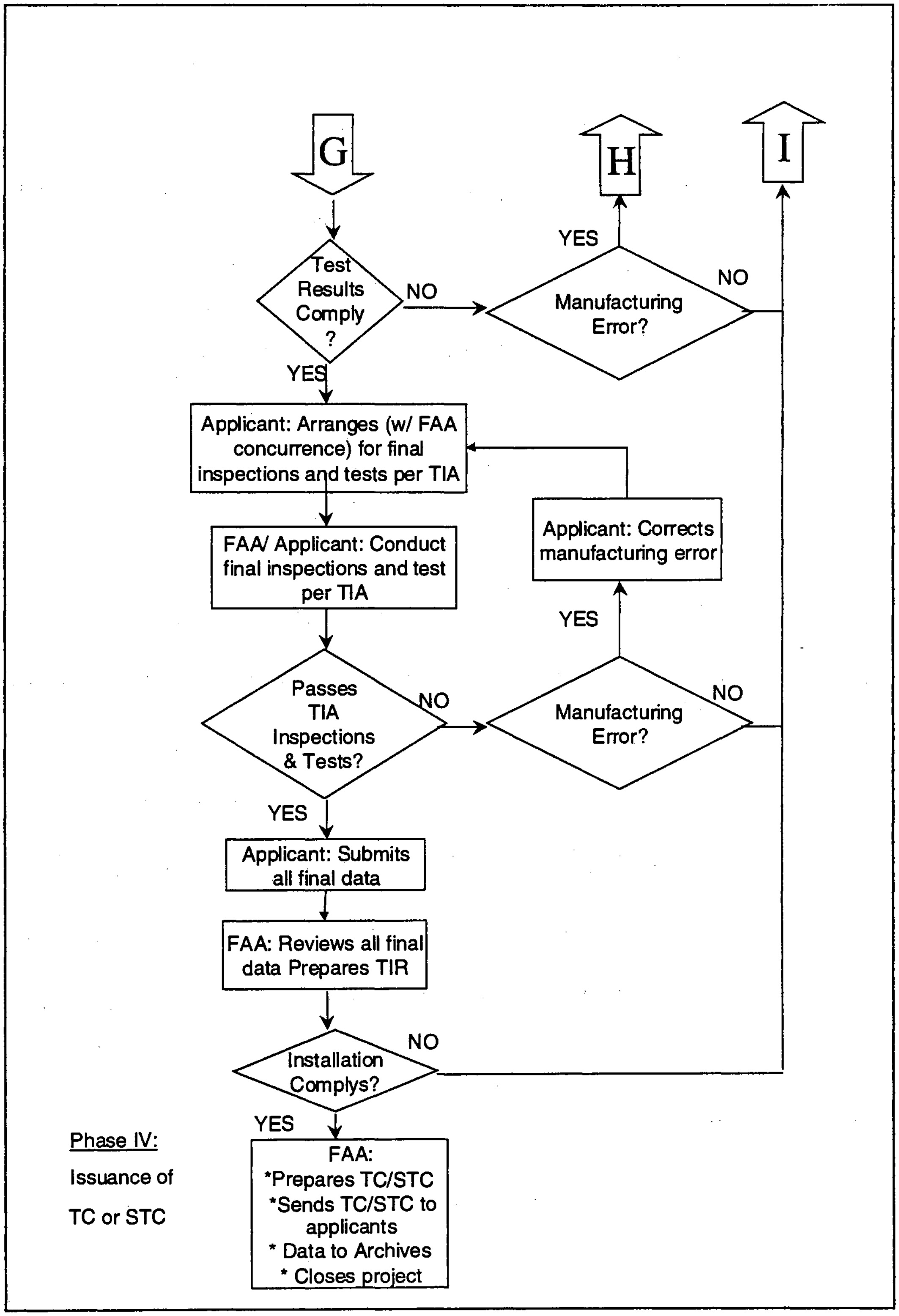


Figure 3. TC & STC Flow Diagram (continued).



Again, S3E and this study's audit are the FAA airworthiness standards per Far Part 121 and FAA Order 8300.10, fashioned and applied to the military. Basically, the audit is what the FAA uses to inspect the airlines. Not following all of the airworthiness criteria called for in FAA regulations all of the time could have catastrophic effects. This can be illustrated in the following brief case study.

The Crash of the Concord: A Case Study Of the Relationship Between S3E, Airworthiness and Experience

Introduction

The audit in this study does not represent the entirety of the S3E concept but is an important indicator of how well S3E functions as an instrument to gauge and maintain the aircraft's airworthiness. Audit factors such as: general condition of the facilities; the ramp being free of debris that could cause foreign object damage (FOD); personnel training; general maintenance procedures, quality assurance; maintenance control; engineering; production control and record keeping of engineering issues; production control, record keeping and planning of flight sorties all have potential critical role in the safety and airworthiness of aircraft (FAA Order 8300.10, 1988; FAA Order 8400.10, 1988; AMCI 21-103, 1997; NAVAIRINST 4790.22, 1998; ASO INST 4400.18C, 1997; AMCI 21-108, 1996; DOD 4145.19-R-1, 1979). This study's S3E audit instrument will audit all of these items and many more. This case study of the very recent Concorde accident serves well to illustrate how factors such as these comprising airworthiness are critical to aviation safety.

The Concorde

The Concorde operates daily out of London Heathrow and Paris' Charles de Gaulle airport to North America. The aircraft cruises at around the remarkable speed of 1350 mph (Mach Two) at an altitude of up to 60,000 feet (11 miles) with a range of 4300 miles (BBC Bulletin, 2000). A crossing from Europe to New York takes less than three and a half hours - less than half the normal flying time for other jet transport aircraft. Indeed, the record crossing stands at 2hrs 52mins 59secs. Traveling westward the five-hour timed difference means Concorde lands before local arrival time catches up with the local departure time.

History of the Aircraft

The Concorde was born out of separate French and British projects that joined forces in 1962. The partnership led to the British Aircraft Corporation (later British Aerospace) and Aerospatiale of France to build 20 Concordes. The first prototype plane (001) was rolled out of its hangar at Toulouse in France in 1967 (BBC Bulletin, 2000). Its first flight took place on March 2,1969 from Toulouse. The first flight of Concorde 002 took place from Filton, near Bristol in the UK, on April 9,1969. Then the following milestones were achieved and are worthy of review.

- 1969: Concorde successfully completed its first supersonic flight on 1 October.
- 1973: Concorde 002 lands at Dallas/Ft Worth on its first visit to the USA.
- 1974: The aircraft completes its first double transatlantic journey in one day on 17 June.

During this period the aircraft was subjected to a robust 5,000 hours of testing by the time it was ready for passenger service.

The first commercial flights took place on January 21, 1976 when British Airways flew from London Heathrow to Bahrain and Air France from Paris to Rio. Transatlantic flights began later that year. This has been one of the most exhaustively tested and scrutinized commercial aviation endeavors in history. Likewise, its engineering safety record remains one of the best of any type or model commercial aircraft.

The Concorde Accident

On July 25, 2000, Flight 4590, an Air France Concorde filled with 109 passengers and crew-members prepared to depart from runway 26 right of the Charles de Gaulle Airport outside of Paris. From all evidence thus far, during take-off roll, at 195.5 mph, the aircraft experienced a tire burst *most probably* due to the incursion of foreign object damage (FOD) left on the runway from another aircraft and missed by clean-up crews (USA Today, 2000). At that point, a sequence was started that concluded in multiple aircraft failures that put it in a performance "coffin corner" from which recovery was all but impossible (Aviation Week and Space Technology, 2000). The aircraft crashed shortly after take-off killing all 109 on board as well as 4 souls on the ground.

Closer investigation yields data that is of merit in illustrating factors in the roots of aviation safety. After the tire burst on the Concorde, pieces of debris, some weighing nine pounds or more as measured in the accident investigation, were projected outward. Also, among the pieces of debris found was a portion of the left gear metal water deflector. This component had been installed on the Concorde to mitigate the negative effect on thrust that the ingestion of standing water into the engine would have. An earlier incident experienced by the British operators of the Concorde where this same component dislodged after a tire burst, impacted the wing's imbedded fuel tank causing a fuel leak and fire. Due to this experience, the British operators had modified the design such that it had a secondary fail-safe attachment point to the main landing gear structure. The French Authorities has elected not to incorporate this modification. It is possible that even had this modification taken place; the tire debris alone might have still caused the wing fuel tank puncture.

There is no definite sign in the French BEA accident investigation report of August 31, 2000 that the crew knew that they had a tire problem. According to the Concorde's pilot manual, the tire failure warning system is inhibited above 135 knots and the tire burst seems to have occurred roughly 30 knots beyond that according to the BEA flight data recorder analysis. Further, there are no comments on the cockpit voice recorder (CVR) or on the departure radio frequency recorder about a tire failure. There is only a

CVR interpretation that says "low-frequency noise" 4 seconds after reaching the 150 knot V_1 go / no-go decision speed (Aviation Week and Space Technology, 2000).

The Concorde's highly swept, low aspect-ratio ogival wing creates an unusually high degree of induced drag when producing lift at low speeds, and thus large amounts of thrust are required to climb in order to overcome this drag (Aerospetial, Concorde Pilots Manual, 1998). At the maximum takeoff weight of 408,000 pounds, the speed for minimum drag is approximately 400 knots, but according to the calculated take-off and landing data (TOLD), the V_2 engine-out climb speed is only 220 knots. This is done so as to keep the take-off distance reasonable thus allowing a larger range of available operational venues and conditions, especially runways. From a commercial standpoint, the market share is limited if the type aircraft is restricted to too few airdromes for operation. Therefore, the designers of the Concorde opted to accept a very large delta V between V_1 decision speed and V_2 minimum drag speed at take-off configuration for engine out climb operations. While V_1 would be 220 knots typically, V_2 would be 440 knots putting the decision speed very far on the back side of the power curve where every knot slower than optimum meant considerably more stilted ability to climb. As perspective, a more conventional transport may only be 15-30 knots away from minimum drag speed at the calculated V_1.

The Concorde V_2 speed is referenced to the zero rate of climb speed V_{zrc} for a particular weight and condition (Concorde Pilots Manual, 1998). Under the accident conditions, the V_{zrc} was 193 knots with the gear up and 215 knots with the gear down.

The flight engineer had announced that engine No. 2 had failed one second before it lifted off. The pilot had rotated the aircraft slightly prior to the calculated rotation speed V_r. As a result, Flight 4590 flew at 200-215 knots for about a minute, which was below V_{zrc} (USA Today, 2000). Then engine No. 1 failed 50 seconds past liftoff further eroding the climb capability at the target calculated 2 engine out V_{zrc} of 300 knots. The pilot was unable to climb out due to the tire loss which, in turn, led to the loss of two engines. In addition, he had rotated prematurely on take-off. The fire that ensued due to fuel leakage and the damage that was causing led the pilot to face having to avoid a populated area. This was due to the proximity of the airport to a small city outside of Paris. All of these factors were causal to the accident and loss of life.

Therefore, the list of root causes to date is as follows:

1. A fundamental design decision affecting aircraft take-off and climb performance.
2. FOD on the runway due to a configuration control issue with a previous aircraft.
3. A FOD prevention program that did not detect the offending runway debris.
4. French non-compliance with a British design modification to secure the water deflectors.
5. Pilot non-compliance with the design driven rotation speed.

All of these root causes might have been avoided with correct application of the S3E airworthiness factors mentioned earlier. Again these were: the general condition of the facilities; the ramp being free of debris that could cause foreign object damage (FOD); personnel training; general maintenance procedures, quality assurance; maintenance control; engineering; production control and record keeping of engineering issues; production control, record keeping and planning of flight sorties.

For the first root cause, fundamental design decision affecting aircraft take-off and climb performance, more attention to engineering and sortie production would have mitigated this cause. For root cause 2, the presence of FOD was due to some oversight in procedures, quality assurance and production control on whichever aircraft lost the offending debris. Root cause 3 was the failure of the FOD prevention program. A more competent area inspection would have been relieved with inspection of general conditions, the ramp itself, proper training and general maintenance procedures. Quality assurance and maintenance control may have also mitigated these root causes. The same is true for the fourth cause, French non-compliance with a British design modification to secure the water deflectors. Quality assurance, maintenance control, engineering and its production control would have averted this root cause. As for the fifth factor, pilot non-compliance with the design driven rotation speed, training and aircrew quality assurance would have resolved that factor.

Conclusion

Aircraft certification and finding airworthiness is all about using all knowledge and experience available to create an airworthy vehicle. A majority of the root causes identified to date directly relate to aircraft certification, that is, fundamental engineering design and configuration control to maintain the aircraft's airworthiness. The complex process and flow diagram of FAA certification discussed earlier exist to facilitate this mission both for the original aircraft and for subsequent improvements to engineering design. A near flawless original design, evolving redesign for safety considerations and configuration control, is essential to maintaining the aircraft's airworthiness in accordance with its certification basis. All of these, in turn, are part of S3E and form the basis of the audit used in this study.

CHAPTER III

METHODOLOGY

Introduction

The military acquires aircraft originally designed and built for commercial purposes and uses them for military service. These aircraft are called military derivative aircraft. They are labeled as such since these are military derivations of commercial aircraft acquired to fulfill DOD mission requirements. The military does not maintain the airworthiness of these aircraft by using the same processes and standards that are in concert with the original design criteria as does their commercial counterparts (DOD Regulation 4140.1-R, 1993).

Commercial standards are controlled and enforced by the FAA (FAR 21, 2000). As a separate and autonomous governmental agency, the DOD does not answer to the FAA for establishing airworthiness but rather, self certifies its aircraft as airworthy (DOD Directive 5000.2-R, 1996). Further, the military uses its own standards for airworthiness based upon a combination of DOD regulations which do not follow *all* of the commercial standards from which these aircraft were designed, built, certified, operated and maintained (DOD Directive 4151.18, 1992).

When an aircraft is "certified," this means the legal, governmental recognition that the aircraft, aircraft system or aircraft part complies with all of the applicable Federal Regulatory requirements (SAE, ARP 4754. 1996). Such "certification" comprises the activity of technically scrutinizing the aircraft, aircraft system or aircraft part and the formal recognition of its compliance with all applicable Federal requirements. The formal recognition is achieved by the FAA issuing an aircraft type certificate (TC) for the original design or a supplemental type certificate (STC) for follow-on approved modifications.

"Airworthiness" is defined as the condition of an aircraft, aircraft system or aircraft part in which that item *operates in a safe manner to accomplish its intended function* (SAE, ARP 4754. 1996). Commercial engineering standards for airworthiness are embodied in Federal Aviation Regulation Part 121 and FAA Order 8300.10, Airworthiness Inspectors Handbook. This document sets the criteria for using *all* of the original *and* follow-on commercial engineering requirements from which the aircraft was certified. Since these aircraft were certified as commercial vehicles for commercial use, adhering to these requirements is the most appropriate manner in which to ensure that the aircraft is in an airworthy condition. This order is what is used by the FAA to ensure the commercial airlines comply with all airworthiness standards (FAA Order 8300.10, 1988). The single standard of engineering safety (S3E) is this same criterion for airworthiness but directed and applied specifically to the DODs military derivative aircraft. *Again*, the S3E concept is a product of this investigation and is therefore unique to this study.

Considering the above, this study's problem statement emanates from the following questions. If you do not strictly follow *all* of the standards from which the aircraft was designed, built and certified, which includes the follow-on requirements that evolved through service life experience, then how do you determine with certainty that the aircraft can still perform its intended function safely? In other words, how do you know with certainty that the aircraft is airworthy? With this in mind, should there not be a single standard of engineering safety for these aircraft based upon all of the available engineering data from which the aircraft was certified and maintained airworthy?

Statement of the Problem

Are military (DOD) units that operate military derivative aircraft maintaining the vehicles airworthiness using standards that achieve an equivalent level of safety with their commercial counterparts? If not, what instrument can be used to determine this as well as assess their level of compliance to the original certified airworthiness standards? Armed with an accurate compliance assessment, could the units then target appropriate corrective measures using a single standard of engineering safety (S3E) for airworthiness?

This study was based upon an engineering audit of aircraft maintenance facilities and functions conducted on units operating and maintaining military derivative aircraft. The following sections detail the process used to develop the audit instrument, conduct the audit, collect the data and then analyze the data so that it may be interpreted.

Hypothesis

There is a significant difference in airworthiness compliance with the original commercial design standards in DOD units operating military derivative aircraft that receive instruction in the single standard of engineering safety (S3E) and those who do not.

Research Questions

In order to fully understand the hypothesis, the following research questions are proposed. These questions emanate from the FAA regulations and serve to satisfy five safety areas of concern regarding the airworthiness of aircraft. These major areas are: engineering and safety practices; approved parts, hardware and instruments; approved maintenance facilities; engineering and tracking documentation; and aircraft production. Aircraft production is the ability to actually maintain and prepare the aircraft for flight in accordance with approved engineering standards. These safety groupings are shown in Table I.

TABLE I

SAFETY GROUPINGS AND CORRESPONDING RESEARCH QUESTIONS

S3E Safety Grouping	Research Questions
Engineering and Safety Practices	B, D, L, & R
Parts, Hardware & Instruments	J,K,G,M,& N
Approved Facility	A,C, & P
Engineering and Tracking Documentation	I,Q, & H
Aircraft Production	E,F,O,S, & T

The research questions below satisfy the above safety groupings as shown as follows:

A. Does the general condition and appearance of the facilities comply with S3E?

B. Is the fire protection S3E compliant?

C. Is the ramp S3E compliant?

D. Is first aid and personnel safety S3E compliant?

E. Is the manning adequate to maintain the aircraft according to S3E?

F. Is the training adequate to maintain the aircraft according to S3E?

G. Is the shelf life of aircraft parts monitored according to S3E?

H. Are the aircraft general maintenance procedures S3E compliant?

I. Are the aircraft technical manuals adequate and current to maintain the aircraft according to S3E?

J. Are the tools and test equipment calibrations S3E compliant?

K. Are aircraft parts controlled and handled according to S3E?

L. Is quality assurance S3E compliant?

M. Is aircraft weight and balance performed according to S3E?

N. Is the aircraft non-destructive testing program (NDT) S3E compliant?

O. Is the maintenance control program S3E compliant?

P. Is the tool room organized and used according to S3E?

Q. Is management of technical manuals and tool calibration S3E compliant?

R. Are engineering data and directives treated so as to comply with S3E?

S. Are the production control and records of engineering directives S3E compliant?

T. Is the aircraft sortie production, records and planning S3E compliant?

Instrument

After first comparing commercial and military engineering maintenance safety standards, an audit instrument was developed based upon the commercial engineering standards embodied in Federal Aviation Regulation Part 121 and FAA Order 8300.10, Airworthiness Inspectors Handbook. This order is the bedrock upon which all of the airlines aircraft engineering continued airworthiness is based and is also the foundation of S3E. The order is designed to ensure that the aircraft is maintained in a manner that keeps the engineering integrity of the original type certification and accounts for any supplemental type certifications as well as engineering safety improvements made since the original design and approval. The audit instrument is virtually identical to those used by the FAA for major airlines (Appendix A). The comparison to military regulations was to ensure that every military general item was addressed and that nomenclature was unambiguous and understandable for the military auditors.

The instrument is comprised of twenty categories covering this study's twenty research questions that were derived from airline audits conducted by the FAA. They are:

A. General Condition/Appearance

B. Fire Protection

C. Ramp

D. First Aid/Safety

E. Manning

F. Training

G. Shelf Life

H. General Maintenance Procedures

I. Manuals

J. Calibrated Tooling

K. Parts Control/Handing

L. Quality Assurance

M. Weight and Balance

N. Non-Destructive Testing Program

O. Maintenance Control

P. Tool Room

Q. Technical Publications/Tool Calibration

R. Engineering

S. Production Control/Records (Engineering)

T. Production Control/Records/Planning (Sorties)

These categories embody the five major areas of concern in this regard (FAA Order 8300.10, 1988). Again these major areas are: engineering and safety practices; approved parts, hardware and instruments; approved maintenance facilities; engineering and tracking documentation; and aircraft production. Aircraft production is the ability to actually maintain and prepare the aircraft for flight in accordance with approved engineering standards.

The audit was designed in the classic style with which it is done for use in the commercial airline industry. The audit's sole purpose was to establish *fact* through inspection and as such was created with "Yes," "No," or "N/A" responses by the auditor. The "N/A" responses are rarely utilized unless the maintenance organization is limited in scope. Should the organization have the standard complete mission of maintaining engineering aircraft airworthiness, the responses should be "Yes" or "No" with no "N/As" and indeed that was the case in this study.

Validation

The first draft of the audit was developed and then reviewed by volunteers from the FAA and DOD that were also subject matter experts in the engineering, operations and maintenance functions of the similar organizations. Since the material was based upon very mature and previously tested audits from subject matter experts from both the FAA and the military inspector general, the review was accomplished to learn if the questions flowed smoothly; if the auditors could understand the questions; and whether the group found any unfamiliar terms or expressions. Only very minor editorial changes were made to create the final audit instrument.

Subjects

The study did not involve the examination of human subjects. The audit instrument was designed to examine the state of facilities, tooling and documentation related to the maintenance of military derivative aircraft. The experiment was designed to use two DOD units. One was to be treated and one was the control subject. The selection of the two subject units was completely random to this study, crossing military service lines and weapon systems.

Since humans were not being examined, measures were taken to eliminate any threats to validity caused by humans. Two reactive arrangement factors were of particular concern to this investigator. They are the Hawthorne effect and the John Henry effect. The Hawthorne effect is used to describe any situation in which subjects' behavior is affected not by the treatment per se, but by their knowledge of participation in a study (Gay, 1996). A related effect to the Hawthorne is the John Henry effect whereby the subjects feel challenged by the competition of the experiment and perform way beyond what would normally be expected (Gay, 1996).

The following steps were taken to eliminate the corruption of the experiment. All individuals involved were assured of complete anonymity. The participation was voluntary. No one except for the sole Pentagon official knew that the audit was for a study nor that the results would be compared to that of any other unit. No one but the same Pentagon official was aware that there would be a post-test audit.

In spite of the fact that humans were not being tested, this investigator was aware that the internal validity issue of "pretest sensitization" and/or the external validity issue of "pretest-treatment interaction" might have an effect on the results. These validity issues were considered in the summary and conclusion of this study.

Once the random selection was completed of the two subject DOD units, one unit was treated with the actual S3E engineering safety standards per Order 8300.10, as well as access to guidance as needed while the other was not. After approximately 90 days, both units were tested again and the results were compared and analyzed.

The selection was blind to this study in that a highly placed unnamed Pentagon official with whom the study is working accomplished it. The only guidance offered and followed was that the units operate aircraft platforms that share a common commercial airworthiness baseline type as well as have the same size fleet.

What is meant by a common commercial airworthiness baseline type is that the aircraft came off the same commercial assembly line. For instance, the Navy, the Air Force, NASA and the Army all have used the same commercially built Boeing 737. These organizations do not use these B 737s in the same manner or for equivalent missions nor do they refer to them by the same weapon systems designation, but these aircraft all began their "lives" as Boeing 737s engineered and approved in accordance with commercial safety airworthiness standards enforced by the FAA.

There were literally hundreds of military flying units within the military services to choose from. These services include the U.S. Army; the U.S. Navy; the U.S. Air Force, the U.S. Marines and the U.S. Coast Guard. Please note that the Coast Guard, while a military organization, is the only one of those listed that does not come under the auspices of the U.S. Department of Defense. Rather it falls under the Department of Transportation. Nevertheless, the U.S. Coast Guard operates military derivative aircraft and is culturally linked to DOD. This investigator was informed by the DOD that personnel numbers and technical expertise for both the control and experimental units were virtually identical. This would be expected for organizations operating the same basic equipment and mission and number of airframes although they were of different branches within DOD.

The audit instrument by which the unit maintenance facilities, instruments and documentation were to be measured was baselined in its commercial counterpart. Thus, specialized military attributes of these aircraft were not involved as part of the test. These attributes that are not part of the audit include such functions such as air-refueling capability, air drop capability, specialized military sensors, navigation and communication among many others.

Collection of Data

The same very senior member of the armed services agreed, with the understanding of their complete anonymity, to have independent professional military auditors that were subject matter experts, administer the audit. Since the experiment involved facilities, tooling, and documentation but no human subjects, the Oklahoma State University Institutional Review Board finding was that no further review or comment was necessary to proceed with the audit (Appendix B). The senior DOD official was the only conduit in the dissemination of the audit and collection of the raw data. That same official randomly selected the DOD units that participated in the study. The Unit's participation was completely voluntary and was couched as an informal self-assessment that would be totally anonymous. Because of this, there was virtually no possibility of data contamination from intimidation of review or evaluation through formal military channels. There was 100% participation and cooperation from the units.

Analysis of Data

The data analysis was as important in determining the methodology and in particular, the instrument as was the S3E concept. It was the intent of the study to use both a graphical depiction of the results as well as the chi-squared technique to determine significance. These analysis decisions were solidified in nature and scope after numerous in-depth consultations with the Department Head of Boeing Aircraft Corporation's Statistical Analysis Group as well as the OSU Director of Research (Johnson & Bhattacharyya, 1996; Key, 1997; Steward & Kamis, 1993).

There were trinomial responses to the twenty individual categories corresponding to the twenty research questions. These categories served to satisfy the S3E groupings of engineering and safety practices; approved parts, hardware and instruments; approved maintenance facilities; engineering and tracking documentation; and aircraft production. The results fit easily into a graphical depiction as well as the chi square technique for establishing significance (Gay, 1996).

The graphical depiction was performed by taking the raw data results of both the pre-test and post-test, scoring them by percentages per category and then using Microsoft Excel to produce the comparative bar graph (Berk & Cary, 1998; Dretzke & Heilman, 1998). The chi square was used to compare frequencies occurring in the independent categories of the audit that covered the five different groupings (engineering and safety practices; approved parts, hardware and instruments; approved maintenance facilities; engineering and tracking documentation; and aircraft production) with respect to the frequency of occurrence of "Yes" responses (Gay, 1996; Spence & Cotton, 1983). A "Yes" response indicated that a particular sub-element was found by the auditor to be in compliance with S3E. The data was presented in a contingency table depicting observed versus expected frequencies of a "Yes" S3E compliance response. As advised by the Boeing statisticians, the expected responses, fe, were calculated predicated upon the average initially observed "Yes" responses for all of the independent categories.

To determine whether the observed frequencies were significantly different from the expected frequencies, a one-dimensional chi square test was applied to each of the major groupings (Gay, 1996). A 95 percent approach was used with $p=.05$ and degrees of freedom (*df*) = number of columns (within each S3E grouping) -1 (Gay, 1996; Spence & Cotton, 1983). If the chi square were significant, then the study's hypothesis that the S3E treatment had a significant effect, would be accepted. For each grouping, the distribution of X^2 from a statistical table was used to compare the X^2 values so as to accept or reject the study's hypothesis (Gay, 1996).

CHAPTER IV

FINDINGS

General

After the introductory and review sections, this chapter's findings are divided into three areas that examine the hypothesis of this study. The first comprises the raw data associated with the research questions. The second is the graphical depiction of the data converted to percentage of compliance with safety criteria and associated examination of the results. The third is the chi squared analysis test for significance of the results.

Statement of the Problem

Are military (DOD) units that operate military derivative aircraft maintaining the vehicles airworthiness using standards that achieve an equivalent level of safety with their commercial counterparts? If not, what instrument can be used to determine this as well as assess their level of compliance to the original certified airworthiness standards? Armed with an accurate compliance assessment, could the units then target appropriate corrective measures using a single standard of engineering safety (S3E) for airworthiness? As a result of these questions, this study was based upon an engineering audit of aircraft maintenance facilities and functions conducted on units operating and maintaining military derivative aircraft.

Hypothesis

There is a significant difference in airworthiness compliance with the original commercial design standards in DOD units operating military derivative aircraft that receive instruction in the single standard of engineering safety (S3E) and those who do not.

Methodology

Two DOD units were randomly selected from a population of flying units that operated the same type of commercial aircraft and had the same size fleet and manning authorization. Complete anonymity was strictly observed. The research questions were developed and targeted toward the military but were based upon standard FAA maintenance airworthiness audits. These questions were in turn developed into the audit instrument by safety category. Each category had a number of sub-element questions coinciding with the standard FAA audit. The number of sub-elements varied with each question/ category. Professional military maintenance inspection auditors conducted the audit inspection. Both units were pre-tested using the audit instrument. The single standard of engineering safety (S3E) criteria embodied in FAA Order 8300.10 was made available as well as assistance with interpretation from subject matter experts. The subject matter experts were never called upon. Unit A was treated with S3E and Unit B, the control unit, was not. After 87 days, both units were re-tested with the audit instrument.

The study used both a graphical depiction of the results as well as the chi squared technique to determine significance. These analysis decisions were solidified in nature and scope after numerous, in-depth consultations with the Department Head of Boeing Aircraft Corporation's Statistical Analysis Group as well as the OSU Director of Research.

There were trinomial responses to the twenty individual categories corresponding to the twenty research questions. These categories served to satisfy the S3E groupings of engineering and safety practices; approved parts, hardware and instruments; approved maintenance facilities; engineering and tracking documentation; and aircraft production. The results fit easily into graphical depictions as well as the chi square technique for establishing significance (Gay, 1996).

Results of the Audited Research Questions

In order to fully understand the hypothesis, the following research questions were put forth in an audit and answered by the observations of the professional maintenance inspection auditors. These questions emanated from the FAA regulations and served to satisfy five safety areas of concern regarding the airworthiness of aircraft. These major areas are: engineering and safety practices; approved parts, hardware and instruments; approved maintenance facilities; engineering and tracking documentation; and aircraft production. Aircraft production is the ability to actually maintain and prepare the aircraft for flight in accordance with approved engineering standards. The research questions satisfy the safety groupings as shown in Table I, Chapter III of this study.

The results of the audit were as follows. The "Y" is a "yes" response signifying that there was compliance to this number of sub-elements of the research questions. A "N" is a "no" response signifying non-compliance. The percent figure was calculated by dividing the number of "yes" responses by the total number of sub-elements for that question/research category. The overall results of the research questions, the graphical analysis and the chi squared analysis support the hypothesis that exposure to S3E criteria leads to an increase in airworthiness compliance. Indeed, even alluding to S3E criteria by exposure to the audit itself assisted the control unit to a higher level of compliance to airworthiness criteria even though the improvement in safety compliance did not meet the chi squared test for significance.

Raw Data of Research Questions/Categories

Question A – *Does the General Condition and Appearance of the Facilities Comply with S3E?* Category A– *General Condition/Appearance*

TABLE II

RESULTS RESEARCH QUESTION A – CATEGORY A

Unit A Pre-test	Unit A Post-test	Unit B Pre-test	Unit B Post-test
N=3	N=1	N=4	N=2
Y=6	Y=8	Y=5	Y=7
66.67%	88.89%	55.56%	77.78%

Both units showed increased compliance scores from the pre to post test but Unit A went from 66.67% to 88.89% while Unit B improved from 55.56% to 77.78%.

Question B – *Is the Fire Protection S3E Compliant?* Category B – *Fire Protection*

TABLE III

RESULTS RESEARCH QUESTION B – CATEGORY B

Unit A Pre-test	Unit A Post-test	Unit B Pre-test	Unit B Post-test
N=3	N=0	N=2	N=2
Y=2	Y=5	Y=3	Y=3
40%	100%	60%	60%

Unit A increased from 40% compliance to full 100% compliance while Unit B remained unchanged.

Question C – *Is the Ramp S3E Compliant?* Category C – *Ramp*

TABLE IV

RESULTS RESEARCH QUESTION C – CATEGORY C

Unit A Pre-test	Unit A Post-test	Unit B Pre-test	Unit B Post-test
N=2	N=1	N=2	N=2
Y=2	Y=3	Y=2	Y=2
50%	75%	50%	50%

Both units began at the same level but Unit A went from 50% to 75% compliance while Unit B did not improve.

Question D – *Is First Aid and Personnel Safety S3E Compliant?*

Category D – *First Aid/Safety*

TABLE V

RESULTS RESEARCH QUESTION D – CATEGORY D

Unit A Pre-test	Unit A Post-test	Unit B Pre-test	Unit B Post-test
N=2	N=0	N=3	N=1
Y=1	Y=3	Y=0	Y=2
33.33%	100%	0%	66.67%

Both units increased dramatically but Unit A went from 33.33% to full 100% compliance while Unit B went from no compliance to 66.67%.

Question E – *Is the Manning Adequate to Maintain the Aircraft According to S3E?* Category E – *Manning*

TABLE VI

RESULTS RESEARCH QUESTION E – CATEGORY E

Unit A Pre-test	Unit A Post-test	Unit B Pre-test	Unit B Post-test
N=1	N=1	N=1	N=1
Y=0	Y=0	Y=0	Y=0
0%	0%	0%	0%

Neither unit complied in either the pre or post-test.

Question F – *Is the Training Adequate to Maintain The Aircraft According to S3E?* Category F – *Training*

TABLE VII

RESULTS RESEARCH QUESTION F – CATEGORY F

Unit A Pre-test	Unit A Post-test	Unit B Pre-test	Unit B Post-test
N=1	N=0	N=1	N=1
Y=2	Y=3	Y=2	Y=2
66.67%	100%	66.67%	66.67%

Both units began at the same level but Unit A went from 66.67% to 100% compliance while Unit B showed no increase in the post-test.

Question G – *Is the Shelf Life of Aircraft Parts Monitored According to S3E?* Category G – *Shelf Life*

TABLE VIII

RESULTS RESEARCH QUESTION G – CATEGORY G

Unit A Pre-test	Unit A Post-test	Unit B Pre-test	Unit B Post-test
N=1	N=0	N=1	N=0
Y=0	Y=1	Y=0	Y=1
0%	100%	0%	100%

Both units went from no compliance to 100% compliance.

Question H – *Are the Aircraft General Maintenance Procedures S3E Compliant?* Category H – *General Maintenance Procedures*

TABLE IX

RESULTS RESEARCH QUESTION H – CATEGORY H

Unit A Pre-test	Unit A Post-test	Unit B Pre-test	Unit B Post-test
N=4	N=1	N=3	N=3
Y=3	Y=6	Y=4	Y=4
42.86%	85.71%	57.14%	57.14%

Unit A scored lower than Unit B in the pre-test but increased to 85.71% compliance level while Unit B remained unchanged at 57.14%.

Question I – *Are the Aircraft Technical Manuals Adequate and Current to Maintain the Aircraft According to S3E?* Category I – *Manuals*

TABLE X

RESULTS RESEARCH QUESTION I – CATEGORY I

Unit A Pre-test	Unit A Post-test	Unit B Pre-test	Unit B Post-test
N=3	N=1	N=3	N=3
Y=1	Y=4	Y=1	Y=1
25%	100%	25%	25%

Both units began at the same level but Unit A went from 25% to a perfect 100% compliance while Unit B remained unchanged.

Question J – *Are the Tools and Test Equipment Calibrations S3E Compliant?* Category J – *Calibrated Tooling*

TABLE XI

RESULTS RESEARCH QUESTION J – CATEGORY J

Unit A Pre-test	Unit A Post-test	Unit B Pre-test	Unit B Post-test
N=5	N=2	N=6	N=5
Y=1	Y=4	Y=0	Y=1
16.67%	66.67%	0%	16.67%

Both units scored low on the pre-test but Unit A increased to 66.67% from 16.67% while Unit B went from no compliance to 16.67%.

Question K – *Are Aircraft Parts Controlled and Handled According to S3E?* Category K – *Parts Control/Handing*

TABLE XII

RESULTS RESEARCH QUESTION K – CATEGORY K

Unit A Pre-test	Unit A Post-test	Unit B Pre-test	Unit B Post-test
N=4	N=1	N=5	N=3
Y=4	Y=7	Y=3	Y=5
50%	87.50%	37.50%	62.50%

Both units increased their scores but Unit A went to 87.5% from 50% level while Unit B increased from 37.5% only to 62.5%.

Question L – *Is Quality Assurance S3E Compliant?* Category L – *Quality Assurance*

TABLE XIII

RESULTS RESEARCH QUESTION L – CATEGORY L

Unit A Pre-test	Unit A Post-test	Unit B Pre-test	Unit B Post-test
N=7	N=2	N=7	N=6
Y=5	Y=10	Y=5	Y=6
41.67%	83.33%	41.67%	50%

Both units began at the same level but Unit A went from 41.67% to 83.33% compliance while Unit B only increased to 50%.

Question M – *Is Aircraft Weight and Balance Performed According to S3E?* Category M – *Weight and Balance*

TABLE XIV

RESULTS RESEARCH QUESTION M – CATEGORY M

Unit A Pre-test	Unit A Post-test	Unit B Pre-test	Unit B Post-test
N=2	N=0	N=2	N=2
Y=3	Y=5	Y=3	Y=3
60%	100%	60%	60%

Both units began at the same level but Unit A experienced an increase from 60% to a perfect 100% compliance while Unit B remained unchanged.

Question N – *Is the Aircraft Non-Destructive Testing Program (NDT) S3E Compliant?* Category N – *Non-Destructive Testing Program*

TABLE XV

RESULTS RESEARCH QUESTION N – CATEGORY N

Unit A Pre-test	Unit A Post-test	Unit B Pre-test	Unit B Post-test
N=4	N=1	N=4	N=3
Y=2	Y=5	Y=2	Y=3
33.33%	83.33%	33.33%	50%

Both units began at the same level but Unit A increased from 33.33% to 83.33% compliance while Unit B only increased to 50%.

Question O – *Is the Maintenance Control Program S3E Compliant?*

Category O – *Maintenance Control*

TABLE XVI

RESULTS RESEARCH QUESTION O – CATEGORY O

Unit A Pre-test	Unit A Post-test	Unit B Pre-test	Unit B Post-test
N=7	N=1	N=7	N=5
Y=5	Y=11	Y=5	Y=7
41.67%	91.67%	41.67%	58.33%

Both units began at the same level but Unit A went from 41.67% to 91.67% compliance while Unit B only increased to 58.33%.

Question P – *Is the Tool Room Organized and Used According to S3E?*

Category P – *Tool Room*

TABLE XVII

RESULTS RESEARCH QUESTION P – CATEGORY P

Unit A Pre-test	Unit A Post-test	Unit B Pre-test	Unit B Post-test
N=5	N=1	N=5	N=4
Y=4	Y=8	Y=4	Y=5
44.44%	88.89%	44.44%	55.56%

Both units began at the same level but Unit A went from 44.44% to 88.89% compliance while Unit B only increased to 55.56%.

Question Q – *Is Management of Technical Manuals and Tool Calibration S3E Compliant?* Category Q – *Technical Publications/Tool Calibration*

TABLE XVIII

RESULTS RESEARCH QUESTION Q – CATEGORY Q

Unit A Pre-test	Unit A Post-test	Unit B Pre-test	Unit B Post-test
N=7	N=2	N=8	N=6
Y=3	Y=8	Y=2	Y=4
30%	80%	20%	40%

Both units increased their scores but Unit A went from 30% to 80% compliance while Unit B only increased to 40%.

Question R – *Are Engineering Data and Directives Treated So as to Comply with S3E?* Category R – *Engineering*

TABLE XIX

RESULTS RESEARCH QUESTION R – CATEGORY R

Unit A Pre-test	Unit A Post-test	Unit B Pre-test	Unit B Post-test
N=3	N=0	N=3	N=3
Y=2	Y=5	Y=2	Y=2
40%	100%	40%	40%

Unit A experienced an impressive safety compliance increase from 40% to 100% while Unit B remained unchanged at 40%.

Question S – *Are the Production Control and Records of Engineering Directives S3E Compliant?* Category S – *Production Control/Records (Engineering)*

TABLE XX

RESULTS RESEARCH QUESTION S – CATEGORY S

Unit A Pre-test	Unit A Post-test	Unit B Pre-test	Unit B Post-test
N=3	N=0	N=3	N=3
Y=3	Y=6	Y=3	Y=3
50%	100%	50%	50%

While Unit A increased 50% to full 100% compliance, Unit B remained unchanged at 50%.

Question T – *Is the Aircraft Sortie Production, Records and Planning S3E Compliant?* Category T – *Production Control/Records/Planning (Sorties)*

TABLE XXI

RESULTS RESEARCH QUESTION T – CATEGORY T

Unit A Pre-test	Unit A Post-test	Unit B Pre-test	Unit B Post-test
N=5	N=1	N=4	N=5
Y=3	Y=7	Y=4	Y=3
37.50%	87.50%	50%	37.50%

Unit A increased dramatically to 87.5% from 37.5%. Unit B actually suffered a setback to 37.5% from 50%.

TABLE XXII

GRAND TOTAL RESULTS ALL RESEARCH QUESTIONS – ALL CATEGORIES

Unit A Pre-test	Unit A Post-test	Unit B Pre-test	Unit B Post-test
N=72	N=15	N=74	N=60
Y=52	Y=109	Y=50	Y=64
41.94%	87.90%	40.32%	51.61%

Unit A had an overall increase from 41.94% to 87.9% while Unit B increased only from 40.32% to 51.61%.

Bar Chart Analysis

The following bar chart plots are the results of the individual results by percentages. The delta represents the changes, if any, from the pre-test to the post-test for both the treated Unit A in comparison to the control Unit B. The results of the twenty research questions were graphed using Microsoft Excel and are shown in Figures 4 through 23.

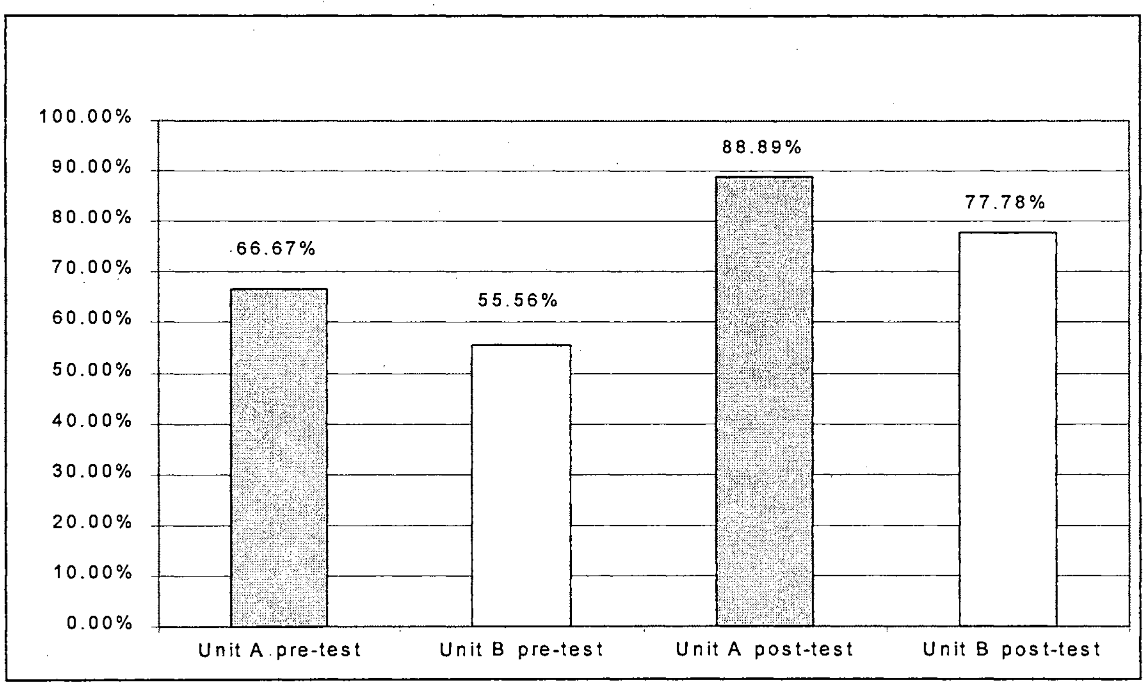


Figure 4. S3E Compliance Category A – General Condition.

Figure 4 shows and compares the two units' pre and post-test results regarding items as varied as lighting to the static grounding proper of the aircraft. Both units showed improvements even though the control unit had no training. The treated Unit A reached a very high 88.89% compliance level. The audit itself served as a useful indicator of condition for the control Unit B. Many of the non-compliance items were easily remedied and they increased to 77.78% compliance.

Figure 5 shows and compares the two units' pre and post-test results regarding items such as extinguisher accessibility and fire exit obstructions to name only two. The control Unit B actually had a higher level of compliance on the pre-test but no change in the post-test. Meanwhile the treated Unit A rose to 100% compliance in the post-test.

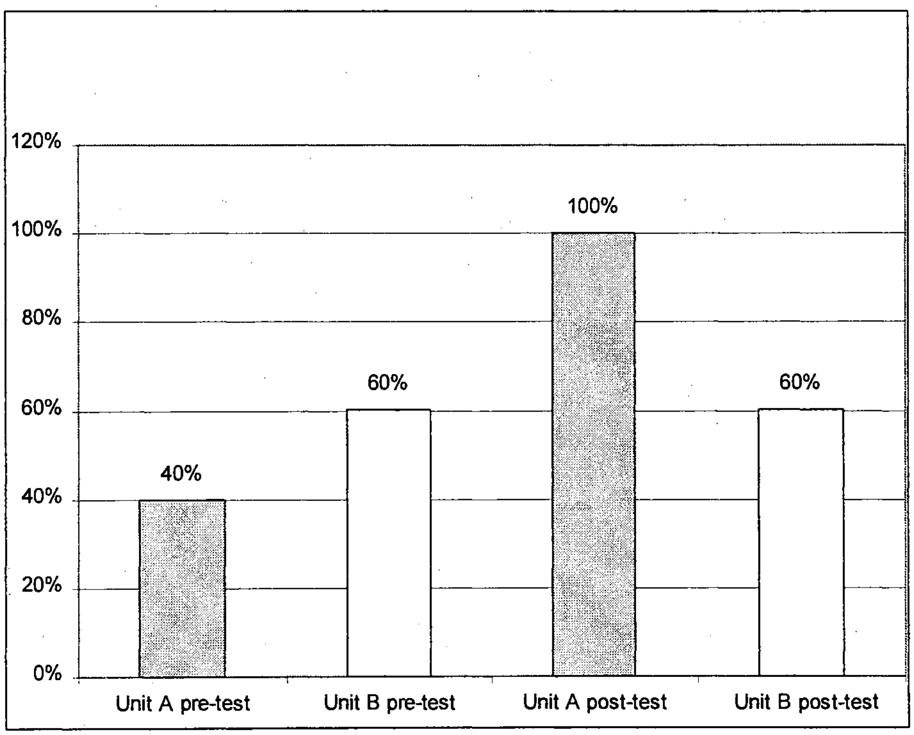


Figure 5. S3E Compliance Category B – Fire Protection.

Foreign Object Damage (FOD) avoidance plays a significant role in aircraft airworthiness. There was no level of increase in compliance with the control Unit B while the treated Unit A was exposed to techniques that led to a dramatic 25% increase in safety compliance in this safety category (Figure 6).

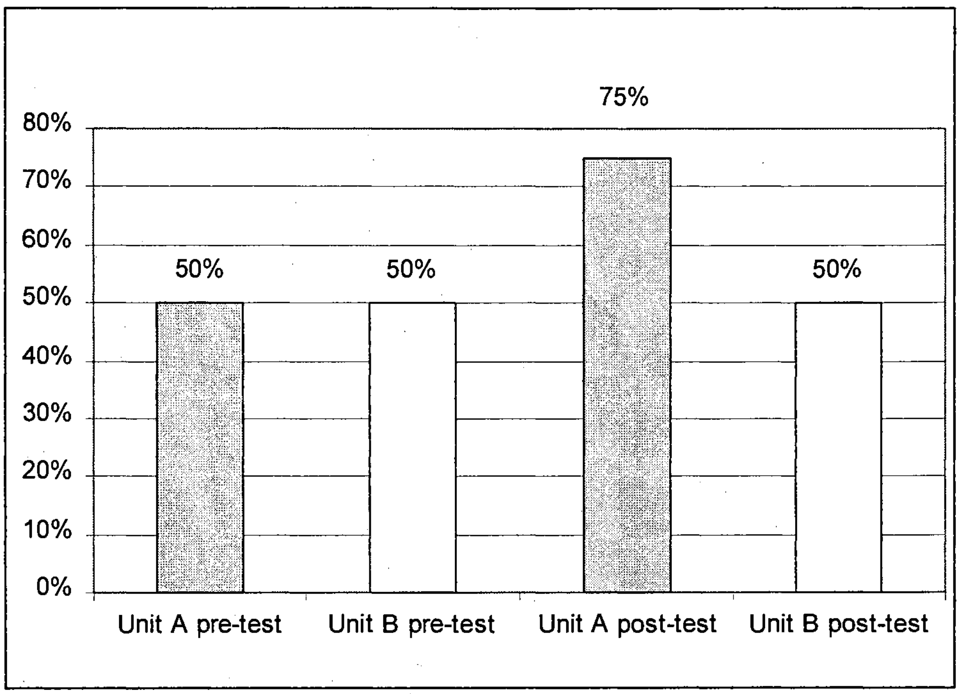


Figure 6. S3E Compliance Category C – Ramp.

The next category deals with personnel workplace safety and its role in maintaining aircraft airworthiness. Both units experienced impressive increases in safety compliance. The treated Unit A was able to achieve full compliance on the post-test audit (Figure 7).

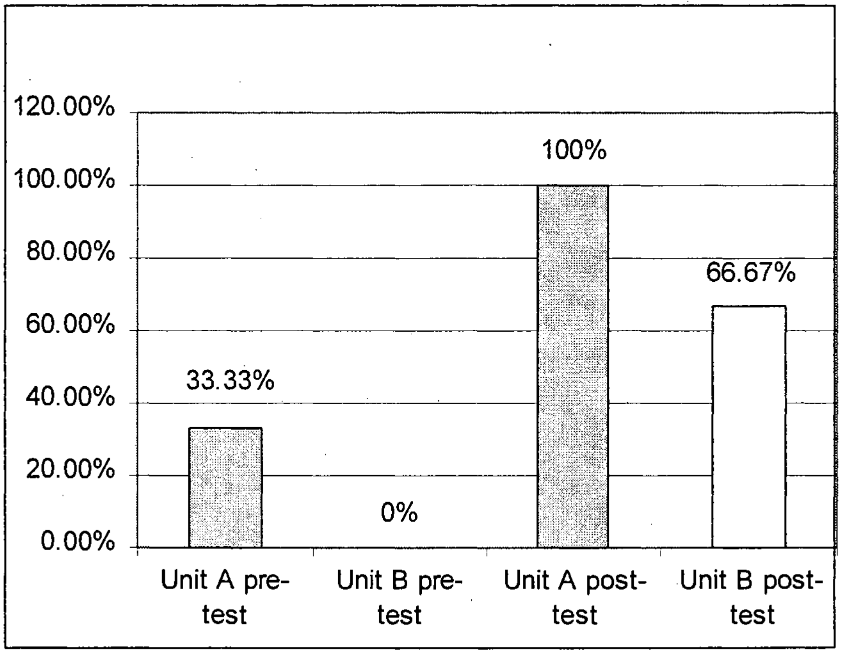


Figure 7. S3E Compliance Category D – First Aid/Safety.

Both units experienced a serious under-manning status. Although both units added personnel during the 87-day time period, they were still lacking sufficient personnel and thus were below acceptable manning levels. This was an issue that demanded resolution at much higher levels within the DOD (Figure 8).

Training records and documentation are critical to maintaining aircraft airworthiness. The control Unit A was able to achieve complete compliance with relatively little effort in ensuring adequate training and appropriate documentation (Figure 9).

Some aircraft components and chemical compounds are life limited and thus their shelf life must be monitored. Both Units achieved compliance in this area by instituting a periodic check and documenting the action (Figure 10).

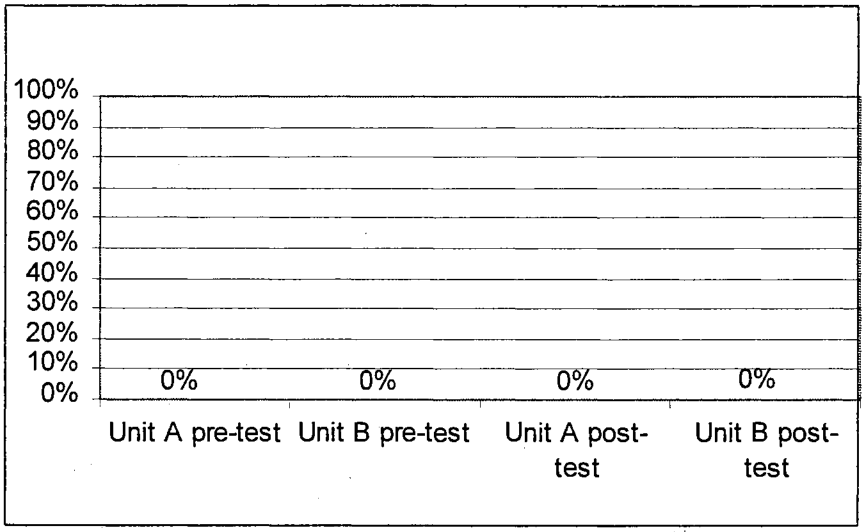


Figure 8. S3E Compliance Category E – Manning.

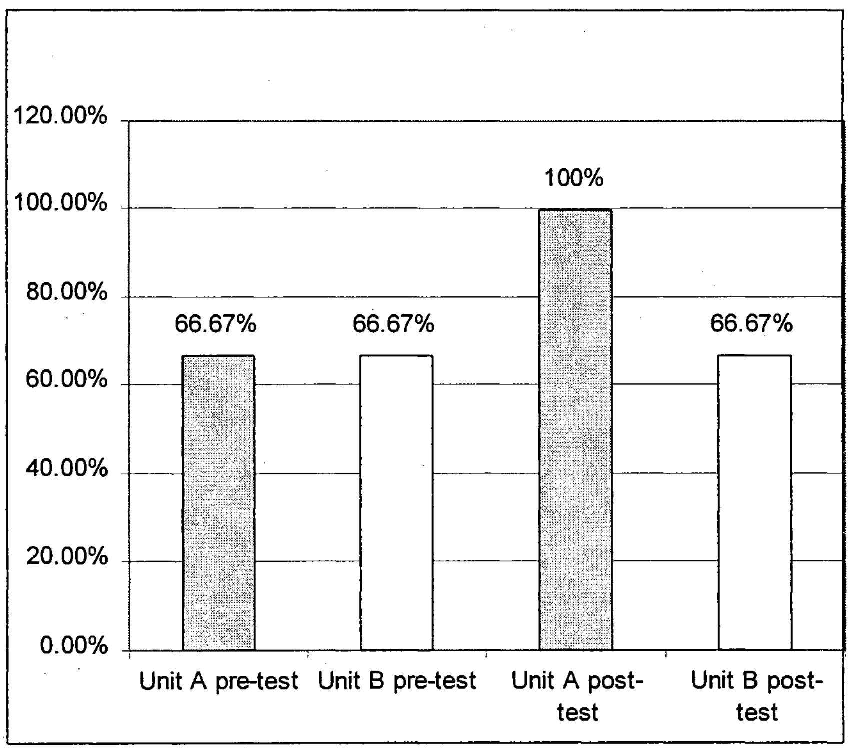


Figure 9. S3E Compliance Category F – Training.

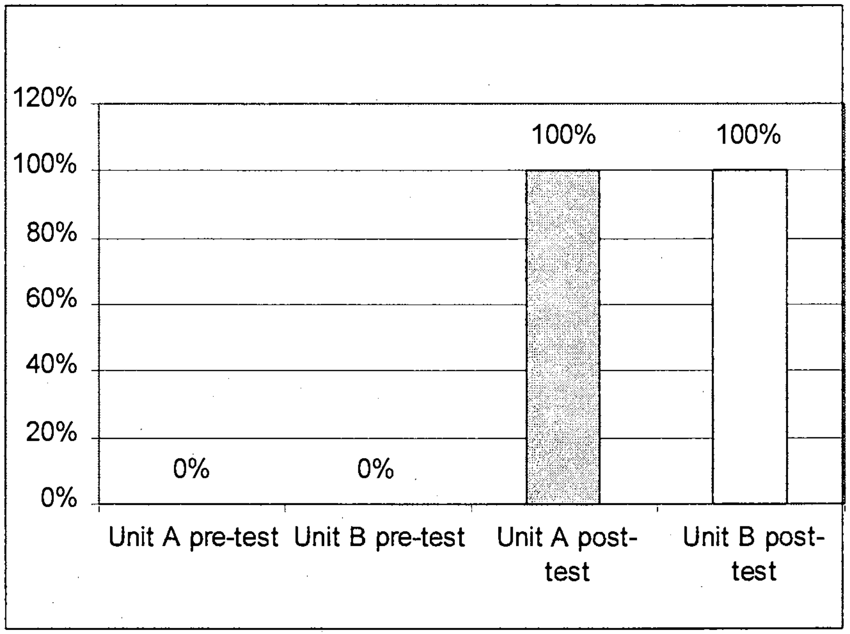


Figure 10. S3E Compliance Category G – Shelf Life.

The currency and cross-checking of maintenance procedures plays a critical role in aircraft airworthiness. The treated Unit A was able to increase its level of compliance to 85.71% while the control Unit B remained static (Figure 11).

Having a full and current technical manual library available is an important safety concern for aircraft airworthiness. The treated Unit A was again able to achieve the 100% level of safety compliance while the control Unit B remained static at the 25% level (Figure 12).

Without proper tool calibration, aircraft safety is compromised. Both units were able to increase their level of compliance with the treated Unit A having the greater improvement (Figure 13).

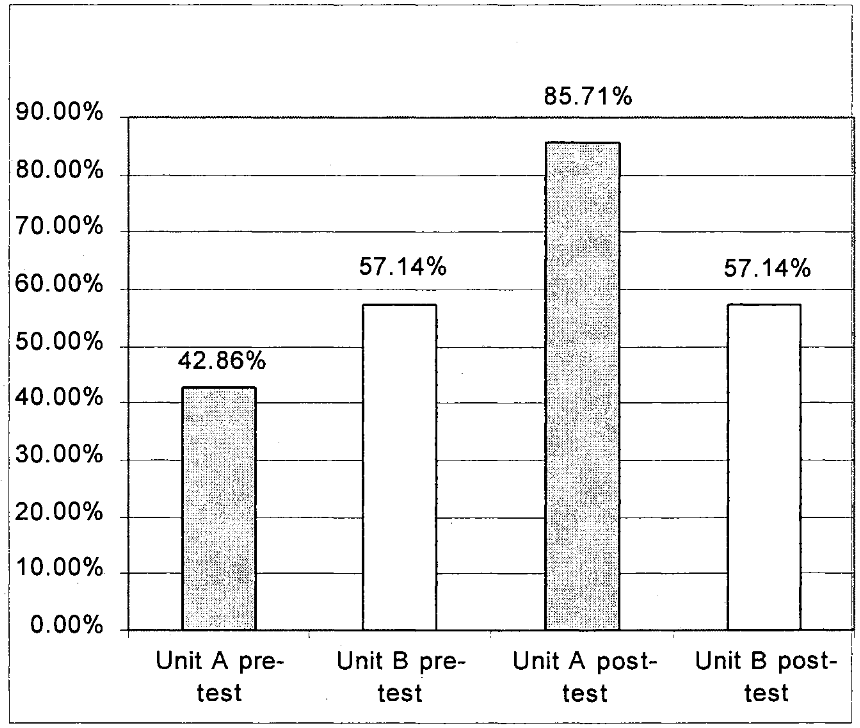


Figure 11. S3E Compliance Category H – General Maintenance Procedures.

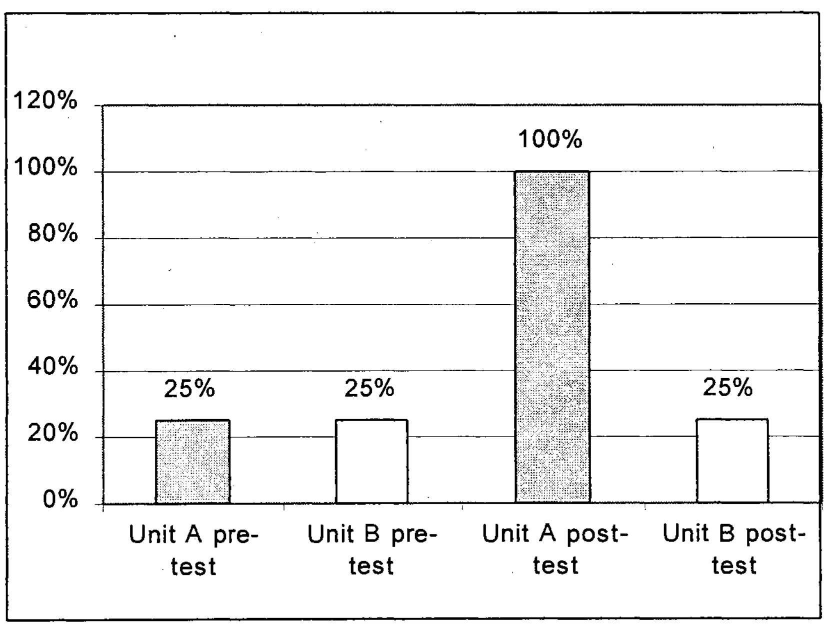


Figure 12. S3E Compliance Category I – Manuals.

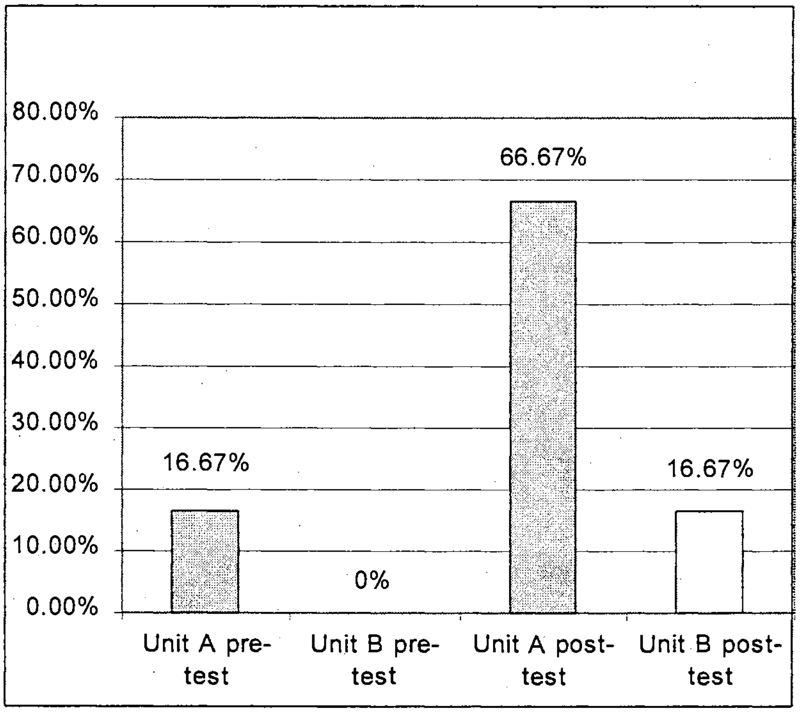


Figure 13. S3E Compliance Category J – Calibrated Tooling.

Component accountability is a fundamental part of airworthiness safety. The treated Unit A was able to dramatically increase its level of compliance to 87.5%. Mere exposure to the audit allowed the control Unit B to make small improvements from 50% to 62.5% (Figure 14).

Surveillance and inspection play an important role in maintaining airworthiness. Both units pre-tested at the same level but again, the treated Unit A experienced a significant increase in the level of safety compliance (Figure 15).

Improper weight and balance of an aircraft can lead to serious difficulty, even total aircraft loss. The control Unit B made no gains in compliance while the treated Unit A became fully compliant (Figure 16).

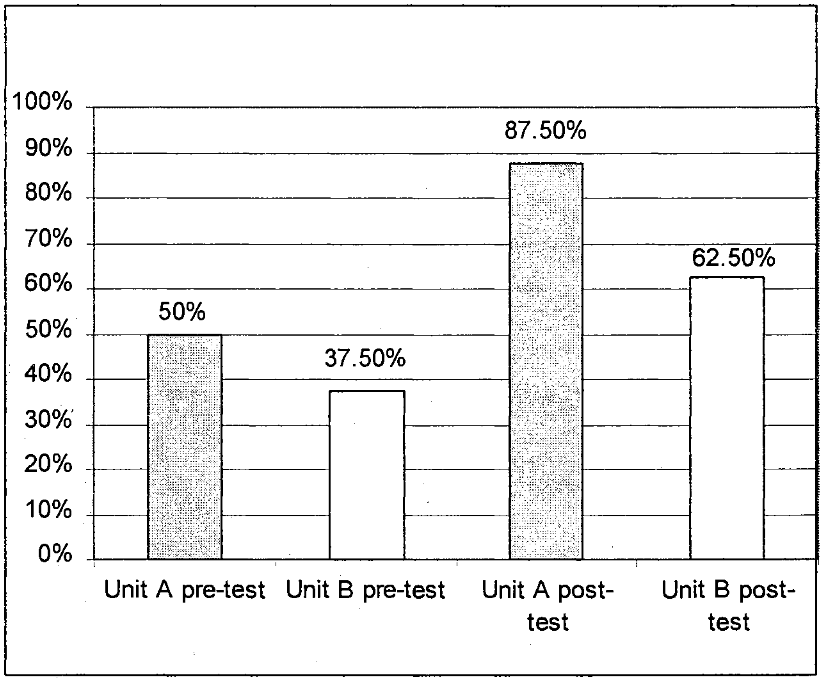


Figure 14. S3E Compliance Category K – Parts Control/Handling.

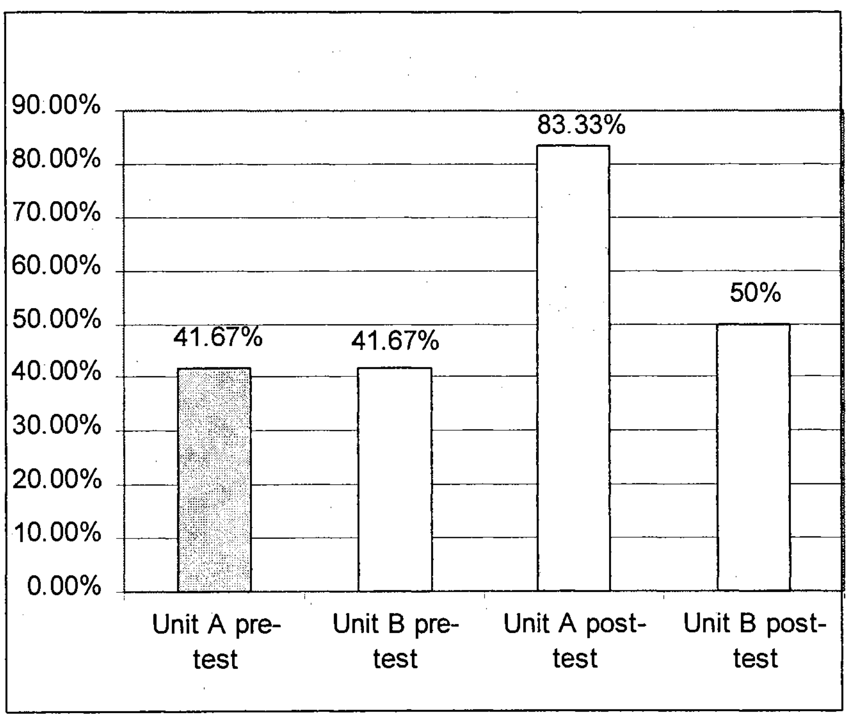


Figure 15. S3E Compliance Category L – Quality Assurance.

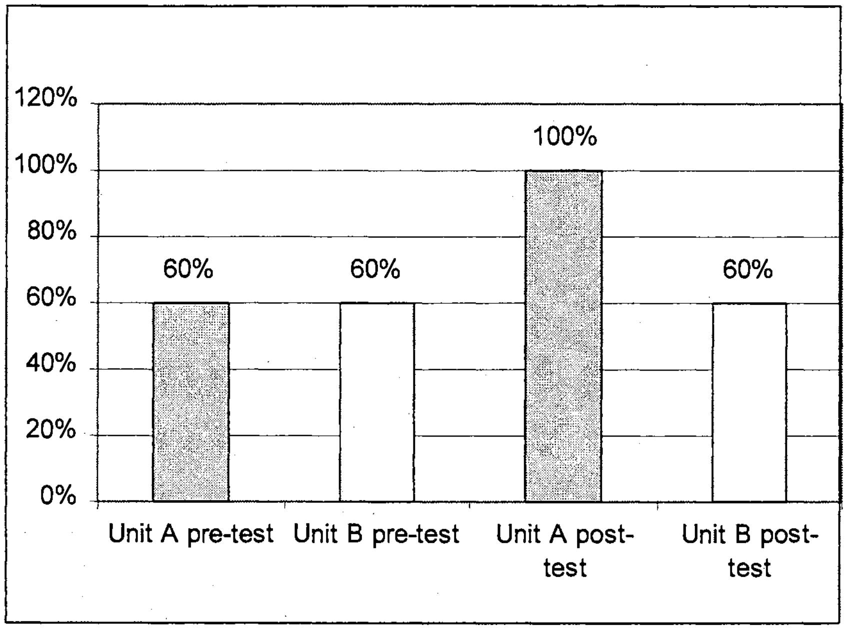


Figure 16. S3E Compliance Category M – Weight and Balance.

Non-destructive test techniques allow for the early detection of flaws in the basic aircraft and associated components. The treated Unit A experienced an increase in safety compliance to 83.33%. The control Unit B did improve to 50% overall safety compliance level solely based upon the audit feedback (Figure 17).

The general tracking of day-to-day maintenance issues plays an important role in airworthiness. Both units began at the same level and then increased scores for the post-test; however, the treated Unit A reached an almost perfect 91.67% level of safety compliance compared to the control Unit B 58.33% (Figure 18).

The tool room is one of the most utilized facilities within the maintenance complex and is therefore important in the airworthiness process. The treated Unit A jumped 44.45% in its compliance level while the control Unit B increased by only 11.12% (Figure 19).

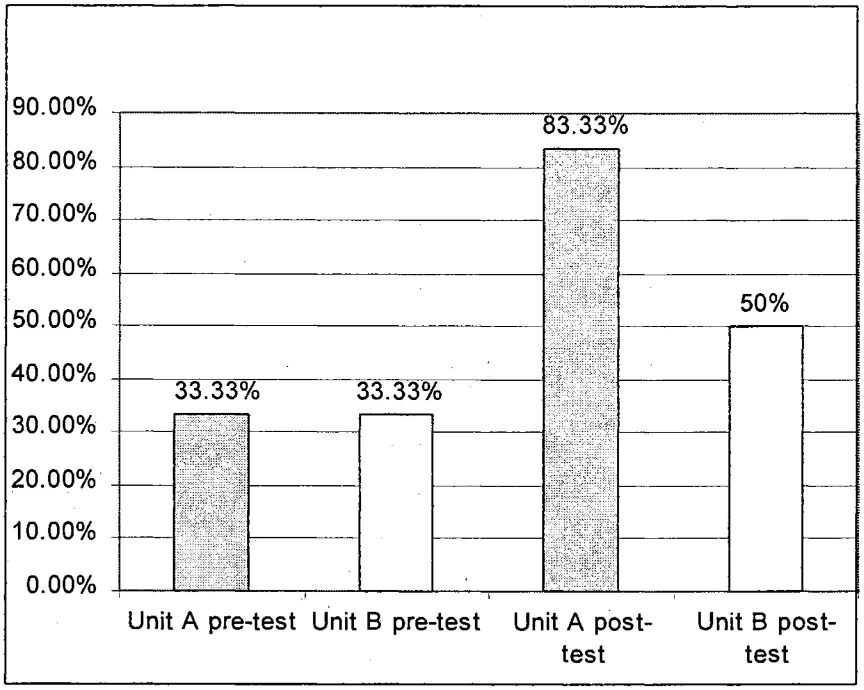


Figure 17. S3E Compliance Category N – N.D.T. Program.

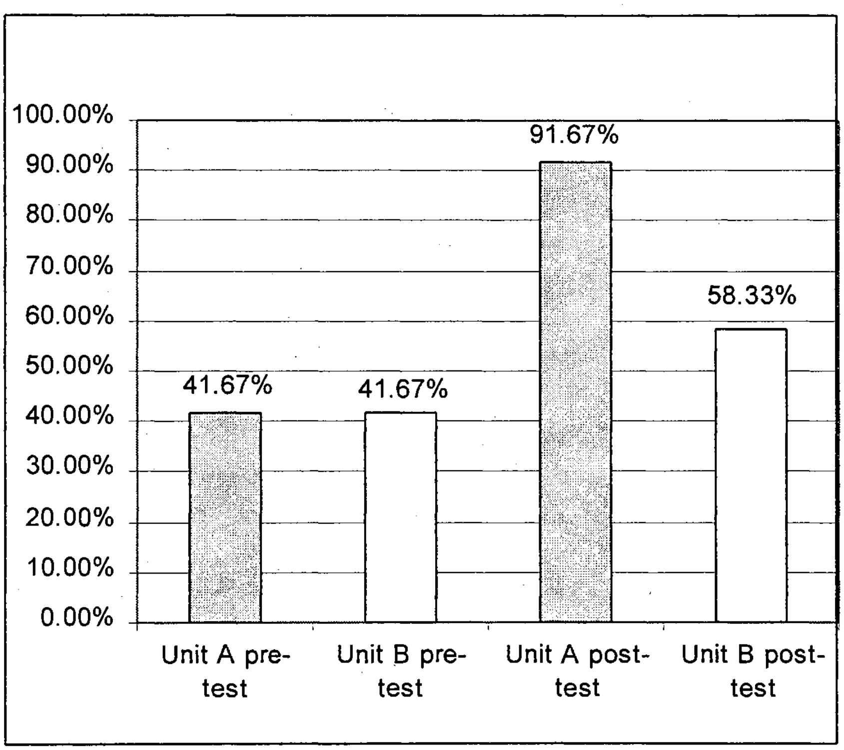


Figure 18. S3E Compliance Category O – Maintenance Control.

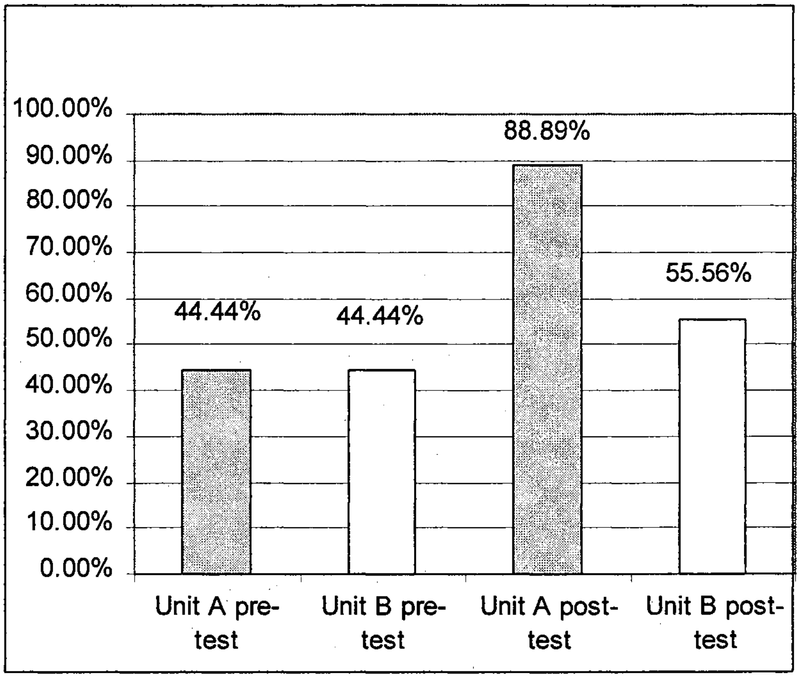


Figure 19. S3E Compliance Category P – Tool Room.

Even with the proper tools, out of date technical data or calibrations can present a serious threat to safety and thus to airworthiness. Neither unit tested well in the pre-test audit. The treated Unit A was able to significantly increase its level of compliance while the control Unit B increased only marginally (Figure 20).

Maintaining compliance with engineering directives is imperative in aircraft airworthiness. The control Unit B showed no improvement while the treated Unit A became fully compliant to the safety criteria (Figure 21).

Proper functional configuration is also critical to airworthiness. Again, the control Unit B showed no improvement while the treated Unit A became fully compliant to safety standards (Figure 22).

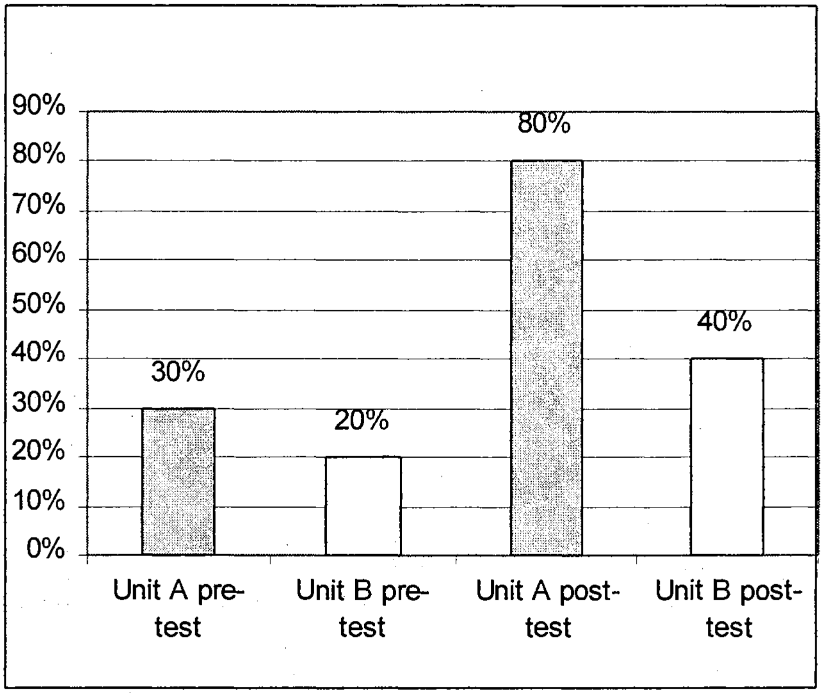


Figure 20. S3E Compliance Category Q – Tech Publications/Tool Calibration.

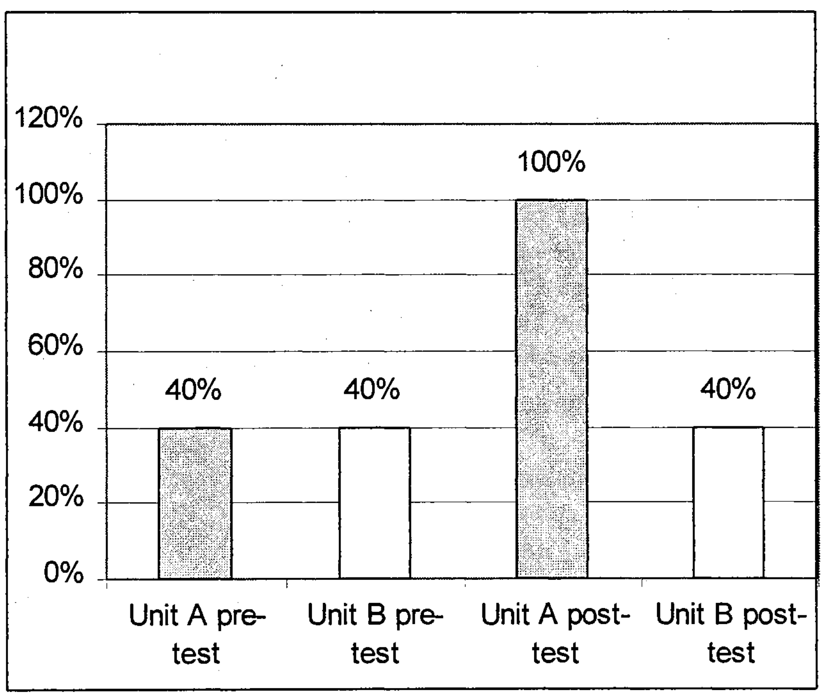


Figure 21. S3E Compliance Category R – Engineering.

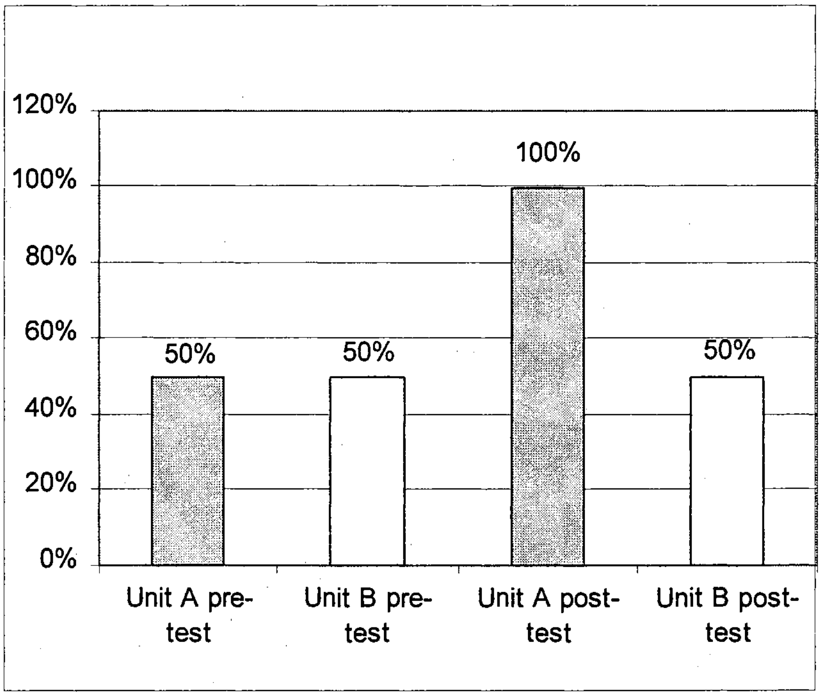


Figure 22. S3E Compliance Category S – Production Control Records.

Sortie generation is the end product for airworthiness (Figure 23). The control Unit B pre-tested much higher than the treated Unit A however, armed with the S3E criteria, Unit A was able to achieve a much higher level of compliance than Unit B in the post-test.

The study's analysis of these results using the Chi Squared technique is forthcoming; however, both the percentages tables and the plots tell a dramatic story. Note that both Unit A and Unit B overall score within a little more than one percentage point (1.62% to be exact) of each other in the pre-test, that is 41.94% compliance for Unit A and 40.32% for Unit B. This is covering twenty different categories and 124 separate sub-categories. This in and of itself is not surprising since they are both military units albeit probably from different branches within DOD and are caring for the airworthiness of the same basic airframe. Both have a roughly equal level of compliance to S3E.

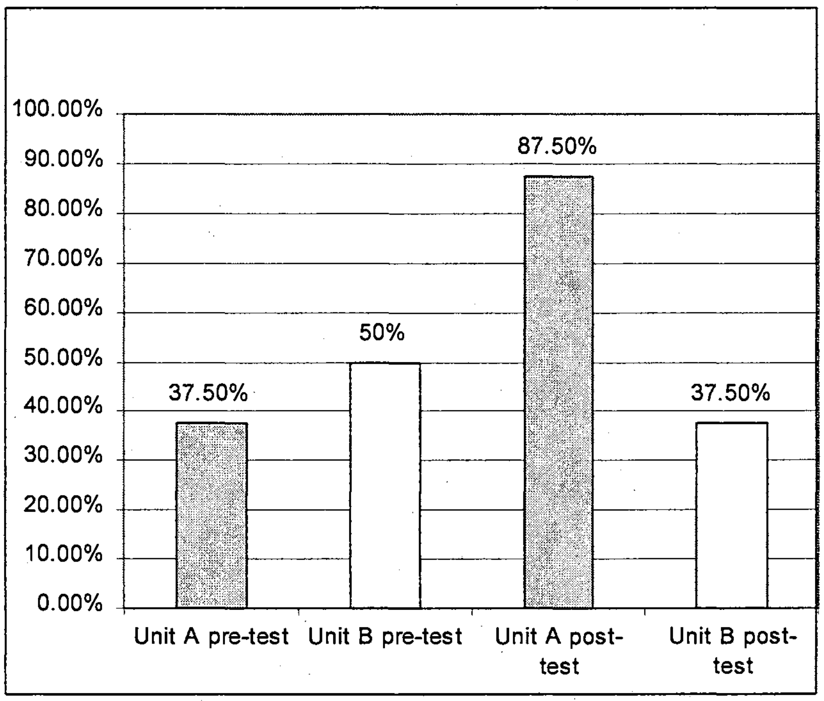


Figure 23. S3E Compliance Category T – Production Control/Records/Planning.

What is surprising is the great disparity in the post-test. After only 87 days worth of work, Unit A is now 87.9% compliant and Unit B improves to 51.61% for a difference of 36.29%! This is dramatic yet reasonable when you take into account the professionalism and desire for perfection that is the military culture. Once having been exposed to S3E, Unit A was able to rather rapidly enact changes that place them in compliance to S3E. Even Unit B was able to improve to an 11.29% compliance score with the mere exposure to the audit itself.

As can be seen in the plots, every category resulted in a very much higher score for the treated military unit while the control unit scored only marginally higher and in fewer categories. How significant these changes were are analyzed and discussed later in this chapter. Certainly, intuitive insight would indicate that the treatment had dramatic positive effects on compliance with S3E.

Some ad hoc comments were accepted as collateral qualitative data. There are a few clues in those remarks that could serve as starting points to further research. The audit was accepted as professionally helpful techniques to improve the overall airworthiness mission of the units. There were very many comments indicating that the guidance had "good ideas" in it to assist the unit. Some frustration was expressed on audit sub-elements that were clearly outside the sphere on influence of the unit. Chief among these was the manning issue which neither unit complied with before or after the time period of this study expired. Both Unit A and Unit B broached compliance using military ingenuity and common sense approaches which assisted them in remedying so many of the non-compliant sub-elements. Unit A had the advantage due to the treatment. Unit B spent time trying to "wing it" as one commentary opined. Change was made easier by the military "can do" attitude and lack of union, monetary or other such factors present outside the military. At least one unit expressed concern about the fact that some tasks presently performed by the uniformed members were due to transition to civilian contractors. One related comment expressed a desire that the contract includes S3E compliance from the contractor.

Chi Squared Analysis

To calculate the chi squared figures, the categories were first grouped by the five major concerns under the S3E model as shown in Table I, Chapter III of this study. The results of the chi square analysis are shown in Tables XXIII and XXIV.

TABLE XXIII

RESULTS OF CHI SQUARED ANALYSIS
UNIT A

S3E Groupings	# of subs	*fe*	*df*	X^2 calculated	X^2 sig p=.05	Accept Hypothesis	X^2 sig p=.01	Accept Hypothesis
S3E Engineering and Safety Practices	25	11	1	13.19	3.841	YES	6.635	YES
S3E Parts, Hardware & Instruments	26	9	1	18.89	3.841	YES	6.635	YES
Approved S3E Facility	22	9	1	12.11	3.841	YES	6.635	YES
S3E Engineering and Tracking Documentation	21	9	1	9.33	3.841	YES	6.635	YES
S3E Aircraft Production	30	13	1	15.08	3.841	YES	6.635	YES

The results indicate that with a confidence level of 95%, the changes in Unit A are significant enough to be not by chance. Unexpectedly, for all groupings of S3E, the confidence level of accepting the study's hypothesis was 99%.

Accordingly, for Unit B, the changes do not meet the chi squared level of significance. This holds true for all of the major S3E groupings for 95% as well as for 99% confidence levels.

TABLE XXIV

RESULTS OF CHI SQUARED ANALYSIS
UNIT B

S3E Groupings	# of subs	*fe*	*df*	X^2 calculated	X^2 sig p=.05	Accept Hypothesis	X^2 sig p=.01	Accept Hypothesis
S3E Engineering and Safety Practices	25	11	1	0.45	3.841	NO	2.706	NO
S3E Parts, Hardware & Instruments	26	9	1	1.89	3.841	NO	2.706	NO
Approved S3E Facility	22	9	1	0.032	3.841	NO	2.706	NO
S3E Engineering and Tracking Documentation	21	9	1	0.44	3.841	NO	2.706	NO
S3E Aircraft Production	30	13	1	0.38	3.841	NO	2.706	NO

Again, the overall results of the research questions, the graphical analysis and the chi squared analysis support the study's hypothesis that exposure to S3E criteria leads to an increase in airworthiness compliance. Indeed, as seen with the results from the control Unit B, even alluding to S3E criteria by exposure to the audit itself assisted the control unit to a higher level of compliance to airworthiness criteria even though the improvement in safety compliance did not meet the chi squared test for significance.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

This study sought to answer the three primary questions that comprise the problem statement. The primary question was to determine if military (DOD) units that operate military derivative aircraft maintaining the vehicles airworthiness are using standards that achieve an equivalent level of safety with their commercial counterparts? The second question asked was, what instrument could be used to determine whether DOD airworthiness was at an equivalent level of safety with DOT as well as assess their level of compliance to the original certified airworthiness standards? The third question asked was if once armed with an accurate compliance assessment, could the units then target appropriate corrective measures using a single standard of engineering safety (S3E) for airworthiness?

The result of the primary question as embodied in the pre-tests, was striking. Using this S3E certified and approved follow-on design criteria as the basis from which to build, train, document, house and equip appropriately so as to maintain fleet airworthiness, *neither* subject unit completely met the S3E criteria for safety. In fact, in the pre-test the Units only scored 41.94% and 40.32% compliance with accepted commercial airworthiness safety criteria.

Bear in mind again that these DOD military derivative aircraft are, in essence, commercial aircraft used by the military. The single standard of engineering safety (S3E) is this same criterion for airworthiness used by the FAA to ensure these same commercial aircraft are maintained by the airlines in a manner that complies with all airworthiness criteria. With these preliminary results, if the units were commercial airlines instead of military units, the FAA would be compelled to ground them thus suspending all flight operations.

Again, the second question of the problem statement was, what instrument could be used to determine whether DOD airworthiness was at an equivalent level of safety with DOT as well as assess their level of compliance to the original certified airworthiness standards. The study used a long-standing audit instrument utilized by the FAA for these same purposes but specially adapted for the DOD. The results of this S3E audit for this question indicated that this was effective as a tool to be used to assess their level of compliance of the subject units with S3E criteria.

The third question of the problem statement asked if once armed with an accurate compliance assessment, could the units then target appropriate corrective measures using a single standard of engineering safety for airworthiness. For this question the results indicated that armed with an accurate compliance assessment, the units could indeed then target appropriate corrective measures using a single standard of engineering safety for airworthiness. In fact, even the control unit increased its compliance score in many areas having been only exposed to the audit instrument itself.

Discussion of Research Findings

The hypothesis states that there is a significant difference in airworthiness compliance with the original commercial design standards in DOD units operating military derivative aircraft that receive instruction in the single standard of engineering safety (S3E) and those who do not. In order to fully understand the hypothesis, the twenty research questions were proposed. These questions emanated from the FAA regulations and served to satisfy five safety areas of concern regarding the airworthiness of aircraft. These major areas are engineering and safety practices; approved parts, hardware and instruments; approved maintenance facilities; engineering and tracking documentation; and aircraft production.

The research questions were converted into categories to be audited. Most of the categories had multiple sub-elements to fully explore the research question from which the category emanated. These categories were:

A. General Condition/Appearance

B. Fire Protection

C. Ramp

D. First Aid/Safety

E. Manning

F. Training

G. Shelf Life

H. General Maintenance Procedures

I. Manuals

J. Calibrated Tooling

K. Parts Control/Handing

L. Quality Assurance

M. Weight and Balance

N. Non-Destructive Testing Program

O. Maintenance Control

P. Tool Room

Q. Technical Publications/Tool Calibration

R. Engineering

S. Production Control/Records (Engineering)

T. Production Control/Records/Planning (Sorties)

In all but Category E – Manning; the treated unit experienced an increase in its level of compliance to commercial safety standards as defined in S3E. This is reasonable since unit manning is the only area that is generally outside the immediate control of the unit itself. Using the chi squared test for significance, all of the improvements for the treated unit met the study's p=.05 level as well as unexpectedly the p=.01 level.

For the control group the following categories experienced no change:

B. Fire Protection

C. Ramp

E. Manning

F. Training

H. General Maintenance Procedures

I. Manuals

M. Weight and Balance

N. Non-Destructive Testing Program

R. Engineering

S. Production Control/Records (Engineering)

Category T – Production Control/Records/Planning (Sorties), actually experienced a lower level of compliance in the post-audit. Since the DOD units were not available for direct examination, the reason for the decrease is unknown. The control group did however experience a marginal increase in the following categories:

A. General Condition/Appearance

D. First Aid/Safety

G. Shelf Life

J. Calibrated Tooling

K. Parts Control/Handing

L. Quality Assurance

N. Non-Destructive Testing Program

O. Maintenance Control

P. Tool Room

Q. Technical Publications/Tool Calibration

Experimental Validity

Results of the control group indicated that the internal validity issue of "pretest sensitization" had an effect on the results. Indirect feedback indicated that the improvement in the control group was due, in part, to exposure to the audit itself. Although they were not left in possession of the audit nor were given any treatment, obviously, they were able to glean at least *some* knowledge of areas that required improvement. It is likely that the control unit attempted to correct deficiencies identified in the pre-test. However, as expected, without access to the S3E criteria or the subject matter experts, the improvements did not meet the chi squared criteria for significance either at 99% or even 95% level. As a result, this investigator postulates that the effects of pretest sensitization were minimal.

Concerning the related external validity issue of "pretest-treatment interaction" whereby the results are only generalizable to other pre-tested groups, the following observations are made. There were no human subjects and the audit test was very technical in nature. The treatment was also very technical in nature. Military inspectors from *outside* the units administered the tests. The two units scored remarkably the same in the pre-test and significantly differently in the post-test. As a result, this investigator postulates that the effect of pretest-treatment interaction were minimal.

Two reactive arrangement factors were of particular concern to this investigator. They are the Hawthorne effect and the John Henry effect. Neither of these applied in this study for the following reasons. First, neither the auditors nor the unit members knew that they were participating in a study. Secondly, the audit was one of pure facts on the state of facilities, tooling, documentation etc., not individual human subjects therefore feelings and attitudes were not an issue. Thirdly, the units were not able to prepare for the pre-test since it was conducted without notice to the maintenance shop chiefs and the audited areas were not disclosed in advance. Fourth, the units were unaware that any other units had volunteered to be audited. They were also unaware that the results of the tests would be compared to any other unit. Indeed, the feedback was that the units were not only in different locations but in different branches of the DOD as well.

Conclusions

The overall results clearly support the hypothesis in that the treated unit had very significant improvements in its compliance to the fleet airworthiness standards. Accordingly, the control unit, while showing some improvement, did not significantly increase its compliance to airworthiness standards. The treated unit went from a compliance rate of 41.94% to one of 87.9%. The results met the chi squared test for significance at the originally planned 95% level as well as the 99% level.

What is most important however was the fact that the S3E treated unit made great strides in one aspect of maintaining engineering airworthiness of their fleet of aircraft. Compared to *both* military as well as commercial units, that particular organization's airworthiness standards are 87.9% compliant. It is reasonable to postulate that this incremental change toward maintaining true engineering airworthiness compliance with the commercial side of the aircraft fleet will greatly enhance safety. Safety is enhanced because the aircraft was originally designed and built to commercial airworthiness standards as enforced by the FAA and the unit is now closer to compliance with these standards. In addition, the aircraft is maintained in that airworthy condition through the combined engineering efforts of the original aircraft manufacturer as well as the user airlines that put millions of flight hours per year on their combined fleets.

Recommendations

- This is a first of its kind study in this field and as such further research should be performed.
- Future S3E ventures should cast a much broader net to include very many units.
- Future S3E experiments should include the operational or aircrew portion of the airworthiness of aircraft.
- DOD should ask for feedback on how to better tailor S3E for each unit and mission.
- DOD should enact the S3E changes, not as a directive or order but rather as a method to better perform the mission. Mission performance appeared to be a great motivator in the military culture.
- DOD should eventually provide feedback to the commercial sector on airworthiness matters.

The study spoke of the nature of engineering safety and the importance of evolving a single standard of airworthiness for aircraft regardless of the end user.

Certainly, staying true to the original engineering design and following fleet engineering improvements will ensure aircraft airworthiness.

The DOD wartime mission dictates that their aircraft fly safely, reliably and consistently. S3E will enhance that wartime mission. If by setting up S3E system of tracking and response to engineering safety discoveries in the commercial sector, the military can glean knowledge and techniques to better maintain the airworthiness of their commercially based "weapon systems," then DOD flight safety is enriched and the mission readiness of the aircraft fleet should increase accordingly.

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APPENDIXES

APPENDIX A

SURVEY/AUDIT INSTRUMENT

The Military Aircraft
Engineering / Maintenance

Completing the Internal Audit checklist:

1. The audit checklist will indicate, but not limit, areas or subjects to be checked during the audit.

2. Check-off areas provided are identified as "Y" for satisfactory findings, "N" for unsatisfactory findings, and "N/A" for items which are not applicable.

3. Each "N" circled may require comment.

4. If the audit was not performed on a particular required item, enter "deferred" in the check-off area and state the reason for deferring the item in comments.

5. The primary checklist will be utilized for Unit maintenance facilities, shops, etc.

6. The Supplemental Checklists detail specific audit focus in the Organizations listed.

7. Outside repair facilities will be audited using current S3E standards and checklists.

Completing the Audit Log:

1. When beginning an audit, the Auditor will begin an entry in the Audit Log.

2. Audit numbers will be assigned sequentially beginning with the year, a dash, and the next number in sequence. For example, the first audit in 2000 would be numbered 00-1.

3. In the Subject block, indicate the area of the audit i.e., Records, Maintenance Control, Acme Repair Station, etc.

4. The remaining blocks will be utilized to indicate dates of completion of each phase of the audit process. The person completing each block will date and sign his/her initials to indicate they have completed that phase.

Completing the Significant Finding Report:

The Unit Commander or Director of Quality Assurance will initiate the Significant Finding Report, (refer to the facsimile of the form at the end of this Section). Items 1 through 7 will be completed as follows:

1. Address to the Officer in Charge responsible for facility audited, with a copy forwarded to the Director.
2. Audit number as recorded on Audit Log.
3. Date on which the audit occurred.
4. Specific Manual reference addressing finding, including section and/or paragraph number.
5. Finding as written on Audit Report, . Additional comments by the Director of Quality Assurance may be included for clarification.
6. Date on which the response is due. This will generally be ten (10) calendar days.
7. Director of Quality Assurance signature.

Management responsible for area audited will complete items 8 through 13 as follows:

8. Officer in Charge's explanation of underlying cause of system problem.
9. Direct action to correct discrepancy.
10. System corrective action implemented.
11. Date on which all corrective action is scheduled for completion and finding can be inspected for satisfactory resolution.
12. Signature of head of Organization or facility.
13. Date response was completed.

Quality Assurance will verify corrective action and close the Significant Finding Report. If the corrective action is unsatisfactory, a new Significant Finding Report will be initiated

Internal Audit Checklist: General Audit Areas

A.	General Condition/Appearance			
1.	Facilities, lighting, and ventilation adequate?	Y	N	N/A
2.	Work areas clean and organized?	Y	N	N/A
3.	Fluid dispensing containers/servicing units properly marked, clean, and stowed with lines capped?	Y	N	N/A
4.	Are work stands and lift trucks clean and serviceable? Are safety rails in place?	Y	N	N/A
5.	Ladders clean and in safe condition?	Y	N	N/A
6.	Is GSE serviceable, clean, power cables and chocks properly stored?	Y	N	N/A
7.	Aircraft in hangar grounded?	Y	N	N/A
8.	Parts removed from aircraft to FOM properly stored?	Y	N	N/A
9.	Correct number of wing walkers utilized during towing?	Y	N	N/A

B.	Fire Protection			
1.	Fire extinguisher accessible, inspection tags current?	Y	N	N/A
2.	Emergency access numbers prominently displayed?	Y	N	N/A
3.	Fire lanes and door areas clear of obstruction?	Y	N	N/A
4.	Fire proof cans utilized?	Y	N	N/A
5	Adequate fire extinguisher positioned on ramp?	Y	N	N/A

Internal Audit Checklist: General Audit Areas (continued)

C.	Ramp			
1	Ramp area clean, is FOD potential eliminated?	Y	N	N/A
2.	Adequate positioning aids and grounding points?	Y	N	N/A
3.	During engine run-up, are there properly trained personnel in the cockpit, fire guards in place, ground equipment removed from proximity of the A/C?	Y	N	N/A
4.	A/C on ramp have gear pins, covers installed as required?	Y	N	N/A

D.	First Aid/Safety			
1.	First aid kits available and of proper size in relation to number of personnel assigned?	Y	N	N/A
2.	Are adequate eye-wash stations available?	Y	N	N/A
3.	Adequate number of personnel trained in First-Aid, CPR?	Y	N	N/A

E.	Manning			
1.	Are adequate number of personnel available to accomplish assigned tasks?	Y	N	N/A

Internal Audit Checklist: General Audit Areas (continued)

F.	Training			
1.	Do personnel receive minimum training requirements?	Y	N	N/A
2.	Individual training records current and retained indefinitely?	Y	N	N/A
3.	Is OJT documented?	Y	N	N/A

G.	Shelf Life			
1.	Is a monthly shelf life inspection performed?	Y	N	N/A

H.	General Maintenance Procedures			
1.	All forms for the accomplishment of maintenance have form numbers assigned?	Y	N	N/A
2.	Shift turnover log utilized and retained for at least 30 days?	Y	N	N/A
3.	Maintenance Work Orders retained as required?	Y	N	N/A
4.	Post Maintenance Walk-around used and retained?	Y	N	N/A
5.	GSE checklists filled out daily?	Y	N	N/A
6.	Read and initial sheets for MX Memos and Tech Notices?	Y	N	N/A
7.	Are mechanics using manuals or work cards at work site?	Y	N	N/A

Internal Audit Checklist: General Audit Areas (continued)

I.	Manuals			
1.	Does manual inventory agree with Tech Pubs Master Listing?	Y	N	N/A
2.	Manuals sampled current?	Y	N	N/A
3.	Manuals in serviceable condition no tom or missing pages?	Y	N	N/A
4.	Maintenance Assurance Manual available for use?	Y	N	N/A

J.	Calibrated Tooling			
1.	Tools and test equipment in use listed on Tech Pubs Master listing?	Y	N	N/A
2.	All tools sampled, within calibration?	Y	N	N/A
3.	Are calibrated tools identified with a Calibration Placard?	Y	N	N/A
4.	Are tools stored in an orderly manner?	Y	N	N/A
5.	Calibrations traceable to National Institute of Standards and Technology?	Y	N	N/A
6.	Personal tools identified and calibrated?	Y	N	N/A

K.	Parts Control/Handing			
1.	Are parts and components property identified?	Y	N	N/A
2.	Property stored?	Y	N	N/A
3.	Are serviceable aircraft rotable components bagged and lines and fittings capped?	Y	N	N/A

4.	Serviceable and unserviceable parts segregated?	Y	N	N/A
5.	Suitable segregation of and storage of hazardous materials such as flammable, lubricants, pressure vessels, oxygen, batteries, etc.?	Y	N	N/A
6.	Quarantine area property designated and no "Q" parts retained over 72 hours?	Y	N	N/A
7.	Shelf life limits established and controlled?	Y	N	N/A
8	Adequate spare parts to support complexity of operation?	Y	N	N/A

L.	Quality Assurance			
1.	Mechanical Reliability Reports generated in a timely manner and property logged?	Y	N	N/A
2.	Is list of qualified/authorized Designated Inspectors current?	Y	N	N/A
3.	Surveillance Program and Authorized Vendor Listing on file and current?	Y	N	N/A
4.	Operations Specifications retained in Director of QA Office, is current, and signed by appropriate personnel designated by Unit and the DOD?	Y	N	N/A
5.	Continuing Analysis Report Forms on file?	Y	N	N/A
6.	Are reports Periodically reviewed for recurring trends?	Y	N	N/A
7.	Are Parts Received and Inspected Reports being reviewed and corrective action taken to correct discrepancies?	Y	N	N/A
8.	Are Inspectors property trained and certified?	Y	N	N/A

9.	Are inspection write ups being identified as S3E when required?	Y	N	N/A
10.	Are all parts and materials received from outside sources for use or installation on aircraft subject to receiving inspection?	Y	N	N/A
11.	Component Tear-down Reports being sent to Reliability Analyst?	Y	N	N/A
12.	AD Logs maintained and current?	Y	N	N/A

M.	Weight and Balance			
1.	Scales calibrated Yearly?	Y	N	N/A
2.	Are weight and balance changes entered in AFM using the appropriate WB tables and forms?	Y	N	N/A
3.	Is most current weight change in aircraft permanent record?	Y	N	N/A
4.	Are the last and the next weigh dates in the Time Control System?	Y	N	N/A
5.	Does W&B File in MX Control/Dispatch agree with Records file?	Y	N	N/A

N.	N.D.T. Program			
1.	Are dosimeters calibrated annually?	Y	N	N/A
2.	Are any Radiographer film badges processed quarterly and results maintained on file?	Y	N	N/A
3.	Radiation survey instruments calibrated at 3 month intervals?	Y	N	N/A

4.	Posting signs "Caution - Radiation Area" property stored and available for use?	Y	N	N/A
5.	Copy of applicable radiation regulations available?	Y	N	N/A
6.	Registration of radiation machine current?	Y	N	N/A

O.	Maintenance Control			
1.	Ferry Flight maintained and current?	Y	N	N/A
2.	MEL Extension Request filed for 6 months?	Y	N	N/A
3.	MEL Parts Info Request filed for 6 months?	Y	N	N/A
4.	Enroute Rescheduled Maintenance Items filed for 60 days?	Y	N	N/A
5.	Parts info Request filed for 6 months?	Y	N	N/A
6.	Aircraft Dent and Scratch Record maintained?	Y	N	N/A
7.	Copies of Technical Notice on file and all Controllers have -initialed?	Y	N	N/A
8.	Are Controllers property trained and certificated?	Y	N	N/A
9.	Is Reliability notified of repetitive trends?	Y	N	N/A
10.	Is a shift turnover log being property used?	Y	N	N/A
11.	Are incident reporting and notification procedures in place?	Y	N	N/A
12.	Are outstation maintenance activities being recorded?	Y	N	N/A

Internal Audit Checklist: General Audit Areas (continued)

P.	Tool Room			
1.	Is there a person responsible for the tool room?	Y	N	N/A
2.	In the event of that person's absence, are there other personnel knowledgeable in tool room procedures?	Y	N	N/A
3.	Inventory Record of all serialized tools maintained?	Y	N	N/A
4.	Follow-up action in effect for tools not returned?	Y	N	N/A
5.	Calibrated Placards installed and Calibration of tooling is current?	Y	N	N/A
6.	Are tools property identified and stored?	Y	N	N/A
7.	Are unserviceable tools segregated from serviceable?	Y	N	N/A
8.	Is calibration traceable to NIST?	Y	N	N/A
9.	Is the tool room secure?	Y	N	N/A

Q.	Tech Publications/Tool Calibration			
1.	Monthly Tool Calibration report issued to shops and employees owning calibrated tools?	Y	N	N/A
2.	Follow-up of overdue tool list for planned action and to ensure out of service tools are not being used?	Y	N	N/A
3.	Spare technical manuals are of current revision status?	Y	N	N/A
4.	Inventory index cards reflect current status?	Y	N	N/A

5.	Master List reflects current status?	Y	N	N/A
6.	Maintenance Form Master List reflects current status?	Y	N	N/A
7.	Signature roster current?	Y	N	N/A
8.	Files have timely follow-up action?	Y	N	N/A
9.	Service Bulletins tracked throughout review process and log kept?	Y	N	N/A
10.	Are station/shop inventories being performed?	Y	N	N/A

R.	Engineering			
1.	Are Service Bulletin Committee meetings held per schedule?	Y	N	N/A
2.	Original Engineering Orders maintained on file in Engineering with copy in project file after approval?	Y	N	N/A
3.	Completed Engineering Research Information filed for a minimum of 24 months?	Y	N	N/A
4.	Copies of Tech. Notices retained?	Y	N	N/A
5.	Fleet Campaign Directives retained In Master File?	Y	N	N/A

S.	Production Control/Records			
1.	Do Production Planners verify all E.O.s issued are current prior to issuing work package?	Y	N	N/A
2.	Are results of inspection findings, reliability reports, and Mechanical interruption summaries reviewed for possible inspection program changes?	Y	N	N/A

3.	Is Compliance Order Log complete and up to date?	Y	N	N/A
4.	Are ADs being logged on the Index?	Y	N	N/A
5.	Do all aircraft flex hose sampled comply with specified hours?	Y	N	N/A
6.	Are working copies of Functional Configuration Documents (FCD) current?	Y	N	N/A

T.	Production Control/Records/Planning			
1.	Are the equivalent procedures specified in the Maintenance Control Manual, Chapter 21.1321 - 21.1325 (Master Rescheduled Maintenance Item Control-MRSI) being adhered to?	Y	N	N/A
2.	Are the items presently on MRSI acceptable to being there?	Y	N	N/A
3.	Review time-limited components to ensure that the appropriate service code is assigned in the computer tracking system.	Y	N	N/A
4.	Review of phased-event inspections to ensure that the inspection is being tracked at the appropriate interval.	Y	N	N/A
5.	Are records on file as equivalent specified in the Maintenance Control Manual, Chapter 21.2511 (Magnetic Compass Swings)?	Y	N	N/A
6.	Are records on file as equivalent specified in the Maintenance Control Manual, Chapter 21.2517 (Pitot Static Leak Checks)?	Y	N	N/A
7.	Are records on file as equivalent specified in the Maintenance Control Manual, Chapter 21.2577 (Transponder Checks)?	Y	N	N/A
8.	Review of in-house escalation intervals, if adjusted.	Y	N	N/A

Audit Log Form (Facsimile)

AUDIT NO.	SUBJECT	AUDIT DATE(S)	REPORT ISSUED	RESPONSE(S) RECEIVED	CLOSED OUT

Audit Report Form (Facsimile)

AUDIT REPORT
To: ______________________ Date: ______________
Type of Audit ______________________ Audit Number: __________
Military Facility: ______________________ Unit / Department: __________
Auditor: ______________________
Findings:
Corrective Action:
Preventive Action:
Commanders Signature Date
Address all replies to the Director of Quality Assurance within ten (10) days of this report.

Internal Audit Significant Finding Report Form (Facsimile)

INTERNAL AUDIT SIGNIFICANT FINDING REPORT

To: ______________________________ Audit No.: ____________
Audit Date:____________

Quality Assurance has found the following discrepancy during

____

Audit and is concerned that there is a system problem creating the discrepancy.

Manual ____________ Rev. ______________ Section/ Para. ________

Significant Finding: ____

____

____

____

Response Due Date __________ Director of Quality Assurance ______________
Inspector No. (if applicable)

Root Cause of Discrepancy:

____

____

____

Action Taken to Correct Discrepancy:

____

____

____

Action Taken to Prevent Recurrence:

____

____

____

Scheduled Completion Date ______________
Signature of Director__________________________ Date________________
Corrective Action Verified: Satisfactory _____ Unsatisfactory ______

Finding Closed: Yes _____ No _____

Quality Assurance Signature Date

APPENDIX B

INSTITUTIONAL REVIEW BOARD

APPROVAL FORM

Institutional Review Board (IRB) Approval Form submitted with a reply on November 16, 2000 (ED-01-48) indicating that there was no approval required since no human subjects were being tested.

2

VITA

Victor M. LaSaxon

Candidate for the Degree of

Doctor of Education

Thesis: THE EFFECT OF A SINGLE STANDARD OF ENGINEERING SAFETY (S3E) ON THE AIRWORTHINESS OF MILITARY DERIVATIVE AIRCRAFT

Major Field: Applied Educational Studies

Biographical:

Personal Data: Born in New York City, New York, March 15, 1953. Married the former M. Katherine Wright from Ocean Springs, Mississippi. Children: Rebecca, Jessica, John and Mary.

Education: Graduated from Cardinal Hayes High School, Bronx, New York , June 1970; received Bachelor of Science degree in General Engineering from the United States Air Force Academy, Colorado Springs, Colorado, June 1974; received Master of Science degree in Systems Management from the University of Southern California, May 1982; received Master of Science degree in Electrical Engineering from California State University, Fresno, California, May 1986. Completed the requirements for the Doctor of Education degree in Applied Educational Studies, specializing in Aviation and Space Education, at Oklahoma State University, Stillwater, Oklahoma, May 2001.

Professional Experience: United States Air Force Officer, 1974 - 1994. United States Air Force Pilot Training, Williams Air Force Base, Phoenix, Arizona, 1974 - 1975; Pilot then Instructor Pilot, WC-130 "Hurricane Hunters", 1974- 1979; Pilot then Instructor Pilot, F-101 Tactical Aerial Interceptor Training Squadron, Tyndall Air Force Base, Panama City, Florida, 1979-1982; Pilot then Instructor Pilot/ Flight Examiner and Test Pilot, F-4, T-38 and F-16, Test Operations, F-16 Test Force, Edwards Air Force Base, California, 1982- 1986; grounded due to Cancer, 1986; Flight

Test Manager, Computer Sciences Corporation, 1986-1989; Test Pilot for the Federal Aviation Administration then concurrent Air Force military recall to support a classified program, (awarded Command Pilot Astronaut Rating in 1991), 1989-1997; Test Pilot (FAA Delegated Engineering Representative) for Boeing Aerospace Operations supporting Air Force One, 1997-Present.

Professional Memberships: Society of Experimental Test Pilots, Associate Fellow; Order of Daedalians, Air Force Association.