# Flight Simulator Transfer of Training Study

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# Abstract

This purpose of this research was to investigate the training effectiveness of two different flight simulators, when student pilots enrolled in a university aviation degree course were trained to fly an instrument holding procedure. A PC-based simulator and an approved instrument simulator were used to teach two experimental groups to fly a Non-directional Beacon (NDB) holding instrument procedure. Their time to reach proficiency and their flight performance in a Cessna 172SP aircraft was compared to a control group that was trained solely in the aircraft. A Pre-flight Questionnaire was used to establish the participants' previous PC-based simulator experience and their current attitudes towards their use. Flight data was recorded to determine the participants' performance when flying the NDB holding pattern in the aircraft and the resulting flight times were used to determine the Percent Transfer and Transfer Effectiveness Ratio (TER) of the approved instrument simulator and the PC-based simulator. The Cost Benefit equation was used to determine the financial savings resulting from the use of these simulators. A Post-flight Questionnaire was used to determine the flight instructor's opinion of the participants' flight performance when flying the NDB holding pattern. The results of this study were unable to confirm significant differences between the two experimental simulator groups and the aircraft control group, however there were indications that prior training in a simulator reduced flight time to criterion and there was a small but positive Percent Transfer and TER. The Cost Benefit analysis revealed that there was generally a negative cost benefit as a result of the small TERs and the relatively close operational cost of the aircraft and simulators. The study concluded that although the transfer of training effects of the simulators were small, they were still a positive indication of what PC-based simulators and approved instrument simulators are capable of as computer technology continues to improve. The study recommended that further research using PC-based simulators to train complicated instrument procedures is required with a larger sample size.

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# Contents

## List of Tables

## List of Figures

## List of Equations

## List of Appendices

# Chapter One

## Introduction

### 1.1    The Organisation of the Thesis

The first chapter outlines the purpose and background of this study, and discusses the use of simulators for flight training. It also provides a brief history of flight simulators and their development as an effective and economical training tool.

Chapter Two provides an overview of the current flight simulator categories, and details the approval and use of Personal Computer (PC) based flight simulators for instrument training. The chapter outlines the contents of a modern flight training syllabus, and the utilisation of flight simulators to reduce aircraft training time. The significance of the Percent Transfer, the Transfer Effectiveness Ratio (TER) and the Incremental Transfer Effectiveness Ratio (ITER) are discussed, as well as the Cost Benefit which equates the resulting cost savings with a positive transfer of training. Recent studies that have tested the TER of PC-based simulators and other aviation authority approved simulators are discussed and the research problem is described at the end of this chapter.

The third chapter presents the experimental design used in this study. The subjects involved and the characteristics of the groups that they belonged to for this research are also presented in this chapter. The equipment used to help gather research data for this study is detailed, including: simulators, aircraft, instructional materials, questionnaires, tracking systems and the procedure that was conducted with the participants.

The results of the research are presented in Chapter Four, including the construction of the dependent and independent variables, and the allowance for weather conditions by the formulation of covariates. The results of the pre-flight questionnaire, flight data, and post-flight

questionnaire are presented. The resulting TERs and Cost Benefit of each simulator used in this study are also detailed in this chapter.

The last chapter provides discussion of the results, offers some recommendations of how this study can be used to improve pilot training, states the limitations of this study, and include areas for further research.

## 1.2 Background

The purpose of this study was to investigate the training effectiveness of two different flight simulators, when student pilots enrolled in a university aviation degree course were trained to fly an instrument holding procedure. Flight training is expensive and therefore methods to reduce the cost of training without affecting the quality of training are constantly being sought (Dennis & Harris, 1998). Theoretically, flight instruction in simulators is a cost-effective way of reducing training expenses when there is a positive transfer of training to the aircraft. All monetary values in this study are New Zealand (NZ) dollars unless otherwise stated.

Flight simulators that are approved by a country's national aviation authorities are currently used to help reduce flight training time in the actual aircraft for pilot licences and ratings. These simulators are relatively cheaper than the aircraft to operate and have the benefit of reducing the students' training costs without reducing the quality of training. New PC-based flight simulators are also being developed for pilot training and their relative purchase and operating costs are even lower than traditional simulators.

## 1.3 Flight Simulator History

The first people to master powered flight one hundred years ago were self taught aviators, who developed their handling skills through trial and error. They were also the first people to provide flight training for new pilots. Student pilots received flight training that initially consisted of

ground lectures and solo practice in an aircraft. When the student had learned how to fly the aircraft and successfully completed a solo cross-country flight, the instructor would then fly with the student. The Wright brothers gave flight instruction to trainee pilots in the aircraft, but in reality they allowed the student to learn through trial and error, only taking control of the aircraft to prevent an accident (Caro, 1988).

Learning to fly an aircraft during the pioneering era of powered flight was a dangerous endeavour that involved the possibility of serious injuries or even death. Basic flight simulators were a safe alternative to an actual aircraft. They allowed trainee pilots to become familiar with the control inputs required to successfully manoeuvre an aircraft without the risk of becoming airborne. One of the first purpose built simulators was built by Eardley Billing in 1910 (O'Hare & Roscoe, 1990). The simulator was fixed to a pivot on the ground and the trainee pilot could rotate the simulator into wind using rudder pedals (Figure 1). The simulator relied on the wind to enable the pilot to balance the aircraft and wind gusts to disturb it, therefore requiring the pilot to put corrective inputs into the controls.
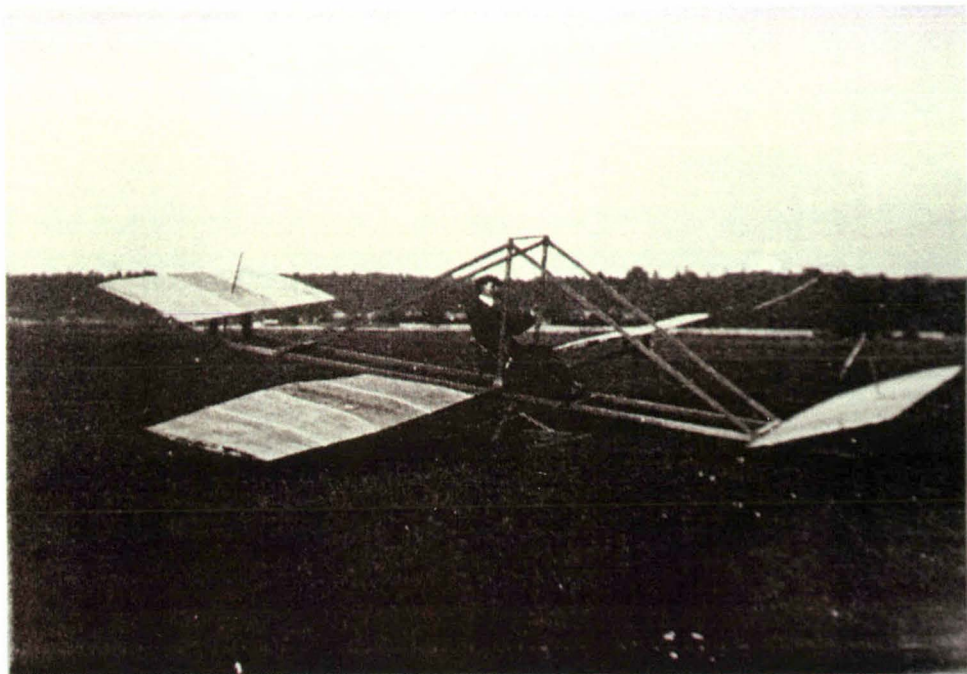


**Figure 1.**    Early Flight Simulator.

The Antoinette 'apprenticeship barrel' was another example of early simulators (Figure 2). The student sat in the barrel and two instructors would create disturbances, which required the student to use the controls to put correcting inputs to right the barrel (Rolfe & Staples, 1986). The French Foreign Legion used a 'Penguin' monoplane aircraft with no wings attached, which could hop along at 65 kph. This enabled the students to get a feel for the aircraft while taxiing, without the risk of the aircraft getting airborne (Caro, 1988). These basic simulators were used during World War One to assist with the initial command inputs required to control the aircraft. Developments in flight simulators did not progress substantially until after the war had finished.



**Figure 2.**    The Anoinette 'Apprenticeship Barrel'.

It was not until the late 1920's that mechanically driven flight simulators were developed for flight training. Edwin A. Link was a piano and organ maker working for his father's company, and in 1929 he built the Link trainer. This was the first successful pneumatic simulator (Figure 3). It was advertised as 'an efficient aeronautical training aid and a novel, profitable amusement device' (Rolfe & Staples, 1986). The basic Link trainer required the pilot to use appropriate control inputs to keep the simulator level with a horizon line painted on the walls of the simulator room. The simulator was considered by training institutes to have limited training value, and it was not until a version with flight instruments was later built that it became used more extensively for flight training. It was used for

instrument training by military organisations throughout World War Two, and was the forerunner of the modern full-motion simulator (Stark, 1989).
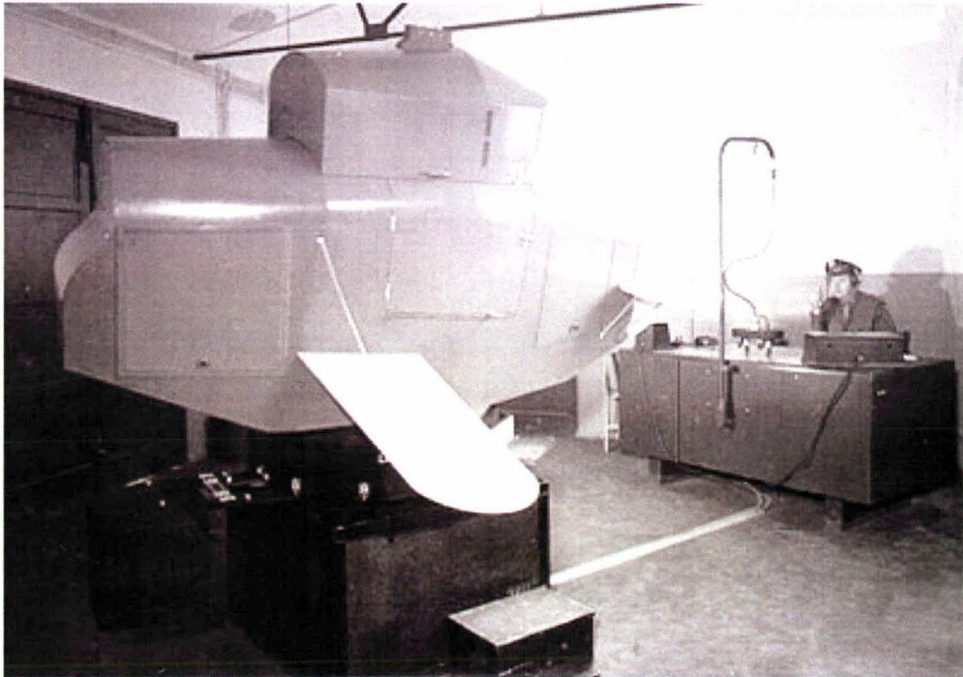


**Figure 3.** The Link Trainer.

World War Two drove the technological development of simulators as well as aircraft. Electro-mechanical simulators were developed. With the advent of analogue computers in the 1950's and later digital computers coupled with hydraulic systems, full-motion simulators were built with representative cockpits and visual representations of the outside world (Koonce & Bramble, 1998).

The development of analogue and digital flight simulators over the last 40 years has been primarily based on the concept of fidelity (Macfarlane, 1997). The level of simulator fidelity (or realism) has been a requirement specified by the certifying authorities for the simulator's particular degree of training (Hawkins, 1993). High fidelity simulators are designed to replicate a specific aircraft type with identical handling characteristics, cockpit layout and a detailed visual representation of the outside environment. Lower fidelity simulators have no physical motion, are made

of low cost materials, have basic flight instruments, and may not even have an external visual display.

Full motion high fidelity simulators are used by airlines for flight crew training on complex turbine and jet aircraft (Figure 4). The cost of operating these aircraft for training purposes is considerably higher than training in a simulator that is advanced enough to replicate the performance characteristics of the actual aircraft. In addition, using an aircraft for airline flight training may require the airline to remove the aircraft from scheduled air transport operations, which could have a negative impact on the airline's operational costs. However, the highest fidelity simulator does not necessarily produce the most effective training environment, and lower fidelity simulators may produce more successful transfer of training results, depending on the training task (Rolfe & Staples, 1986).



**Figure 4.**   Boeing 777 Full-Motion Flight Simulator.

Lower fidelity simulators are generally used for instrument training and learning new flight procedures, and they are used throughout the general aviation industry (Macfarlane, 1997). The introduction of personal computers in the early 1980s saw the creation of basic simulator games. The development of computer technology and software has seen an improvement in the realism of the simulated aircraft and the outside environment of simulator games. There is now the possibility that PC-based simulators are approaching the fidelity required by the certifying authorities to make them a recognised training device, however they need to be checked for their training effectiveness when compared to approved flight simulators.

## Chapter Two

## Literature Review

### 2.1    Official Simulator Categories

Flight simulators are classified by National Aviation Authorities to denote the different levels of sophistication that are present in today's simulators. The Federal Aviation Administration (FAA) in the United States of America (USA) arguably leads the way in simulator approval and currently has four classifications for flight simulators (Homan & Williams, 1998).

1.      A *Simulator* duplicates the actual aircraft, including motion and visual systems. A simulator is used for specific training and skill maintenance on an aircraft type. These simulators can cost more that $40 million (Bradley & Abelson, 1995).

2.      A *Flight Training Device* (FTD) is a full-scale model of the aircraft cockpit, which replicates the panels and controls of a generic aircraft. These FTDs are used by many flight training organisations for instrument training and pilot proficiency. Their cost varies from $60,000 to $200,000 for a basic FTD simulator (Homan & Williams, 1998).

3.      *PC-based Aviation Training Devices* (PCATD) are personal computers with approved software packages installed on them. These PCATD training devices have been classified as multi-task instrument procedure trainers (Kolano, 1997). They have physical controls representative of the actual aircraft controls, such as a control wheel, rudder pedals, throttle lever and radio/navigation stack. PCATDs are primarily used for instrument training and are approved by the FAA for 10 hours of instrument time logged towards an instrument rating which reduces the number of hours

required in an FTD (FAA, 1997). PCATDs devices are relatively low cost when compared to more advanced FTDs and simulators. Their cost varies from $6,000 to $32,000 depending on whether a single pilot or two pilot console is required, and also on the number of aircraft required on the computer software package (Koonce & Bramble, 1998).

4. The last classification of simulator is a *Training Aid*, which is any training aid other than a simulator, FTD, and PCATD, that is used for aviation instruction. These training devices are not approved for instrument training time that can be recorded in a pilot's logbook, however they can still be beneficial for flight training purposes (Ortiz, 1995).

The New Zealand Civil Aviation Authority (CAA) aligns most of its Aviation Rules with the FAA Aviation Rules. Under the New Zealand Civil Aviation Rules however, a flight simulator is termed as a *Synthetic flight trainer*. This definition includes three sub-classifications; flight simulator, flight procedural trainer and basic instrument flight trainer (CAA, 2002). This definition makes no allowance for PCATDs and only accounts for Simulators and FTDs as classified under the FAA Rules.

Simulators are placed into these categories after being assessed by officials from corresponding aviation authorities. They are evaluated for their flight characteristics, performance, feel and motion, and are usually compared to an actual aircraft (Macfarlane, 1997). They are often assessed for their fidelity instead of their training effectiveness and consequently, a simulator may not become certified for logging time towards a pilot's licence or rating. Often in the quest for more realistic simulation, authorities lose sight of the need for an effective training device, which is more important than the simulator fidelity (Salas, Bowers & Rhodenizer, 1998).

## 2.2    Personal Computer Based Flight Simulators

*PC-Based Flight Simulator Games*

Modern PC-based flight simulators are a result of the public's desire for flying an aircraft without the expense of hiring the aircraft. Computer flight games were released soon after the introduction of personal computers in the early 1980's. Early PC simulator games were limited by the power of the computer's graphics processor speed. Frame rates could drop as low as four frames per second during the landing phase, making the aircraft difficult to control (Bradley & Abelson, 1995). Modern computers are able to cope with the high graphics processing demands of PC flight simulators. The basic visual environment of the original PC flight simulator games have advanced over the years to the point where the user is now immersed in a virtual flying environment (Figure 5a & 5b, and Figure 6a & 6b). PC-based flight simulators are capable of simulating poor weather conditions, low cloud, rain, mist, haze, turbulence and different times of day or night. The latest flight simulator games enable users to fly different aircraft types all over the world without leaving the comfort of their homes (Laslo, 1997).



**Figure 5a. & 5b.**    Examples of Early Flight Simulator Games.
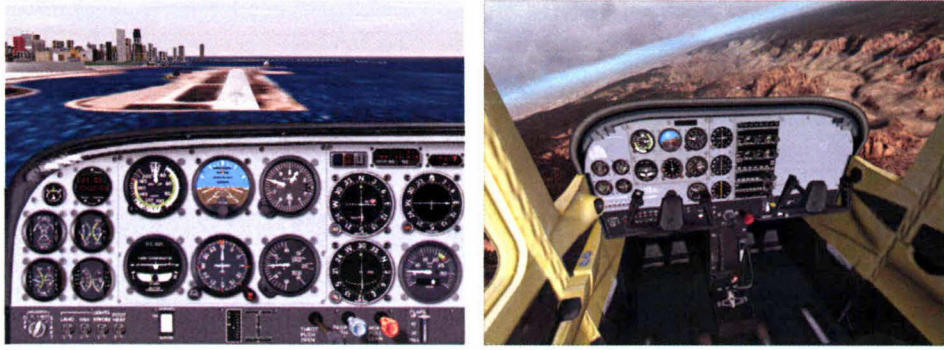
**Figure 6a. & 6b.**    Examples of Recent Flight Simulator Games.

PC-based flight simulator games fall into the training aid category. Software companies have developed a wide range of simulator games, and many of them have the similar training capabilities as more expensive PCATDs and FTDs (Homan & Williams, 1998). Some simulator games also come with detailed manuals and short video tutorials built into the software, that teach basic flight handling skills, navigation and instrument flying. These basic flight simulators have been used in studies to show that there can be an effective transfer of training from a PC-based simulator to the aircraft (Dennis & Harris, 1998).

### *PC-based Aviation Training Devices*

PC-based flight simulators have now advanced to the point where the United States FAA has approved their use for instrument training towards an instrument rating (Moroney & Moroney, 1999). There have been strict guidelines established to ensure that only approved PC-based simulator programs with the appropriate representative aircraft controls are used (Taylor, Talleur, Emanuel, Rantanen, Bradshaw, & Phillips, 2001). These types of PC-based simulators have been used in various research experiments to test their effectiveness as a training device (Taylor, Lintern, Hulin, Talleur, Emanuel, & Phillips, 1997, 1999). The results have shown that they generally provide a positive transfer of training to the aircraft when teaching basic visual flight manoeuvres and initial instrument flying. PCATDs have also been used in studies that show they

have a similar training effectiveness as FAA approved flight training devices (Homan & Williams, 1997, 1998). The results of these studies showed that there was similar flight performance from students who had trained on the PCATD and those students that had trained on the approved FTD simulator.

When compared to full motion simulators and flight training devices, PC-based aviation training devices are substantially less expensive to purchase, maintain and operate. If the PCATD is utilised correctly, it is possible to produce effective training for students at a reduced cost. The requirement for a basic, intermediate or an advanced simulator, will depend on the learner, and whether the simulator's use is for learning or maintaining a skill. Initial basic visual handling skills can be taught on a PCATD. Procedures that require checks to be learned, such as stalling, aerodrome departures and arrivals, and emergency situations, can all be practised on a PC simulator before attempting them in the aircraft. PCATDs were designed primarily for instrument procedures training, and they can be used for training basic instrument flying through to advanced instrument approaches. They can also be used for multi-crew Line Oriented Flight Training (LOFT) scenarios, with two pilots controlling the aircraft and an instructor controlling the events that occur during the flight. A study by Jentsch and Bowers (1998) showed that a PC-based simulator is effective when used to study aircrew coordination. They are therefore ideal for flight training organisations that can not afford expensive flight training devices or full motion simulators.

## 2.3    Flight Training Syllabus

During the 1950's and early 1960's there was rapid growth in the number of commercial aviation operators worldwide. Traditionally, pilots were recruited from the military or from general aviation sources, however the demand for pilots during this period outweighed the supply (Blyth, 1993). To rectify this problem in the United Kingdom, a committee set up by the Minister of Transport, devised an accelerated training program for pilots.

This scheme consisted of 200 hours of flying and 550 hours of ground training, which lasted for 13 months. After completing this course a pilot would be able to command a single crew aircraft, act as a co-pilot in a two-crew general aviation aircraft, or act as a third pilot on a larger jet aircraft. Many countries around the world, with various alterations to the syllabus, adopted this training system. Almost 40 years later this syllabus still stands as the basis for a majority of ab initio pilot training courses.

New Zealand adopted this type of integrated training course for commercial pilots, which is detailed in the Civil Aviation Authority Rules. These rules state the minimum flying hour requirement and the ground subjects that a trainee must obtain before they can hold a Commercial Pilots Licence (CPL). Currently, there is a standard 200 hour CPL, or a 150 hour CPL if the pilot completes their flight training at an approved training organisation (CAA, 2002).

Many pilots also complete their Instrument Rating, which allows them to fly under Instrument Flight Rules (IFR), which means that the aircraft can be flown through cloud on cross country navigation flights, without visual reference to the outside world. There are number of CAA ground papers required for this rating, as well as minimum hour requirements in various areas of flying, including visual cross country flights, night flying experience, and instrument flight experience. Of the 40 hours of instrument time required for the instrument rating, 20 hours can be flown in an approved FTD. This helps to reduce training costs, as well as providing pre-training in a stable learning environment. The FAA allows 10 hours from a PCATD to be included towards the 20 hours of instrument time required from a flight simulator, which also helps to reduce training costs without reducing transfer of training effectiveness.

## 2.4    Percent Transfer

The transfer of training is evaluated by comparing the performance of participants trained in a flight training device and later trained to criterion in an aircraft, to the performance of participants who trained to criterion solely in the aircraft (Taylor et al., 1999). The group that receives simulator training is the experimental group and the aircraft group is termed as the control group. The comparison of the resulting aircraft flight times when training to criterion allows various quantitative measures of training to be made including the percent transfer, the transfer effectiveness ratio, and the incremental transfer ratio (Roscoe & Williges, 1980).

A common formula used to express transfer is the percent transfer equation (Equation 1), which summarises the savings of time in the aircraft that can be achieved by using a flight simulator. The percent transfer represents the difference between a group that trains to criterion solely in the aircraft and a group that receives prior simulator training before training in the aircraft to criterion. A positive percent transfer favours the group that receive prior simulator training and a negative percent transfer favours the group that trained in the aircraft without prior simulator training (Wickens & Hollands, 2000).

### *The Percent Transfer Equation*

**(Equation 1)**

$$\% \; Transfer = \frac{Yc - Yx}{Yc} \times 100$$

Where;

$Yc$ = aircraft training time without the use of simulator training

$Yx$ = aircraft training time with previous simulator training

Using the equation, a comparison of an experimental group and a control group will show how much time was saved by using a simulator for prior training and if the transfer is positive. An example is shown below from a

study by Ortiz (1995), where a control group had an average flight time of 20.39 minutes to reach criterion, while an experimental group had an average flight time of 12.38 minutes to reach criterion in the aircraft. The calculation implies that practice using a flight simulator resulted in 39.28% positive savings of flight time in the aircraft.

Eg.

$$Yc = 20.39$$
$$Yx = 12.38$$

$$\% \; Transfer = \frac{20.39 - 12.38}{20.39} \times 100$$

$$\% \; Transfer = 39.28 \; \%$$

A disadvantage with the percent transfer equation is that it does not account for the time spent training in the simulator to achieve an aircraft flight time savings (Taylor, Talleur, Emanuel, Rantanen, Bradshaw, & Phillips, 2002). Transfer of training is a "negatively decelerated" function, which means that the initial flight time savings that results for prior simulator training will decrease progressively as the training device continues to be used for learning a particular task (Roscoe & Williges, 1980). Additional training in a simulator will increase the percent transfer, but because there is no account of the simulator training time required to produce the large percent transfer, the simulator time required may be unnecessarily large. The cost of the simulator may make additional simulator time more expensive than the resulting savings in aircraft flight time. To assess a simulator's transfer effectiveness the measure of transfer of training needs to include the amount of simulator training used to achieve the flight time savings.

## 2.5    Transfer Effectiveness Ratio (TER)

Flight simulators are used to teach the student skills and procedures, that will be transferred into the actual aircraft (Oldfield, Goss, & Meehan, 1996). To determine the extent of this transfer from the simulator to the aircraft, a measurement tool was developed by Povenmire and Roscoe (1971, cited in Koonce & Bramble, 1998). The Transfer Effectiveness Ratio is the ratio of the time saved in an aircraft, relative to the time spent in a simulator (Equation 2).

### *The Transfer Effectiveness Ratio Equation*

**(Equation 2)**

$$TER = \frac{Yc - Yx}{X}$$

Where;

$Yc$ = aircraft training time without the use of simulator training

$Yx$ = aircraft training time with previous simulator training

$X$  = simulator training time

This equation compares the saving of flight time to the time spent training in the simulator. A positive TER means that there is effective transfer from a simulator to the aircraft. If the TER was +1.0, this would mean that an hour in a simulator would have the equivalent effect of being in the actual aircraft. The reality of the matter however is that the usual time saving for every hour spent in the simulator can range from as little as six minutes to half an hour, depending on the complexity of the training task. A negative TER means that the simulator has negatively impacted on the skills being transferred from the simulator to the aircraft, and extra time will be required in the aircraft to reach a satisfactory standard (Rolfe & Staples, 1986).

Negative or low positive TERs can be caused by a variety of interfering factors. The simulator may be inappropriate for the training task. A

complex full motion flight simulator may be inappropriate for being introduced to a simple instrument task, resulting in the student becoming distracted by irrelevant sensory information (Hawkins, 1993). The flight instructor and student may be under time constraints while learning a skill in the simulator, which could lead to a rushing of the lesson and the possibility that important fundamentals of the lesson are omitted. This is likely to produce worse than expected performance in the aircraft from the student and could result in a longer flight time than expected.

An example of the TER equation below uses the results from a simulator study conducted by Ortiz (1995). The control group had an average flight time of 20.39 minutes to reach criterion. The experimental group had a smaller average flight time of 12.38 minutes, which was a result of receiving an average of 16.80 minutes of prior training on a simulator. Therefore the calculation below implies that one hour of practice on the simulator saved the pilots an average of +0.48 hours (29 minutes) in the aircraft.

Eg.

$$Yc = 20.39$$
$$Yx = 12.38$$
$$X = 16.80$$

$$TER = \frac{20.39 - 12.38}{16.80}$$

$$TER = +0.48$$

The results of previous studies using a wide range of simulators have shown TERs ranging from +1.9 to –0.4, with the average being +0.48 (Orlansky & Chatlier, 1983, cited in Rolfe & Staples, 1986). The TER is also a negatively decelerated function, which means that the TER is likely to decrease as the simulator time on a training task increases.

## 2.6    Incremental Transfer Effectiveness Ratio (ITER)

The concept of Incremental Transfer Effectiveness Ratio was also introduced by Povenmire and Roscoe (1971, cited in Koonce & Bramble, 1998). ITER equation addresses the probability that the first hour of training in a simulator may not have the same effect as the next hour, so that over a period of time the TER decreases. Some studies have shown that an initial TER value as high as +1.75 can drop to +0.25 as progressively more time was spent in the simulator (Roscoe & Williges, 1980). This means that a saving of 105 minutes in the aircraft can drop to a saving of 15 minutes, for every hour spent in a simulator (Equation 3).

### *The Incremental Transfer Effectiveness Ratio Equation*

**(Equation 3)**

$$ITER = \frac{(Yx - \Delta x) - Yx}{\Delta X}$$

Where;

$Yx$ = aircraft training time with previous simulator training

$Yx - \Delta x$ = time required by the simulator group to reach a performance criterion in the aircraft after $x - \Delta x$ trials in a simulator

$\Delta X$ = Incremental unit in time for the simulator group

An example of the ITER equation is shown below. It is based on the hypothetical data created by Povenmire and Roscoe (1971, cited in Roscoe & Williges, 1980). The ITER for the fifth hour of practice in a simulator is calculated by comparing the flight time results of the group given 5 hours practice with that of the group given one less hour of simulator practice. The group with 5 hours training in the simulator took 5.01 hours to reach criterion in the aircraft, while the group with 4 hours training in the simulator took 5.68 hours. The results show that the ITER for the fifth hour is +0.67 hours per hour. The TER for the first hour of simulator

training was +1.40, which by the fifth hour has dropped to +0.67, indicating the negatively decelerated function of the transfer of training.

Eg.

$$Y_4 \quad = \; 5.68 \text{ hours}$$
$$Y_5 \quad = \; 5.01 \text{ hours}$$
$$Yx - \Delta x \; = \; Y_{5\text{-}1}$$
$$\Delta X \quad = \; 5.00 \text{ hours}$$

$$ITER = \; \frac{(Yx - \Delta x) - Yx}{\Delta X}$$

$$ITER = \; \frac{(Y_5 - 1) - Y_5}{5 - 4}$$

$$ITER = \; \frac{Y_4 - Y_5}{5 - 4}$$

$$ITER = \; \frac{5.68 - 5.01}{1}$$

$$ITER = \; \frac{5.68 - 5.01}{1}$$

$$ITER = \; 0.67 \text{ hour per hour}$$

The ITER needs to be taken into account when using expensive simulators for training, as it will identify the point at which additional instruction in the simulator is not longer cost effective (Koonce & Bramble, 1998, Taylor et al., 1999). Although the simulator may have a diminishing TER there are some situations where the simulator is still required for training purposes, even though it does not appear to be cost effective.

Considerations such as local traffic congestion, weather, aircraft availability, or safety, may make the continued use of the simulator advantageous, even when the simulator is no longer cost effective (Roscoe & Williges, 1980).

## 2.7    Cost Benefit

The cost savings involved in using a simulator can be financially beneficial for students and aviation companies alike. Ortiz (1994, 1995), demonstrated that a PC simulator used during instrument training could help to save a student US $256.80. Using a cost benefit equation (Equation 4), the cost of using a PC simulator can be subtracted from the cost of using the actual aircraft at the TER rate, and the difference between the two is the trainee's financial savings. Depending on the training circumstances, there can be a cost benefit to a student's private training or an aviation company's training of its pilots. The cheaper the simulator is to run in comparison to the actual aircraft, the greater the potential savings.

### *The Cost Benefit Equation*

**(Equation 4)**

$$Cost\ Benefit = (X \times TER \times Ca) - (Cs \times X)$$

Where;

$X$       = time in hours spent on the simulator

$TER$   = transfer effectiveness ratio

$Ca$      = the hourly cost of aircraft and instructor

$Cs$      = the hourly cost of simulator and instructor

The example below uses a single engine aircraft which costs $170 per hour to hire, a flight simulator that costs $50 per hour to hire, the flight instructor cost of $30 per hour, and a resulting TER of +0.48 for 10 hours in the flight simulator.

Eg.

$X$ = 10 hours

$TER$ = +0.48

$Ca$ = \$200 per hour (single-engine aircraft, including flight instructor)

$Cs$ = \$80 per hour (including flight instructor)

$$Cost\ Benefit = (X \times TER \times Ca) - (Cs \times X)$$
$$= (10 \times 0.48 \times 200) - (80 \times 10)$$
$$= \$160$$

This means that 10 hours spent in a simulator with a resulting TER of +0.48, instead of a single-engine aircraft, will save the student \$160. This is beneficial for the student, as there is no reduction in the quality of training for the money saved, and the student now has the opportunity to use the money saved for more advanced flight training.

Orlansky, Knapp, and String (1984, cited Pohlman & Fletcher, 1999) studied the use of flight simulators in the military. They concluded that: the cost to operate the flight simulator is about one tenth the operational cost of the aircraft, one hour of simulator time saves about 30 minutes in an aircraft, and that the use of flight simulators is cost effective if the TER is 0.20 or greater. This case would be similar to high fidelity full-motion simulators that airlines use to train their flight crew. With smaller civil aviation aircraft, the savings may be smaller due to the fact that the operating cost of the aircraft may not be substantially greater than the simulator.

An approved FTD simulator, such as a Frasca 141, is used primarily for instrument training and usually costs around \$80 per hour including the flight instructor costs. A PC-based simulator or approved PCATD may cost as little as \$45-60 per hour to hire including the flight instructor. Therefore a student would potentially save \$360-510 on their training

towards their instrument rating, if they were able to log 10 hours of instrument time from a PCATD with a TER of +0.48. As already mentioned, the New Zealand CAA has made no provision for the approval of PC-based Aviation Training Devices and therefore there is no present cost savings in this country for using the devices. However, this does not mean that these training devices should be overlooked by training organisations in this country, or simply used as IFR trainers in the USA. PC-based simulators and unapproved PC flight simulator games still have training value that can be exploited (Koonce & Bramble, 1998).

## 2.8    Recent Studies Using PC-based Simulators

In the last fifteen years there have been many studies into the use of PC-based flight simulators and their effectiveness as flight training devices.

Ortiz (1994, 1995), used the Azoresoft ELITE software package, with representative aircraft controls. Sixty aviation students with no previous flying experience volunteered to take part in the project. The students were randomly divided into a control group and a PC flight simulator experimental group. They were required to fly a square pattern within certain limitations that helped to determine their performance of the task. Subjects in the experimental group were allowed pre-training on the ELITE flight simulator, before they flew the manoeuvre in the actual aircraft. The control group was taken straight to the aircraft and asked to perform the same manoeuvre. The results of the study showed that the simulator had a TER of +0.48 and that the experimental group generally saved 29 minutes in the aircraft, for every hour that they had spent in the simulator. Ortiz (1994, 1995), recommended that PC-based flight simulators be introduced to flight training programs, as they have the potential to reduce the number of hours required in the aircraft to meet specified criterion, and therefore save money. Another recommendation was that further research into the ITER of PC-based flight simulators was required, and more research is required for more complex flight manoeuvres and different software-hardware combinations.

A study by Homan and Williams (1998), compared an approved PC-based Aviation Training Device, with an approved Flight Training Device, to see if there were any difference in students' performance when carrying out an instrument flight maneouvre. 64 civilian pilots who all held a flying licence, volunteered for the study. The participants were randomly divided into two groups. The experimental group used the ELITE (PCATD) program to practise an instrument flight procedure three times and the control group had three practice attempts in an AST-300 (FTD) flight simulator. Both groups then had to fly the same procedure in an AST-300 simulator. The results showed that both groups performed the instrument flight manoeuvre within the required FAA testing criterion and the only difference was a small deviation from height holding in the experimental group. This may have been caused by the pitch sensitivity of the PCATDs flight controls, which differs from that of the AST-300. This shows that PCATDs and FTD may have similar training benefits. Therefore there may be potential cost benefits for students and flight training organisations, as the PCATDs are substantially cheaper to purchase, maintain and operate, than FTDs. There was no attempt to measure the amount of transfer to an actual aircraft for this study. The authors recommend that the study should be replicated with other PC-based flight simulators, with a larger population, and that other instrument flight procedures are tested.

The Institute of Aviation of the University of Illinois at Urbana-Champaign in the USA has been conducting various experiments with PCATDs over the last seven years. A transfer of training study (Taylor, Lintern, Hulin, Talleur, Emanual and Phillips, 1996, 1997, 1999) set out to investigate the TER of a number of different flight exercises ranging from visual handling manoeuvres to instrument procedures. The experiment placed 144 subjects into a Control group and a PCATD group. For the Control group, all new manoeuvres were introduced and trained to proficiency in the aircraft. The PCATD group received prior simulator training on the new manoeuvre before training to proficiency in the aircraft. The results of the study showed that on a range of different flight

exercises, the TER varied from +0.15 to +0.40. In general, the transfer savings were positive and substantial when students were introduced to new tasks, however the transfer savings were low and occasionally negative when repeating a previously learned lesson.

The Institute of Aviation has also investigated the ITER, when 157 students were taught a variety of instrument flight exercises using a PCATD (Taylor et al., 2002). The students were placed in three PCATD groups and a Control group. The Control group received training to proficiency in the aircraft, while the three PCATD groups received 5 hours, 10 hours, and 15 hours, spread across eight instrument flight lessons. The TERs were generally positive and ranged from +0.15 to +0.57 for the PCATD groups. The concept of the ITER was shown by the resulting decrease in TER for the PCATD 10 hour and 15 hour groups. The ITER decreased from as high as +0.57 for the 5 hour simulator group to -0.41 for the 15 hour simulator group. The study concluded that there was no appreciable benefit found in having more than 5 hours of PCATD training, and there was no support to increase the FAA approval for 10 hours of PCATD time to 15 hours.

These studies have all shown the training effectiveness of using PC-based flight simulators and PCATD, and the potential cost benefits that could result. They all recommend further studies that use more complex flight exercises on PC simulators, and find out whether these exercises transfer successfully to the aircraft. Some of the recent studies show a trend that will see PC-based flight simulators being utilised in training organisations in the years to come (Homan & Williams, 1998).

## 2.9    Defining the Research Problem

With the advancements in PC technology, simulator flight games have become a potential rival to the approved FTDs, which are currently being used for flight simulator instruction. Affordable flight simulator games and flight control accessories are providing an exciting challenge for aviation enthusiasts and the potential to reduce flight training cost without degrading flight training standards for both aviation students and training organisations.

This study is intended to investigate the training effectiveness of two flight simulators used by a university aviation degree programme. A non-approved PC-based simulator and an approved FTD will be used to teach two experimental groups to fly an instrument flight procedure. Their time to reach proficiency and their flight performance in the actual aircraft will be compared to a control group that is trained solely in the aircraft. The transfer of training equations will be used to determine the effectiveness of the FTD and the PC-based simulator. This study is unable to investigate the ITER the simulator groups as the experimental group participants only receive one simulator flight.

Based on the findings of the previous research conducted using FTDs, PCATDs and PC-based simulators as reviewed in Chapter Two of this thesis, the following hypotheses are to be tested when training aviation students to fly an instrument holding procedure:

1)      Pre-training of an instrument procedure on a PC-based simulator or FTD, results in shorter flight time to proficiency in the aircraft, when compared to being trained solely in the aircraft.

2)      The PC-based simulator and FTD produce a positive Percent Transfer and TER for students who receive pre-training on them.

3)     Students trained on a PC-based simulator produce similar aircraft flight performance to students trained on an approved FTD simulator. Both simulator groups produce better flight performance than the aircraft group.

4)     Students who receive prior simulator training display better performance that students who do not receive prior simulator training, when flying the instrument procedure in the aircraft, when assessed by the training flight instructor (based on their expert judgement).

# Chapter Three

## Method

### 3.1 Experimental Design

This experiment was designed with three independent groups, i.e., a control group and two simulator groups. The control group was used to establish the average time required to learn an instrument flight procedure in an aircraft, with no prior practice in a simulator. The two simulator groups were given prior training on a simulator before conducting the lesson in the aircraft. An CAA approved Frasca 141 (F141) simulator and a PC-based SAV-1 flight simulator were used to establish whether or not prior learning in a simulator reduces the aircraft flight time. The use of two simulator groups also allowed for a comparison of the relative savings of flight times and flight performance resulting from the students training in those particular simulators.

A Non-Directional Beacon (NDB) instrument holding pattern was chosen for the training task, as this procedure had not been taught to the participants previously. The holding pattern required the aircraft to be flown in a racecourse shaped pattern, holding its position over an NDB ground station. This procedure is flown with sole reference to the aircraft's instruments, requires constant monitoring of the aircraft's position relative to the navigational beacon, and an understanding of how to make tracking corrections which result in consistent and accurate holding patterns.

The criteria for successful performance included: consistent holding pattern procedures, consistent inbound tracking within $\pm10°$, height holding within $\pm100$ feet of the reference altitude, an attempt to maintain this altitude, and evidence that the student had an understanding of the corrections required to fly consistent instrument holding patterns. The student was asked situational awareness questions about the aircraft's

present position in the hold and what was required next to ensure that it remained in the specified holding pattern. The student's responses allowed the flight instructor to assess the student's understanding of the instrument procedure, while flying in the holding pattern.

## 3.2 Subjects

Ten male subjects enrolled in the Air Transport Pilot (ATP) Programme at the Massey University School of Aviation Albany Campus volunteered to participate in this study. The participants were between 18 and 44 years of age (*Mean* = 24.30; *SD* = 7.75).

The ATP Programme at Massey University School of Aviation is a three year Bachelor degree. The first two years contain compulsory papers and flying practicum, which contribute towards their Private Pilot Licence (PPL), Commercial Pilot Licence (CPL), Airline Transport Pilot Licence (ATPL) theory credits, Multi-Engine Instrument Rating (MEIR) and Basic Gas Turbine Rating (BGT) theory requirements. This also includes 170 hours of flight time in a single engine aircraft, 40 hours of flight time in a multi-engine aircraft, and 60.2 hours of simulator time. The third year of study can be conducted on a full-time or part-time basis with the opportunity to study the areas of flight instructor, Airline First Officer, or Airline Management. On completion of the third year of study, students graduate with a Bachelor of Aviation and are qualified as a commercial pilot. (Massey University, 2003).

Flight training requires a considerable financial commitment, making the course one of the more expensive degree programmes in New Zealand. The course is also time intensive with students being required to fly during most university holidays and occasionally on weekends as well. As a result of these factors and the dedication required to complete the course, new semester intakes are relatively small when compared to other professional university courses. The two ATP course intakes per year generally range between 15 to 40 students, with some students culled

during the first semester due to underachievement in flight practicum and/or academic studies.

The statistical "power" is the probability of being able to confirm an actual group difference, when it occurs (Trochim, 2002). A power of 95 % means that the study has enough power to detect the smallest significant differences 95% of the time. The researcher determines the minimum sample size necessary to produce the desired power, or certainty of accurate identification of group differences (Sawilowsky & Hillman, 1992). The GPOWER V 2.0 program was utilised in a priori calculation before this study took place to determine the required sample size for this study with a 95% power. A transfer of training study by Taylor et al. (1996) provided statistical results that could be used to calculate the approximate sample size required to achieve a 95% power. The power calculation revealed that 44 subjects would be required (*Effect Size* = 0.5612, *Alpha* = 0.05).

An intermediary was used to invite students currently enrolled on the ATP course at Ardmore, to participate in this study. They were informed of the study's purpose, the intended timeframe for briefings, simulator sessions and aircraft flights, and how the recorded data would be used in the study.

70 students from five current Massey Aviation intakes were asked to become participants in the study. As there was no funding source for the study, participants were asked to volunteer up to a maximum of 2.0 hours of their allocated single engine time towards the research. Although all of the flight hours of the ATP course are allocated to specific sorties, 8.9 hours of single engine aircraft sorties are specified as extra handling flights. These flights can be used for remedial training or extra handling practice for a flight test if required. There are also 6.6 single engine aircraft hours allocated to instrument flight training. It was anticipated that if a student had not over-flown their allocated hours for their semester of flying or if they had not yet flown one of the instrument training flights, then they would be able to take part in the study.

The current intakes available to participate in this study ranged from Massey intake 35 to Massey intake 39. The study contained two Massey 37, three Massey 38 and five Massey 39 students. The 10 participants were systematically placed into three groups, in an attempt to create groups with similar characteristics of flight experience, pilot licences, age, and instrument training experience.

### 3.2.1   Characteristics of the Groups

Participants were given a Flight Experience sheet to complete when they agreed to take part in this study. This summary was used to help ascertain which group the subject would be placed into. The summary was updated before the participant's simulator flight or aircraft flight, according to their group membership. This was to ensure that an accurate record of their flight experience was taken at the time of their flights.

The ATP students who took part in this study had all been flying light single-engine aircraft and had a total flight experience ranging from 38.8 to 213.2 hours (*Mean* = 95.47; *SD* = 60.08). As the students were being taught how to fly an instrument holding pattern, it was important to establish the participants' previous simulator and aircraft time flying with sole reference to instruments. They had between 1.5 to 10.0 hours in an CAA approved flight simulator (*Mean* = 4.01; *SD* = 3.22) and between 1.3 to 8.7 hours (*Mean* = 3.52; *SD* = 2.06) in an aircraft flying on instruments.

### *The Control Group*

The Control Group consisted of three members. This group contained one Massey 38 student and two Massey 39 students, whose ages were 18, 23, and 23. Total flight experience was 42.1, 51.6, and 104.1 hours, and one of the members held a PPL. The approved simulator experience was 1.9, 2.0, and 3.2 hours, and the instrument aircraft flight time was from 2.9, 3.0, and 3.2 hours (see Table 1. for summary statistics).

*The SAV-1 Group*

The SAV-1 Group contained four members, one Massey 37, one Massey 38 and two Massey 39 students. Ages were 19, 19, 20, and 30 years. Their total flight experience was 39.8, 60.0, 105.9, and 139.3 hours, with two members holding a PPL licence. Their approved simulator experience was 1.5, 2.0, 2.4, and 9.5 hours. Instrument aircraft flight time was 1.9, 2.6, 3.1, and 3.5 hours.

*The F141 Group*

The F141 Group had three members, one Massey 37, one Massey 38 and one Massey 39 student. Their ages were 23, 24, and 44 years. Their total flight experience was 38.8, 160.0, and 213.2 hours, and two members held a PPL licence. Their approved simulator experience was 2.2, 5.4, and 10.0 hours, and their instrument aircraft flight time was 1.3, 5.0, and 8.7 hours.

The resulting groups differed slightly in the area of flight experience, however there was a relatively even spread of ages, Massey course intakes, flight licences held, and previous instrument flying in both simulators and aircraft (Table 1). None of the participants had flown the NDB instrument holding pattern in the simulator or in the aircraft. This meant that all participants began on an even platform when it came to learning the complicated holding procedure.

**Table 1.**     Means and Standard Deviations for Group Characteristic Variables.

| Variables | Groups* | Mean | Std. Deviation | N |
|---|---|---|---|---|
| **Student's Age (years)** | Control | 21.33 | 2.89 | 3 |
| | SAV-1 | 22.00 | 5.35 | 4 |
| | F141 | 30.33 | 11.85 | 3 |
| | Total | 24.30 | 2.89 | 10 |
| **Total Flight Experience (hours)** | Control | 65.90 | 33.43 | 3 |
| | SAV-1 | 65.90 | 44.90 | 4 |
| | F141 | 137.33 | 89.38 | 3 |
| | Total | 95.47 | 60.08 | 10 |
| **Instrument Flight Experience (hours)** | Control | 3.03 | .15 | 3 |
| | SAV-1 | 2.78 | .69 | 4 |
| | F141 | 5.00 | 3.70 | 3 |
| | Total | 3.52 | 2.06 | 10 |
| **Instrument Simulator Experience (hours)** | Control | 2.37 | .72 | 3 |
| | SAV-1 | 3.85 | 3.78 | 4 |
| | F141 | 5.87 | 3.92 | 3 |
| | Total | 4.01 | 3.22 | 10 |

**\* Groups**

**Control = Aircraft Control Group**

**SAV-1 = SAV-1 Experimental PC-based Simulator Group**

**F141 = F141 Experimental FTD Simulator Group**

## 3.3    Equipment

This study required a variety of resources. This included simulators, aircraft, instructional materials, and a Global Positioning System (GPS) tracking system to record flight data.

### 3.3.1 Simulators

The study used two simulators, a PC-based simulator and a CAA approved Flight Training Device, so that a comparison of simulator transfer of training effectiveness and resulting student performance could be undertaken.

### *SAV-1 PC Simulator*

The SAV-1 is a PC-based flight simulator constructed by Savern Reweti from Massey University's School of Aviation in Palmerston (Figure 7). The simulator uses Microsoft's Flight Simulator 2002 software, which is run on two personal computers. Each computer has 1.6 MHz Pentium 4 processors, with dual-head Matrox graphics cards. The dual-head cards allow the master computer to run the forward centre scenery and instrument panel and the slave computer to run the forward left and forward right scenery views. The four screens allow for a 135 degree view forward of the aircraft as well as a separate display for the aircraft instruments.



**Figure 7.**    SAV-1 PC-based Flight Simulator.

Both computers have a normal QWERTY keyboard and mouse, which are primarily used for starting up the computer and changing the environmental and aircraft settings. A small panel has been developed with buttons that operate various aircraft systems in an attempt to remove the need to remember keyboard button functions. It is still necessary however, to use the mouse roller wheel to adjust some instrument setting dials, when using this simulator.

The simulator has aircraft representative controls (Figure 8). The control joke and rudder pedals are manufactured by Precision Flight Controls Inc. They are modelled on a light single-engine aircraft and allow the user control inputs and sensory feedback based on a spring tension system.



**Figure 8.**  Cirrus Control Yoke and Rudder Pedals.

The Microsoft Flight Simulator 2002 scenery database has been upgraded with detailed visual scenery and terrain mapping of New Zealand. The simulator is capable of being used for visual aircraft handling lessons and visual cross-country flight training. For this study, the cloud base and visibility were set so that the student had no visual reference to land or water, and they were therefore required to fly the aircraft with sole reference to the aircraft instruments.

The simulator flight characteristics and instrument panel were based on the Cessna 172 SP (C172SP) aircraft. The instrument panel was modified for this study, so that the instrument dials appeared larger, only the crucial instrumentation was visible and navigational instruments used to confirm the aircraft's position when flying in cloud were included on the screen (Figure 9).



**Figure 9.**  SAV-1 Instrument Panel.

The simulator software was also capable of recording flight tracking and altitude data, which could be used at the end of the simulator session to assess flight performance. For this purpose, the master PC was connected to a printer, which was used to print a hard copy of the aircraft's tracking and altitude holding from the simulator session.

*Frasca 141 Instrument Simulator*

The Frasca 141 (F141) is a CAA approved Flight Training Device built by Frasca International Inc, which allows the hours to be logged in the student's logbook (Figure 10). These hours can be used towards gaining a flight licence or instrument rating, and can also be used for instrument flying currency.



**Figure 10.**     Frasca 141 Instrument Simulator.

It has a generic light aircraft cockpit layout, which can be used to simulate single engine and twin engine aircraft. The simulator has aircraft representative controls incorporated into the design, which allow the use of control inputs and sensory feedback based on a spring tension system.

The simulator does not have any visual scenery display and is used purely as an instrument flight trainer. The Instrument panel is not specific to any one type of aircraft, however the layout and navigational instruments are similar to the C172SP cockpit. The simulator instrumentation is made up of real aircraft instruments with functioning dials and knobs, which are

operated by a computer (Figure 11). The students are therefore able to fly the simulator and navigate with reference to the instruments, as though they were flying an aircraft in cloud with no visual reference to the earth's surface.



**Figure 11.** Frasca 141 Instrument Panel.

The F141 simulator has a range of light aircraft programmed into its database to allow for the different performance speeds and characteristics of various light aircraft. As with the SAV-1 simulator, the F141 was set to the C172 mode to allow for performance similar to the new C172SP model.

There is also an instructor console included with the simulator that allows the instructor to control environmental and aircraft system changes during the simulator session. The instructor's station screen is also capable of showing the aircraft tracking and altitude holding for the flight. A printer attached to the instructor console was used to print a hard copy of this data for performance analyses.

### 3.3.2 Aircraft

Two Cessna 172 SP aircraft were used for the aircraft flights of this study. The aircraft registered ZK-JSP and ZK-JMC were identical, four seat, single engine, high wing aircraft (Figure 12).



**Figure 12.**     Cessna 172 SP.

The C172SP is used at Massey University primarily for visual flight training, however the aircraft is fitted with the appropriate instrumentation to conduct basic instrument handling and instrument navigational flights. The aircraft is equipped with navigational instruments including an ADF and a GPS. All of the students were familiar with flying the aircraft on instruments as they had all had basic instrument flight training in Cessna aircraft (Figure 13).

**Figure 13.**     Cessna 172 SP Instrument Panel.

### 3.3.3   Instructional Materials

#### *NDB Holding Pattern Description*

The NDB instrument holding pattern is a relatively complicated holding procedure that enables an aircraft to remain in a specified area of airspace while waiting for a clearance to proceed on track to a destination or commence an instrument approach to land at an airport. It is based around a radio navigation ground based system, which uses a radio transmitter to beam a signal in all directions from the station (Figure 14). The ADF display in the aircraft has a needle, which points in the direction of the ground station (Figure 15.). This allows the pilot to navigate by using the aircraft's magnetic heading and the relative bearing from the nose of the aircraft to the head of the ADF needle to indicate the magnetic track to the station.

**Figure 14.**     The Surrey NDB Ground Station Transmitter.
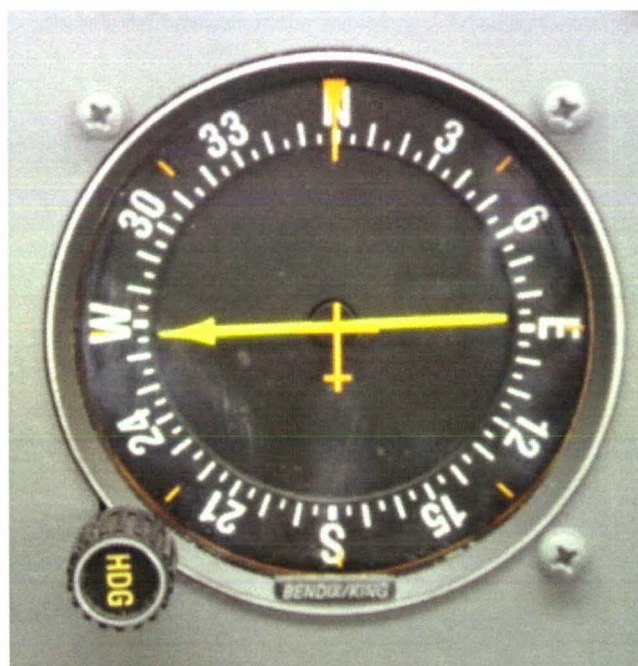


**Figure 15.**     Automatic Direction Finder (ADF) Instrument Display.

NDB holding patterns consist of a racecourse holding pattern with an inbound leg (direction inbound towards the navigational beacon) and an outbound leg (reciprocal direction to the inbound leg), with two 180° turns at the end of each leg (Figure 16). The holding pattern is specified as having all turns to the left, or all turns to the right depending on how the hold is orientated. The inbound leg is specified with a magnetic track in degrees, which must be flown to insure the aircraft remains holding in the correct area of airspace.
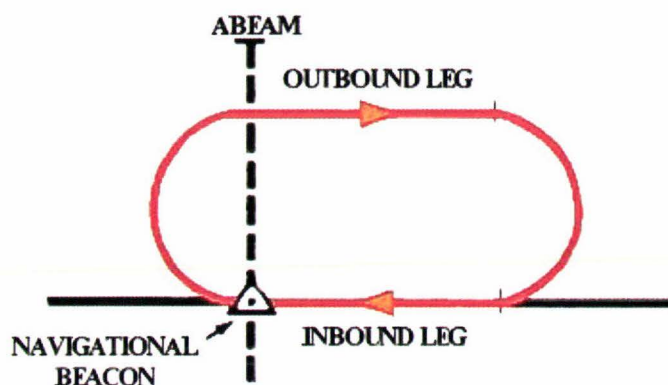


**Figure 16.**    Standard Holding Pattern.

There are three ways to enter a holding pattern. They depend on the aircraft's heading when approaching the pattern and are designated as a specific sector entry. They are the parallel, offset and direct entry patterns (refer to Appendix A, p. 108 for more detail).

Once the aircraft is established on the inbound track and crosses the beacon, the aircraft is established in the holding pattern. To remain in the holding pattern the aircraft is then turned left or right 180°, depending on which way the turns are specified for that particular holding pattern. The turning direction varies between different holding patterns and depends on the orientation of airspace and terrain. The aircraft is then flown for one minute in this reciprocal direction once passing abeam the navigational beacon.  Another 180° turn is then commenced to intercept the inbound track, and complete the racecourse shape holding pattern.

The ADF needle gives important indications of where the aircraft is in the holding pattern and how far inside or outside of the ideal racetrack pattern that the aircraft is being flown, therefore indicating the required heading corrections. These points include the start of the outbound leg, crossing the offset radial, the monitored turn inbound, the inbound tracking and overhead the beacon indication. These are all crucial points which will help the pilot get as close to the inbound track as possible and help to maintain that track all the way to the beacon. When conducting an instrument flight test, the standard of tracking inbound is expected to be within $\pm 5°$ of the designated inbound track. The participants in this study were instructed to attempt to remain as close as possible to the inbound track.

### The Surrey NDB Holding Pattern

The Surrey NDB hold was used for this study. The Surrey ground beacon is situated 15 nautical miles south-east of Ardmore airfield where Massey University School of Aviation has a training base (refer to Appendix B for an aeronautical map of the area). For the purposes of this study, the holding patterns were conducted between 2000 ft to 3500 ft clear of cloud and were flown in uncontrolled airspace. The Surrey hold has an inbound track of 310° magnetic, with all turns to the right.

Most radio navigation beacons have an instrument approach procedure or holding pattern, which appears on an instrument navigation map or instrument plate. They contain important information for an approach or holding pattern, which is used by the pilot to ensure that the correct procedure is being flown. An instrument holding plate was constructed detailing the departure and arrival procedures at Ardmore aerodrome for this study (Appendix C). It contained the relevant Surrey holding pattern information. This instrument plate was also used in the simulator sessions by the participants and was placed on the control yoke of the aircraft for the participants to refer to during the actual flight.

### 3.3.4 Questionnaires – "Soft" Measures

Two questionnaires were used to gather "soft" measures during this study. "Soft" data is based on the subjective responses of participants received from questionnaires and interviews (Webster & Lombard, 1999). The first questionnaire was given to the SAV-1 and F141 participants before their simulator flights, and to the Control group before their aircraft flight.

The Pre-flight Questionnaire (Appendix D) was intended to ascertain the participants' previous experience with PC flight simulators, how many of them have a home PC with a simulator program installed on it, how extensively they use PC simulators at their training organisation and how effective they think the PC simulators are.

The second questionnaire was administered after the participants' aircraft flight. The flight instructor who was blind to the student's group membership, rated their performance when flying the holding pattern and their comprehension of the procedure based on student feedback during the flight (Appendix E). The intention of the second questionnaire was to gain an understanding of the instructor's perspective of the student's performance and knowledge of the procedure. The instructor is responsible for judging when the student has successfully learned the procedure during the aircraft flight. The instructor uses observation and direct questioning to help make a judgement as to whether or not the student has achieved the required competency for the flight lesson.

### 3.3.5 Tracking Systems – "Hard" Measures

An accurate record of the aircraft flight data was required to ascertain the participants' specific performance when flying the holding patterns. Although the students were training to a specified criterion for each of the dependent flight variables, a specific record was required to determine performance differences between the groups. "Hard" data is recorded using objective measurements in a numerical format, such as time, altitude

and aircraft tracking (Webster & Lombard, 1999). To achieve measurement of hard data, a laptop GPS tracking system was constructed to record flight tracking data in real time.

Two laptop computers were used during this study. A Compaq Presario 1240 laptop with an Intel Pentium MMX processor and a Toshiba Intel Pentium 4 1.6 GHz processor. Two laptops were used because the required battery endurance was not enough for one laptop to last for the duration of three flights in one day (Figure 17a and 17b).



**Figure 17a. & 17b.**     Compaq and Toshiba Laptops.

The laptops were connected to a GM48 GPS aerial via the serial port (RS-232 communications port). The GPS aerial was capable of tracking up to 12 satellites, with a position accuracy of $\pm$ 50 ft.

The GPS tracking software was GPS TrackMaker version #11.8. This free software program was created in Brazil by Odilon Ferreira Jr. The software allows the importing of digital maps, and calibration with latitude/longitude co-ordinates. With a GPS aerial, the software then displays position and tracking data. The resulting aircraft flight tracking data was saved on the laptops and a hard copy was printed to analyse the NDB holding pattern performance.

A digital camera was used periodically during the flight to record the tracking progress of the aircraft. This was simply a matter of taking a photo of the laptop screen every two laps of the NDB hold to ensure that

flight tracking data would not be lost if there was a technical failure of the laptop or GPS aerial.

A manual record of the flight tracking data was also made on an aeronautical map as a back-up to the laptop and the digital camera. There was also a manual record made of the altitude holding. Altitude recordings were made every five minutes during the flight and at every time that the altitude deviated substantially from the reference altitude. A record of the flight timing data was also made manually. Points of reference included: aircraft engine start, taxi-out, lining up, take-off, holding entry, holding patterns, departing the hold, landing, and shut down times. This was to ascertain the aircraft flight time, airborne time, holding time while training, and holding time while practising.

## 3.4   Procedure

All of the participants received an Instrument Flight Rules (IFR) Holding Patterns and Procedure Turns Mass Brief. This is a standardised Massey University School of Aviation briefing, which is given to students prior to their first simulator holding pattern lesson. The brief refers to generic holding patterns, which includes Very High Frequency (VHF) Omni-Directional Radio Range (VOR) holding patterns as well as NDB holding patterns (Appendix A).

The students received a pre-sim/pre-flight brief in briefing room at the School of Aviation's Ardmore Flight System Centre. The brief was given on a whiteboard and included more detail on the NDB holding pattern and the indications that the ADF needle will give to help identify their position and progress when flying the holding pattern. The relevant weather conditions were discussed and the effect that they would have on the aircraft during the departure from Ardmore, the tracking to the Surrey, the entry and subsequent holds and the arrival at Ardmore.

After the students received their Mass Brief on holding patterns, they were booked in for the appropriate simulator sessions and aircraft flights. They then received a pre-simulator/pre-flight brief followed by the appropriate sortie. One flight instructor was used to train both simulator groups on the instrument procedure to ensure standardisation with the simulator training. A different flight instructor, who was blind to the students group membership, conducted the flights. To simulate IFR conditions during the aircraft flights the students wore an IFR hood. This device is worn on the student's head and restricts their view to the aircraft instruments (Figure 18). During these flights the instructor ensured that the aircraft was a safe distance from cloud and other aircraft.



**Figure 18.**     Student Wearing IFR Hood While Flying on Instruments.

## The Control Group

The members of this group flew a C172SP with a flight instructor from Ardmore Aerodrome to the Surrey NDB. They entered the hold and received instruction in flying NDB holding patterns until the instructor

decided that they had shown signs of being able to fly the holding pattern without constant prompting. They then vacated the holding pattern, carried out a second entry procedure and practised the holding pattern with minimal input from the instructor. Once the flight instructor was satisfied that the students had shown an appropriate level of understanding of how to fly the holding pattern, and had demonstrated the correct flying of the procedure, the students were instructed to return the aircraft to Ardmore airfield to land.

Therefore, the students received instruction on the entry procedure into the holding pattern and the holding procedure before they were required to re-enter the holding pattern and prove that they had met the appropriate standard of height holding, tracking, and comprehension for maintaining the holding pattern. The number of holding patterns was recorded. The height holding and track maintenance was recorded, as well as overall flight time.

### The SAV-1 PC-based Simulator Group

The members of the PC-based group received prior training in the SAV-1 simulator with a simulator flight instructor, "flying" an aircraft based on a C172SP. IFR flight conditions were achieved on the simulator by setting limited forward visibility and a low cloud base height on the weather menu of the software. This replaced the visual scenery with cloud, and resulted in the simulator being flown with sole reference to the instruments. The simulator flight consisted of an entry into the NDB holding pattern and subsequent holds taught by the flight instructor. The student was asked situational awareness questions about the aircraft's present position in the hold and what actions were required to ensure that the aircraft remained in the holding pattern. The student's responses allowed the flight instructor to assess the student's understanding of the instrument procedure. Once the student had gained an understanding of how to fly the NDB holding pattern, and demonstrated an ability to fly the pattern with minimal prompting, the simulator session was completed.

The student then flew the NDB holding pattern lesson in the aircraft with the same flight instructor who had flown with the Control group. The procedure when flying with the SAV-1 group in the aircraft was identical to that of the Control group.

### *The Frasca 141 Simulator Group*

The Frasca 141 group trained in the Frasca 141 simulator with the same flight instructor used for the SAV-1 group, "flying" an aircraft based on a C172. The simulator flight consisted of an entry into the NDB holding pattern and subsequent holds taught by the flight instructor and practised by the student. Once the student had gained an understanding of the holding pattern and shown consistency in flying the patterns with minimal assistance from the flight instructor, the simulator session ended.

The students then flew the NDB holding pattern lesson with the same flight instructor that had flown with the Control Group and the SAV-1 group members. The procedure when flying with the F141 group in the aircraft was identical to that of the other two groups.

# Chapter Four

## Results

### 4.1    Construction of the Independent & Dependent Variables

*Independent Variables*

The independent variables were based on the experimental design of the three independent groups (Control group, SAV-1 group, and F141 group). Group membership was the primary independent variable.

*Dependent Variables*

The dependent variables were constructed from the measurable elements of flying a holding pattern that could be considered as a result of receiving previous simulator training (Table 2). These included: flight time, airborne time, training time, and practice time, which were obtained from the manual recording of points of reference as mentioned in the Method section 3.3.5 (p. 43). The total number of holds flown during the flight, as well as the number of holds flown during the training period, and during the practice period, were also dependent variables. The number of holds was extracted from the manual recording of flight data. The height deviation from the reference altitude during the holding patterns, including: maximum deviation, average deviation, average deviation during the training period and during the practice period, were used as dependent variables. The height deviation was extracted from height tracking data recorded manually at periodic time intervals. The tracking of the aircraft inbound was also used as a dependent variable. The printout of the flight tracking from the GPS tracking system was used to determine the students inbound tracking relative to the nominated inbound track of 310° for the Surrey hold. The measurement was made one nautical mile from the beacon on the inbound leg.

**Table 2.** Descriptions of the Dependent Variables (Lower Values Indicate Better Performance).

| Dependent Variables | Description |
| --- | --- |
| **Flight Time (Minutes)** | Elapsed time from the aircraft taxiing for the flight until the moment it stops at the end of the flight |
| **Airborne Time (Minutes)** | Elapsed time from the aircraft becoming airborne until it lands at the completion of the flight |
| **Flight Training Time (Minutes)** | Elapsed time from beginning the first training hold until instructed to vacate the hold for the practice period |
| **Flight Practice Time (Minutes)** | Elapsed time from beginning the first practice hold until instructed to return to Ardmore airfield |
| **Total Number of Holds Flown in the Aircraft** | Total number of holds flown during the flight |
| **Number of Training Holds Flown in the Aircraft** | Number of holds flown during the training period |
| **Number of Practice Holds Flown in the Aircraft** | Number of holds flown during the practice period |
| **Maximum Deviation from Reference Altitude (Feet)** | Maximum height deviation from the nominated reference altitude while flying the holding pattern |
| **Average Deviation from Reference Altitude (Feet)** | Average height deviation from the nominated reference altitude while flying the holding patterns |
| **Average Deviation from Reference Altitude During the Training Period (Feet)** | Average height deviation from the nominated reference altitude while flying the holding patterns during the training period |
| **Average Deviation from Reference Altitude During the Practice Period (Feet)** | Average height deviation from the nominated reference altitude while flying the holding patterns during the practice period |
| **Average Inbound Tracking Angle from Reference Inbound 310° (Degrees)** | Average angle deviation from the nominated Surrey inbound track of 310° while flying the holding patterns |
| **Average Inbound Tracking Angle from Reference Inbound 310° During the Training Period (Degrees)** | Average angle deviation from the nominated Surrey inbound track of 310° while flying the holding patterns during the training period |
| **Average Inbound Tracking Angle from Reference Inbound 310° During the Practice Period (Degrees)** | Average angle deviation from the nominated Surrey inbound track of 310° while flying the holding patterns during the practice period |

## 4.2   Flight Conditions

Training flights are always conducted in a changing environment. The weather is the largest uncontrolled variable in flight training and a factor that can add difficulty to flight manoeuvres and procedures that are already challenging for the student. An attempt was made to restrict the flights to times of relatively stable weather and flight conditions that would not adversely effect the students' flight performance. As a result, many flights were cancelled when the wind speed was in excess of 30 knots, the crosswind when tracking inbound in the hold was above 25 kts, there was reported turbulence, or the cloud base and visibility was too low to allow the flight to be conducted safely.

## 4.3   Covariates

Three covariates were created in an attempt to remove the impact that the variability of the weather could have on the resulting performance of the students. These were to take into account the wind speed, wind direction and the turbulence of the atmosphere when the flight data was recorded.

*Wind Speed*

The wind direction and speed was recorded for each flight. Auckland International Airport has an Automatic Terminal Information Service (ATIS) which broadcasts the latest weather on a specified radio frequency. The actual 2000 ft wind is included in this broadcast and is reported to the Auckland air traffic control by aircraft that have instrumentation capable of displaying the real time wind direction and speed. The 2000 ft wind speed was used as a covariate because as the wind speed increases, so does the difficulty of flying the NDB holding pattern.

*Crosswind Component*

A second covariate that was directly related to the wind direction and speed was the crosswind component when tracking inbound in the NDB holding pattern at Surrey. The greater the crosswind component, the greater the drift angle required to maintain the correct inbound track while remaining in the holding pattern. Therefore the crosswind component when tracking inbound in the hold was calculated for each student's flight, and the resulting component of crosswind was used as a covariate.

*Turbulence*

The last covariate, which is also weather related, was the air turbulence encountered on each flight. A turbulence scale from 1 to 5 was created to account for various levels of atmospheric disturbance and a rating of each flight was made to account for the difficulty created for the student. On the scale 1 equated to stable conditions, 2 equated to occasional light turbulence, 3 was moderate disturbances, 4 being frequent turbulence, and 5 was continuous disturbances that would make it difficult to maintain altitude and hold a constant heading. These turbulence ratings were assessed by the flight instructor and researcher, and recorded at the conclusion of each.

## 4.4 Data Analysis

The Statistical Package for the Social Sciences (SPSS) software was used to examine the data extracted from the pre-flight questionnaire, the flight data and the post-flight questionnaire. The results for each group of data gathered are presented in the following sections.

### 4.4.1 Pre-flight Questionnaire Results

The Pre-flight questionnaire was used primarily as a tool to discover the students' previous PC simulator experience and to gauge their attitudes

towards the use of PC simulators in their flight training. The questions are listed in the following grey boxes with a brief indication of the results from the ten participants.

| 1. Do you have access to a Personal Computer at home?  Yes / No |
| --- |

All of the participants of this study had access to a PC in their homes.

| 2. Do you have a flight simulator program installed on your PC?  Yes/No |
| --- |

70% of the participants had a PC flight simulator game installed on their home PC.

| 3. Which flight simulator program(s) do you have? |
| --- |

The Microsoft Flight Simulator (MSFS) brand of simulator game was the most commonly used simulator game. These 7 students all had a version of this software, with some having multiple versions. These included MSFS 95, MSFS 98, MSFS 2000, and 5 of the 7 participants had the latest MSFS 2002 version of this software. One participant also had the F22 Raptor simulator game and the F-16 simulator game.

| 4. Why did you purchase this(these) particular flight simulator program(s)? |
| --- |

The reasons for purchasing these flight simulator games varied slightly, however the main reason given was 'to help their flight training.' Other reasons included; 'for the realistic scenery', 'for a game', 'for fun', and 'it was given as a present'.

> 5. Do you have a joystick or control yoke and rudder pedals for your PC?

57.14% of those participants who had a simulator game on their PC also had a joystick. None of them had a control yoke or rudder pedals for their computer.

> 6. To what extent do you use your home PC flight simulator program for your flight training?
>
> (Not very often)     1     2     3     4     5     (Very often)

A mean rating of 1.86 indicates that of these 7 participants, the PC simulator program is used primarily as a game, rather than to help their flight training. The highest rating given for this question was 3, with a majority answering with a rating of 1 or 2.

> 7. How many hours per week, on average, would you use your PC flight simulator?

On average the participants with PC simulators used them 1.56 hours per week. The most a student used their PC simulator a week was 5.00 hours, and the one student did not use it at all.

> 8. To what extent has your home PC simulator program helped your flight training?
>
> (Not effective)     1     2     3     4     5     (Very effective)

A rating of 2.43 for this question indicated that those participants who do utilise their PC simulator for their training think it has some effect, however it was not perceived to be profoundly effective.

9. To what extent have you used PC base flight simulators at your flight training school?

    (Not at all)     1    2    3    4    5    (Extensively)

The results from this question indicated that all of the participants had used a PC-based simulator for their training at their flight school, however some students had been exposed to this training device more than others had. The average rating of 2.5 indicates that the PC simulators at the training school are slightly under-utilised for some of the participants.

10. To what extent do you think the PC-based flight training device that you used was effective?

    (Not effective)    1    2    3    4    5    (Very effective)

The students rated the PC simulator as relatively effective as a training device, with a mean rating of 3.2.

11. To what extent would you like to see more PC simulation in your flight training?

    (No PC simulation)  1  2  3  4  5  (Extensive PC simulation)

All of the students would like to see more PC simulation in their flight training program. The mean rating of 3.9 indicated a positive response from the students to the use of PC–based simulators to enhance flight training.

> 12. To what extent would you use PC simulators if they were available for use during your spare time at your flight training school?
>
> (Never)  1  2  3  4  5  (Frequently)

Half of the participants responded that they would use PC simulators frequently during their spare time if they were made available at their training school. The rating of 4.3 indicates that the students have a positive attitude towards the use of these simulators and would be willing to use them more often, even if it is unsupervised training.

There were no significant differences between the Control, SAV-1, and F141 groups for each question in the Pre-flight Questionnaire.

### 4.4.2   Flight Data Results

The flight data resulting of the aircraft flights was analysed by using a Multivariate Analysis of Variance (MANOVA) test. There was no significant multivariate difference between the group means (*Pillai's* $F_{(14, 4)} = 1.007, p = $ ns).

A Multivariate Analysis of Covariance (MANCOVA) was also conducted using the covariates specified above (see section 4.3, p. 51). None of the covariates showed significant differences between the three groups [Wind Speed: *Pillai's* $F_{(4, 1)} = 1.254, p = $ ns, Crosswind Component: *Pillai's* $F_{(4, 1)} = 0.461, p = $ ns, Turbulence: *Pillai's* $F_{(4, 1)} = 1.351, p = $ ns]. Similarly, the adjusted multivariate test for differences between the groups in terms of the primary dependent variables yielded a non-significant result (*Pillai's* $F_{(8, 4)} = 1.184, p = $ ns).

The univariate results were also analysed to check for significant differences between the groups in terms of the dependent variables used for the aircraft flight (Table 3). No significant difference was found.

Table 3.　Flight Data Analysis of Variance.

| Dependent Variable | Sum of Squares | df | Mean Square | F | Sig. | P |
|---|---|---|---|---|---|---|
| Flight Time | 140.68 | 2 | 70.34 | 1.701 | .250 | ns |
| Airbourne Time | 130.68 | 2 | 65.34 | 1.791 | .235 | ns |
| Flight Training Time | 45.07 | 2 | 22.53 | .549 | .601 | ns |
| Flight Practice Time | 8.98 | 2 | 4.49 | .567 | .591 | ns |
| Total Number of Holds Flown in the Aircraft | .73 | 2 | .37 | .335 | .726 | ns |
| Number of Training Holds Flown in the Aircraft | .93 | 2 | .47 | .377 | .699 | ns |
| Number of Practice Holds Flown in the Aircraft | .07 | 2 | .03 | .100 | .906 | ns |
| Maximum Deviation from Reference Altitude | 540.00 | 2 | 270.00 | .036 | .965 | ns |
| Average Deviation from Reference Altitude | 453.43 | 2 | 226.71 | .281 | .763 | ns |
| Average Deviation from Reference Altitude During the Training Period | 3.17 | 2 | 1.59 | .002 | .998 | ns |
| Average Deviation from Reference Altitude During the Practice Period | 1815.76 | 2 | 907.88 | .486 | .634 | ns |
| Average Inbound Tracking Angle from Reference Inbound 310° | 3.76 | 2 | 1.88 | .350 | .716 | ns |
| Average Inbound Tracking Angle from Reference Inbound 310° During the Training Period | 13.49 | 2 | 6.75 | .641 | .555 | ns |
| Average Inbound Tracking Angle from Reference Inbound 310° During the Practice Period | 14.83 | 2 | 7.41 | .645 | .553 | ns |

As a result of the small sample size and the small membership of each independent group, there were statistical problems that limit the possibility of finding significant differences between the groups. Small sample sizes, which are generally classed as less than 30 subjects, encounter statistical reliability problems when attempting to find significant relationships (McPherson, 2001). Using independent groups significantly increases the likelihood of missing true relationships between groups when using small sample sizes (Hart & Clark, 1999).

Two of the errors associated with attempting to find significant differences between groups are Type I and Type II errors. A Type I error rejects the null hypothesis of no difference, even though in fact there is no difference. A null hypothesis states that differences in the samples are caused by chance or methodological procedures (Sarantakos, 1998). Therefore, a Type I error will cause the researcher to find significant difference results in their study when in fact there was no significant difference between their subjects and the general population. Type I error does not change appreciably as the sample size decreases (Hart & Clark, 1999).

Type II error fails to reject the null hypothesis when in fact it is false. Therefore, a Type II error will cause the researcher to find no significant difference between their subjects and the general population when in fact there was one (Sawilowsky & Hillman, 1992). Type II error increases dramatically in smaller samples, because the confidence interval is wider and therefore more likely to overlap zero (Hopkins, 2003). If the confidence interval values do not overlap zero, the effect being tested is said to be statistically significant. The confidence interval is the estimated range of values that contains the true value being sought by the researcher (Argyrous, 1996). The width of the confidence interval depends on the number of subjects. This means that the larger the sample size, the narrower the confidence interval, and conversely the smaller the sample size, the wider the confidence interval (Hopkins, 2003). Therefore, the small sample size used in this study was not large enough to prevent the

confidence intervals from the dependent variables from overlapping zero and finding no significant differences between the independent groups.

The probability of rejecting the null hypothesis given that the alternative hypothesis is true, is termed the "statistical power" (Thomas & Charles, 1997). A power of 95 % means that the study has enough power to detect the smallest significant differences 95% of the time, with the remaining 5% being the Type II error rate (Hopkins, 2003). The GPOWER V 2.0 program was utilised in a post-hoc calculation to ascertain the resulting powers for each of the flight data variables and determine the number of participants required to detect the differences between the groups with a 95 % power. Table 4 displays the observed effect size (f) and the observed power for the dependent flight variables that were measured. The actual n (sample size) and sample size required for a 95% (0.95) power for each variable is also displayed in the table.

The "effect size" is a way of quantifying the difference between groups and shows the standardised difference between group means (Hopkins, 2003). The greatest effect size result came from the flight time variable, which indicates that there was a relatively large difference between the group means when compare to the other flight variables. The observed power from each of the flight variables indicates that the flight time results had the greatest power of 0.30. This means that with only 10 participants in this study, the best opportunity to detect differences between the independent groups was through the flight time results, however there was only a 30% probability of discovering these significant differences. The last column in Table 4 shows the sample size that is required to achieve a power of 0.95 (95% probability) for each variable. The lowest number of participants required to detect significant differences in flight times between the groups was 42, however most of the variables require a sample size between 117 and 285 to detect significant group differences. Therefore to detect significant group differences with a sample size of 10, the differences between the groups would have to be enormous (Hopkins, 2003).

Table 4.     Post Hoc Power Calculations for Flight Data Variables

| Variables | Observed Effect Size f | Observed Power | Actual n | Required n for 0.95 Power |
|---|---|---|---|---|
| Flight Time | 0.65 | 0.30 | 10 | 42 |
| Airborne Time | 0.62 | 0.28 | 10 | 45 |
| Flight Training Time | 0.35 | 0.12 | 10 | 129 |
| Flight Practice Time | 0.34 | 0.11 | 10 | 135 |
| Total Number of Holds Flown in the Aircraft | 0.26 | 0.09 | 10 | 234 |
| Number of Training Holds Flown in the Aircraft | 0.30 | 0.10 | 10 | 183 |
| Number of Practice Holds Flown in the Aircraft | 0.14 | 0.06 | 10 | 753 |
| Maximum Deviation from Reference Altitude | 0.08 | 0.05 | 10 | 2256 |
| Average Deviation from Reference Altitude | 0.23 | 0.08 | 10 | 285 |
| Average Deviation from Reference Altitude During the Training Period | 0.02 | 0.05 | 10 | 34044 |
| Average Deviation from Reference Altitude During the Practice Period | 0.35 | 0.12 | 10 | 132 |
| Average Inbound Tracking Angle from Reference Inbound 310° | 0.27 | 0.09 | 10 | 222 |
| Average Inbound Tracking Angle from Reference Inbound 310° During the Training Period | 0.37 | 0.12 | 10 | 117 |
| Average Inbound Tracking Angle from Reference Inbound 310° During the Practice Period | 0.36 | 0.12 | 10 | 126 |

Although the statistical tests showed no significant group differences from the flight data gathered during the instrument training flights, there were some trends that are apparent in the group mean results. The means and standard deviations for the Control group, the SAV-1 group and the F141

group, for each of the flight dependent variables are located in Appendix F. The corresponding graphs for each of the flight dependent variables and a brief summary of each graph are presented in this section. The graphs show each individual group member's result, as well as the group mean, which are presented in the following colour codes;

CONTROL        = Aircraft Control Group

SAV-1          = SAV-1 Experimental PC-based Simulator Group

F141           = F141 Experimental FTD Simulator Group

GROUP MEAN = The Group Mean of each of the Control, SAV-1, and F141 Groups

*Flight Time*

The shortest mean flight time was produced by the F141 group (Figure 19). Their average time of 76 minutes for the flight was 1 minute shorter than the SAV-1 group, and 8 minutes shorter than the Control group. This shows the trend that prior training on an approved FTD or PC-based simulator can reduce the flight time required to complete an instrument training lesson.
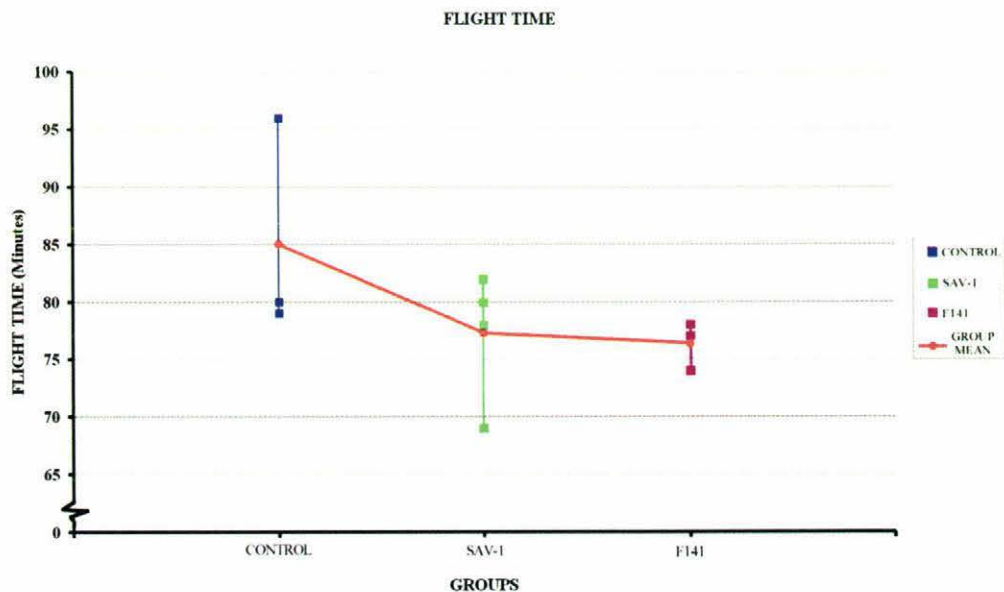


**Figure 19.**    Flight Time (Individual and Mean Results).

## Airborne Time

The Control group spent the most time in the air, on average, when completing the instrument training procedure (Figure 20). The mean airborne time for the Control group was 71 minutes, while the SAV-1 group and F141 group means were 5 minutes and 10 minutes shorter, respectively. This also confirmed that prior training of the instrument procedure on a flight simulator resulted in a reduction of the time required to meet the holding criterion.



**AIRBORNE TIME**

**Figure 20.**    Airborne Time (Individual and Mean Results).
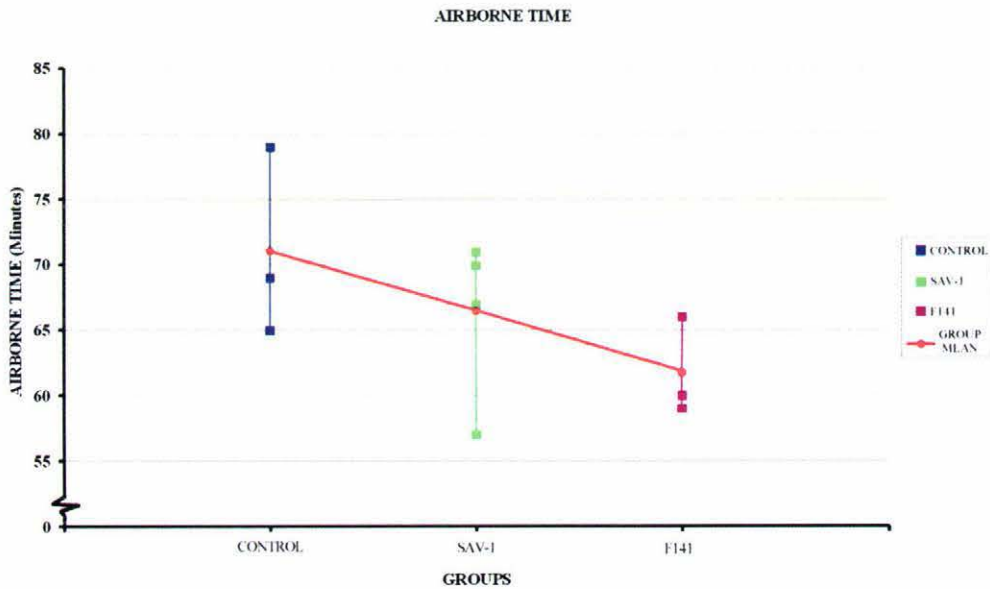
## Training Time

The training time in the actual aircraft required before the students attempted practising the holding, revealed that the Control group had the longest mean time (Figure 21). The SAV-1 group was almost two minutes shorter in required training time and the F141 group finished their training period 5 minutes on average earlier than the Control group.
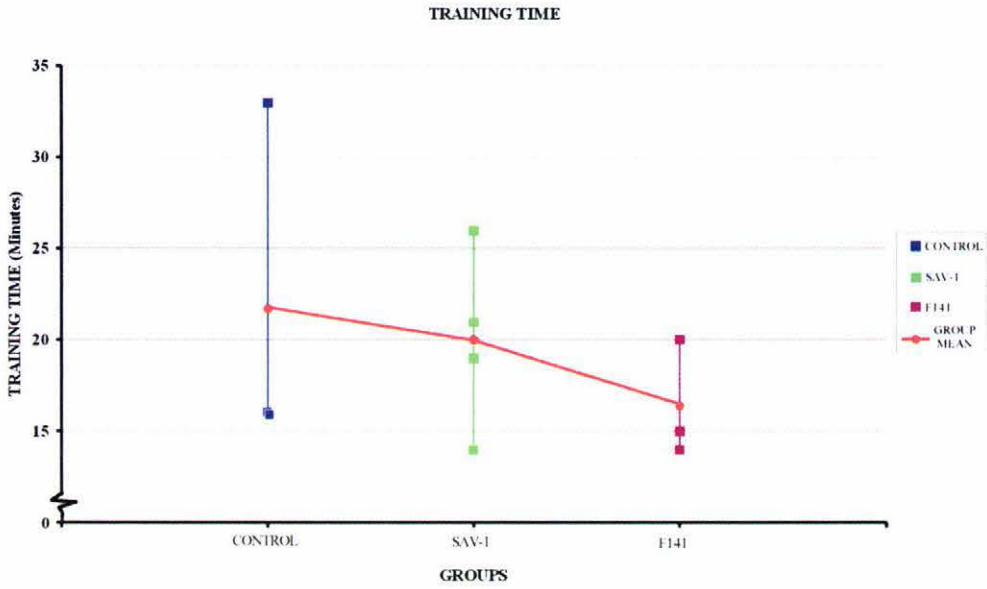
**TRAINING TIME**



**Figure 21.**  Training Time (Individual and Mean Results).

## *Practice Time*

The resulting practice times were 14 minutes for the Control group, less than 12 minutes for the SAV-1 group, and just over 12 minutes for the F141 group (Figure 22). The Control group mean time was the highest as would be anticipated for a group of students who had not received prior training on a flight simulator, and therefore requiring more time in the aircraft to reach the specified criterion for the holding pattern procedure.
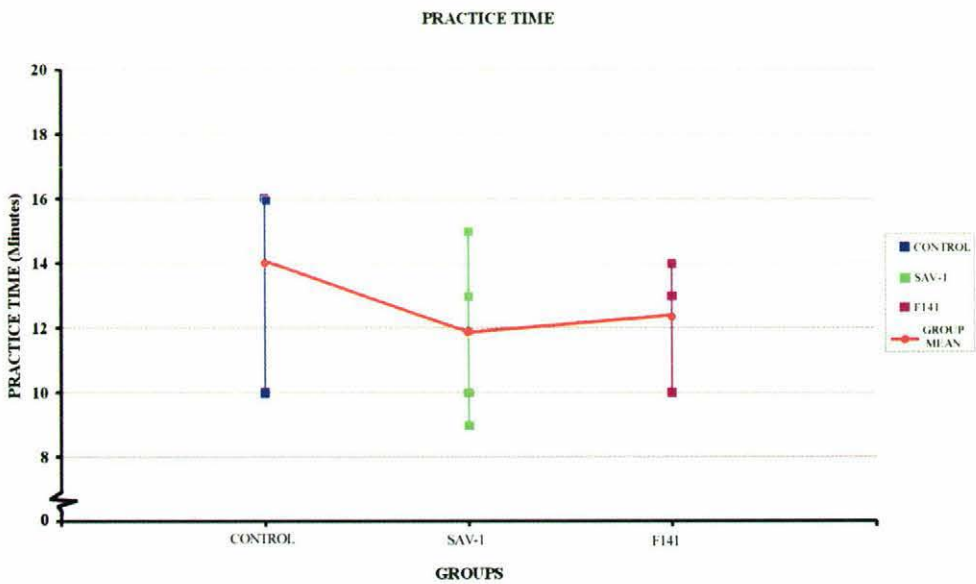
**PRACTICE TIME**



**Figure 22.**  Practice Time (Individual and Mean Results).

### *Total Number of Holds Flown*

The total number of holding patterns flown in the aircraft ranged from 5 to 8 holds (Figure 23). The mean number of holds shows that the F141 group completed 6 holds, the SAV-1 group completed 6.50 and the Control group completed the greatest amount of holds with a mean value of 6.67 holds. The result reveals that on average the groups with prior simulator training required fewer holding patterns to complete the instrument lesson.
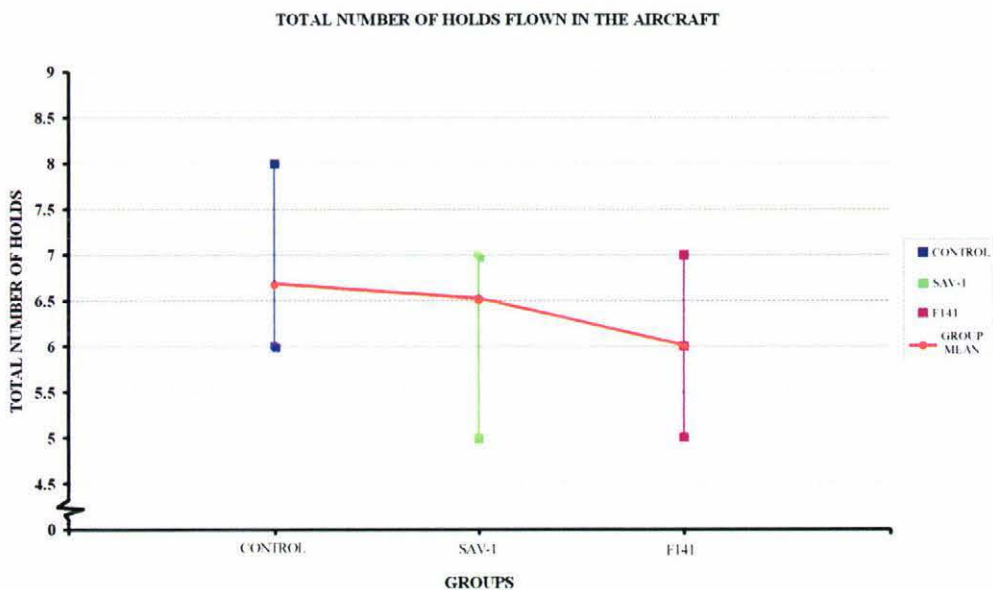


**Figure 23.**    Total Number of Holds Flown in the Aircraft (Individual and Mean Results).

## *Number of Training Holds*

The training period resulted in the number of holds ranging from 3 to 6 holds (Figure 24). The F141 group had the lowest number of training holds with a mean of 3.33, while the SAV-1 and Control groups each had a group mean of 4.
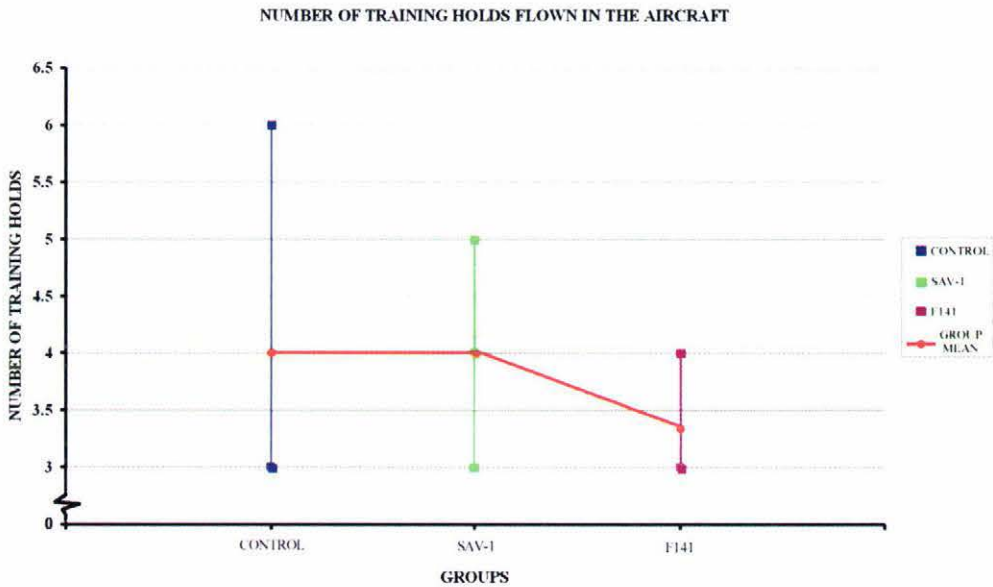


**Figure 24.**    Number of Training Holds Flown in the Aircraft (Individual and Mean Results).

## *Number of Practice Holds*

The resulting number of practice holds required to achieve the specified holding criterion were almost the same for the means of each group (Figure 25). The Control group and the F141 group both required 2.67 holds before they were considered to have reached the required standard and were instructed to vacate the Surrey hold to return to Ardmore airfield. The SAV-1 group reached the standard earlier requiring a mean number of 2.5 holds before they here judged to have met the criterion.

NUMBER OF PRACTICE HOLDS FLOWN IN THE AIRCRAFT
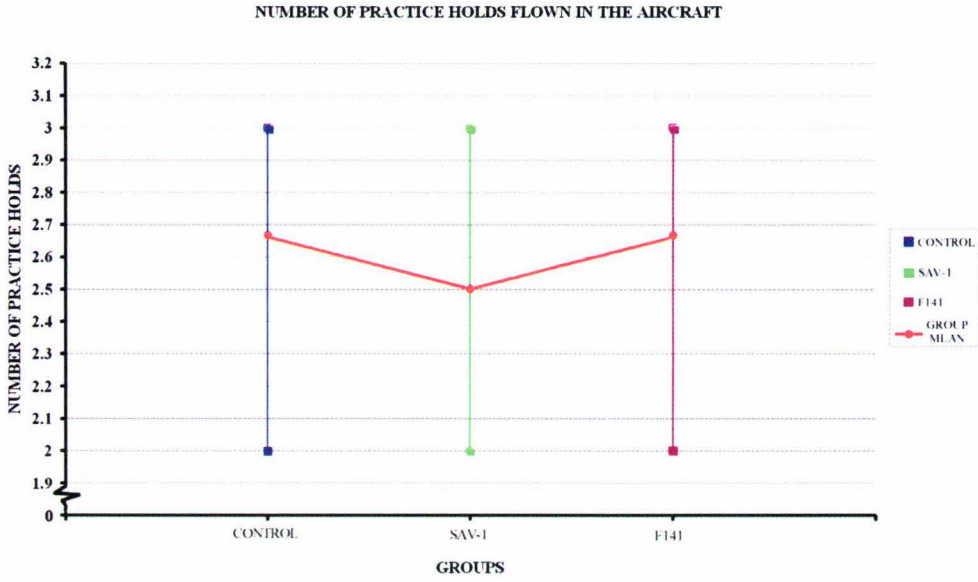


**Figure 25.**    Number of Practice Holds Flown in the Aircraft (Individual and Mean Results).

## *Maximum Deviation from Reference Altitude*

During the holding patterns the maximum height deviation for each student was recorded and the resulting group mean maximum deviations were compared (Figure 26). The Control group and the F141 group had the same mean of 200 ft, while the SAV-1 group had a slightly higher mean of 215 ft.

MAXIMUM DEVIATION FROM REFERENCE ALTITUDE
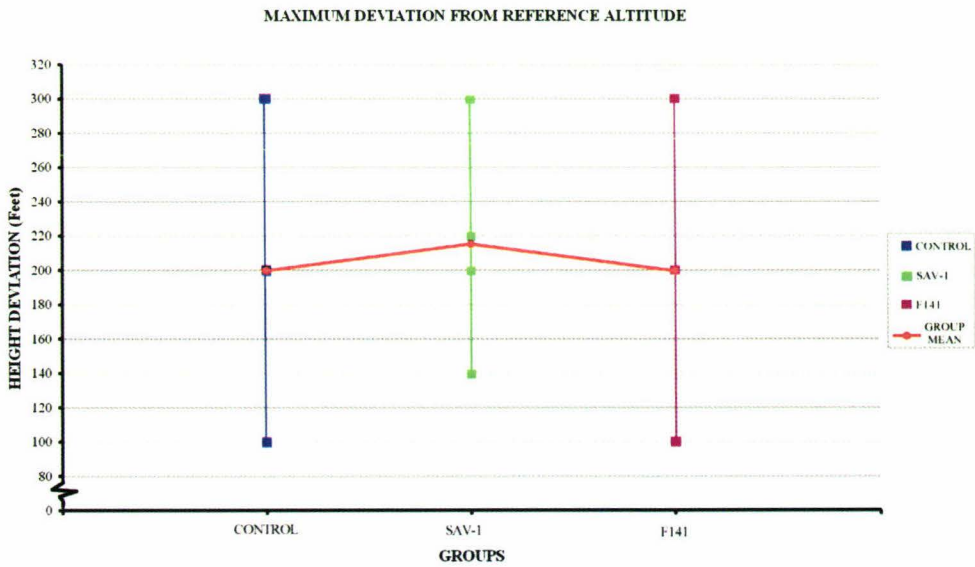


**Figure 26.**    Maximum Deviation from Reference Altitude (Individual and Mean Results).

## *Average Deviation from Reference Altitude*

The average deviation from the reference altitude during the holding patterns was calculated for each student (Figure 27). The results showed that the F141 group had the highest mean deviation of 84 ft, the Control group had a mean deviation of 71 ft, and the SAV-1 group was had the lowest mean altitude deviation of 68 ft. The F141 group would have been expected to produce similar altitude holding performance as the SAV-1 group, as the prior simulator training was expected to help reduce the students' workload and increase their accuracy when flying the holding pattern.
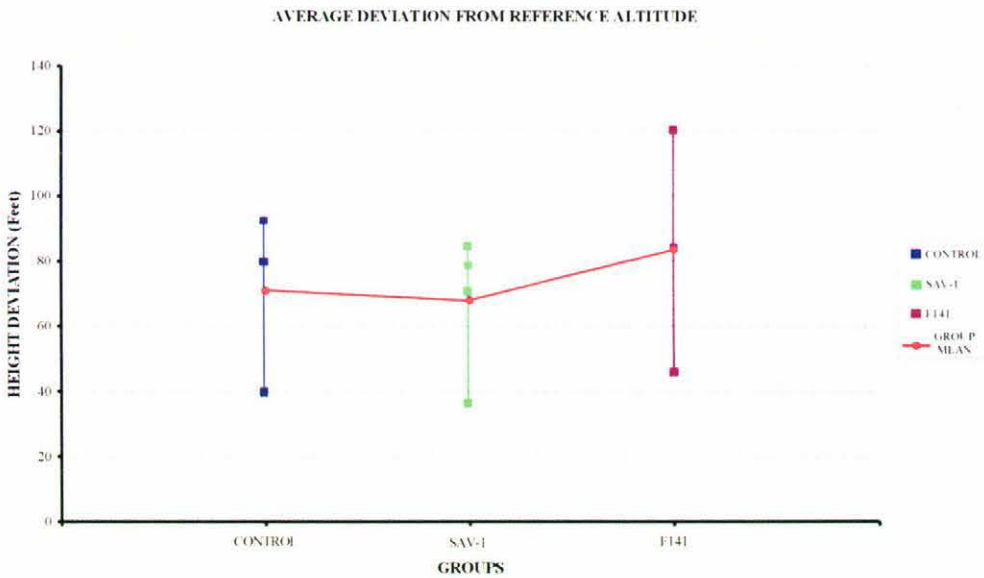


**Figure 27.**    Average Deviation from Reference Altitude (Individual and Mean Results).

## *Average Deviation from Reference Altitude During Training*

The mean deviations from the reference altitude during the training period showed that the groups produce similar altitude holding performance (Figure 28). The Control group's mean was 68.42 ft, the SAV-1 group's mean was 67.55 ft, and the F141 group's mean was 66.97 ft. The two simulator groups producing marginally better altitude holding, however during the training period the instructor ensured that the student was aware of any altitude deviation, which would have helped to regulate the resulting altitude deviation means.
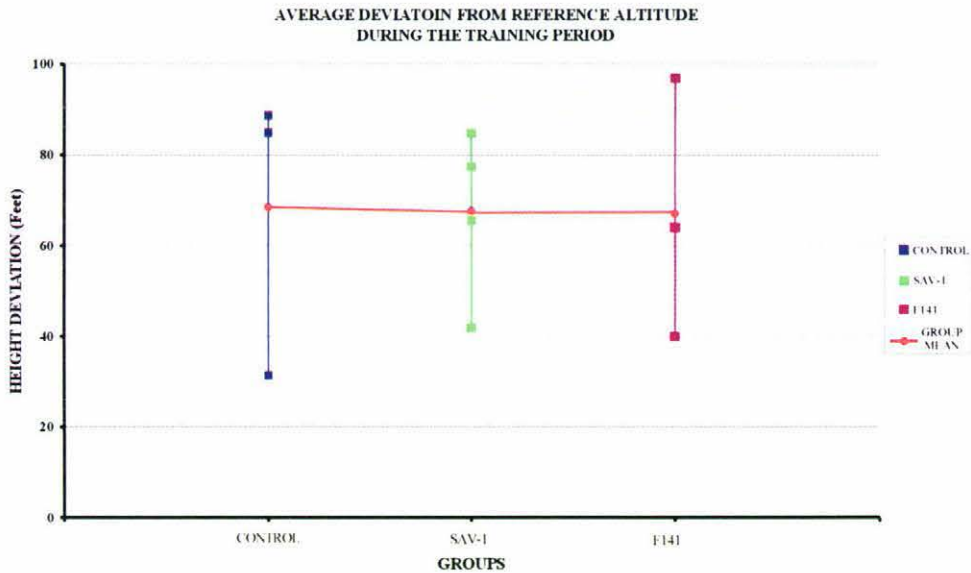


**Figure 28.**    Average Deviation from Reference Altitude During the Training Period (Individual and Mean Results).

### *Average Deviation from Reference Altitude During Practice*

During the practice period the students flew the NDB holding pattern with minimal prompting from the flight instructor. The resulting average altitude deviations for each group revealed that the Control group and SAV-1 group had similar means of 77.49 ft and 77.82 ft (Figure 29). The F141 group's mean of 107.08 ft was a sign that the group did not perform to expectations. The prior simulator training for the F141 group was expected to have produced results that were consistently better than the Control group.
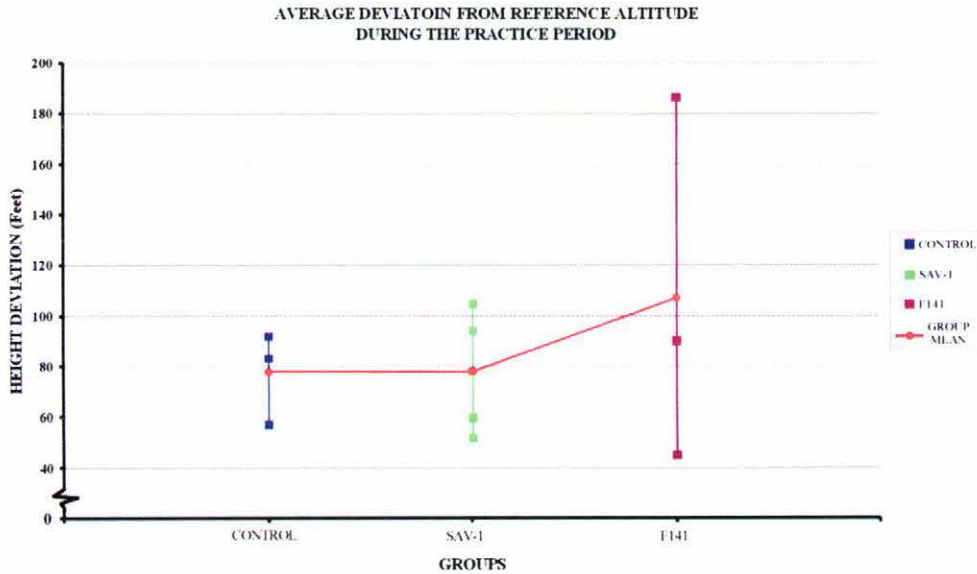


**Figure 29.**     Average Deviation from Reference Altitude During the Practice Period (Individual and Mean Results).

### Average Inbound Tracking Angle from Reference Inbound

The inbound tracking angle was compared to the nominated inbound track of 310° to determine the angular difference. The tracking deviation during the inbound leg was compared by using the group mean deviation results (Figure 30). The SAV-1 group had the closest tracking with a mean deviation of 6.37°. The Control group and F141 group had similar inbound tracking results with means of 7.61° and 7.63°. This demonstrates once again that the resulting flight performance from the F141 group was less than expected.
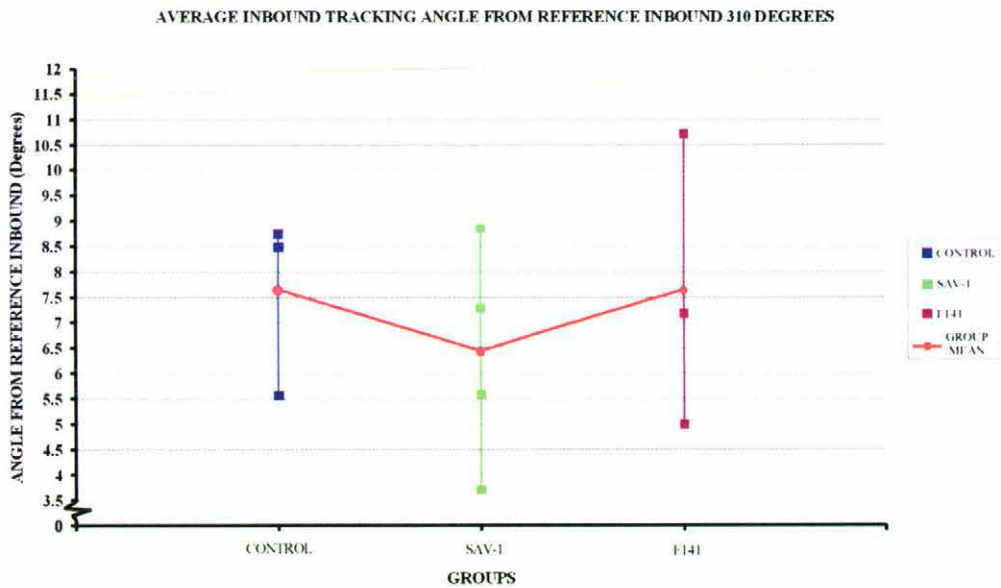


**Figure 30.** Average Inbound Tracking Angle from Reference Inbound 310 Degrees (Individual and Mean Results).

*Average Inbound Tracking Angle from Reference Inbound During Training*

During the training period the SAV-1 group produced the closest tracking to the required inbound track with a mean deviation angle of 6.18° (Figure 31). The Control group was the next with an average tracking deviation of 7.89° and then the F141 group with an average of 8.92°.
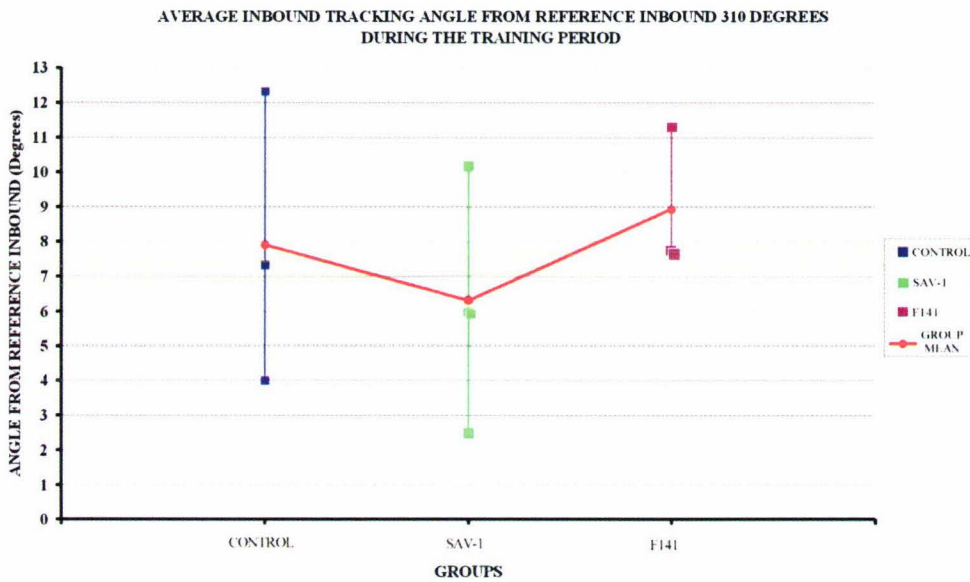


**Figure 31.**    Average Inbound Tracking Angle from Reference Inbound 310 Degrees During the Training Period (Individual and Mean Results).

*Average Inbound Tracking Angle from Reference Inbound During Practice*

The practice period results showed a similar trend to the training period results (Figure 32). The SAV-1 group's mean was 6.21°, the Control group's mean was 8.45°, and the F141 group mean was 8.89°. The SAV-1 group therefore produced the best tracking performance of the three groups, and the F141 group did not perform to prior expectations.
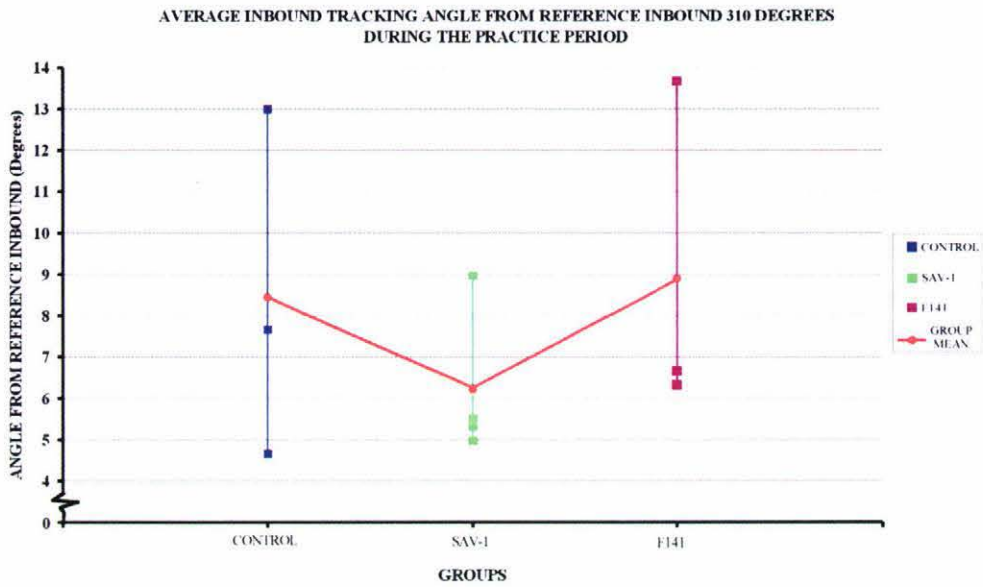
**Figure 32.**     Average Inbound Tracking Angle from Reference Inbound 310 Degrees During the Practice Period (Individual and Mean Result).

In summary, the timing results from the flight indicated that the Control group mean had greatest elapsed time in all of these cases. The F141 group mean times were the lowest for all but the practice time, which was achieved by the SAV-1 group. Overall the Control group had the greatest mean number of holds, followed by SAV-1 group, and finally the F141 group with the least mean number of holds. The SAV-1 group had the lowest mean height deviation from the reference altitude, followed by the Control group, and the F141 group had the greatest mean altitude deviation. Finally, the SAV-1 group had the best inbound tracking with the smallest mean deviation from the inbound track, followed by the Control group and F141 group which had similar inbound tracking results.

### 4.4.3 Post-flight Instructor Questionnaire Results

The students' performance was rated by the Post-flight Instructor questionnaire. The results were analysed by using a MANOVA test. There was no significant multivariate difference between the group means (*Pillai's* $F_{(14, 4)} = 1.008$, $p =$ ns).

The univariate results were also analysed to check for significant differences between the groups (Table 5). No significant difference was found with the questionnaire results. The group means and standard deviations for the Questionnaire are displayed in Appendix G, and are displayed in the following section by the use of graphs.

**Table 5.** Univariate Results for the Post-flight Instructor Questionnaire.

| Dependent Variable | Sum of Squares | df | Mean Square | F | Sig. | *P* |
|---|---|---|---|---|---|---|
| Height holding in the aircraft in general | 1.483 | 2 | .742 | .387 | .693 | ns |
| Conscious attempt to regain assigned altitude in the aircraft | .667 | 2 | .333 | .206 | .819 | ns |
| Attempt to maintain the correct inbound tracking in the aircraft | 1.517 | 2 | .758 | .526 | .612 | ns |
| Demonstrated an improvement in flying the correct holding pattern in the aircraft | .233 | 2 | .117 | .175 | .843 | ns |
| Demonstrated an understanding of the holding procedure in the aircraft | .233 | 2 | .117 | .064 | .938 | ns |
| Rate the student's performance based on your expectations of a student learning to fly this procedure | .183 | 2 | .092 | .048 | .954 | ns |

## Height Holding in General

The instructor judged the Control group members to have the best height holding in general with a mean of 3.67 (Figure 33). The F141 group was rated with a mean score of 3.00 and the SAV-1 group's mean was 2.75.

HEIGHT HOLDING IN GENERAL
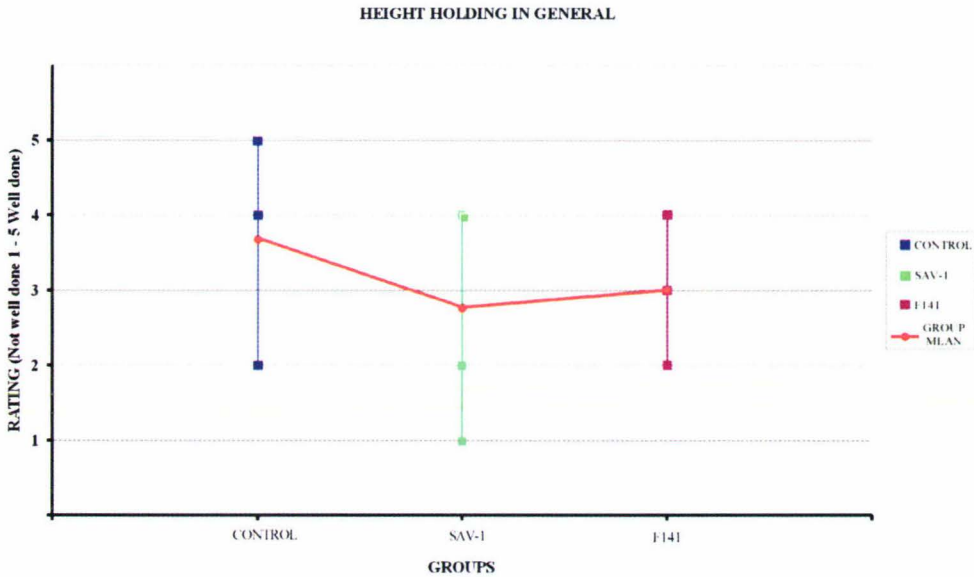


**Figure 33.** Height Holding in General (Individual and Mean Results).

## Attempt to Regain Altitude

The flight instructor rated the Control group as the group that most attempted to regain their reference altitude once they had deviated from it (Figure 34). The Control group's mean score was 3.33, the SAV-1 group's mean score was 3.00, and the F141 group's mean score was 2.67. This result indicated that the F141 and SAV-1 groups were not attempting to regain their reference altitude as much as the Control group.

75

ATTEMPT TO REGAIN ASSIGNED ALTITUDE
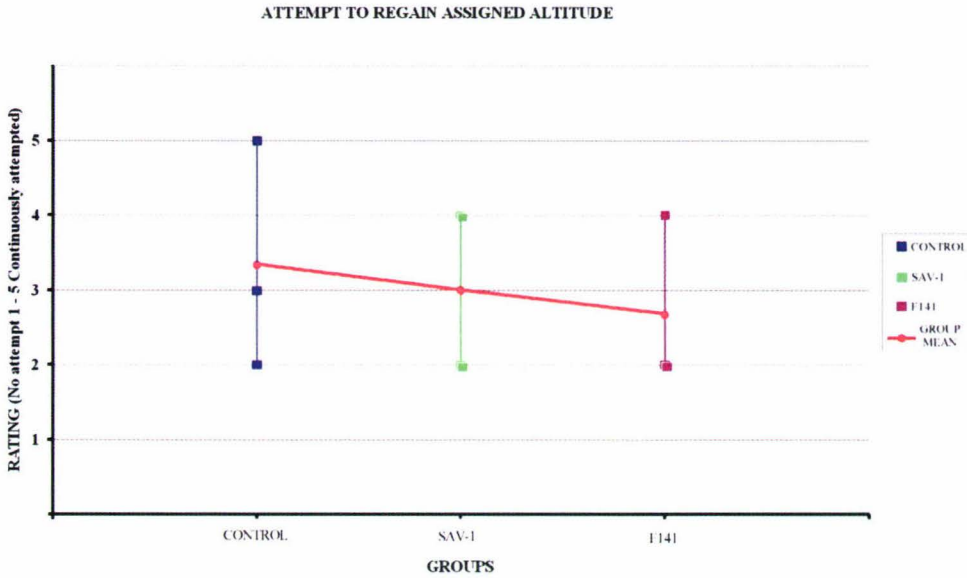


**Figure 34.**     Attempt to Regain Assigned Altitude (Individual and Mean Results).

## *Attempt to Maintain the Correct Inbound Tracking*

The F141 group was rated as being the best group when attempting to maintain the correct inbound tracking in the hold (Figure 35). The F141 group's mean score was 3.67, the SAV-1 group was next with a mean rating of 3.00, and the Control group received the worst mean rating of 2.67. This indicated that the two simulator groups were more conscious of maintaining the correct inbound tracking, which had been practised previously in the simulators.

ATTEMPT TO MAINTAIN CORRECT INBOUND TRACKING
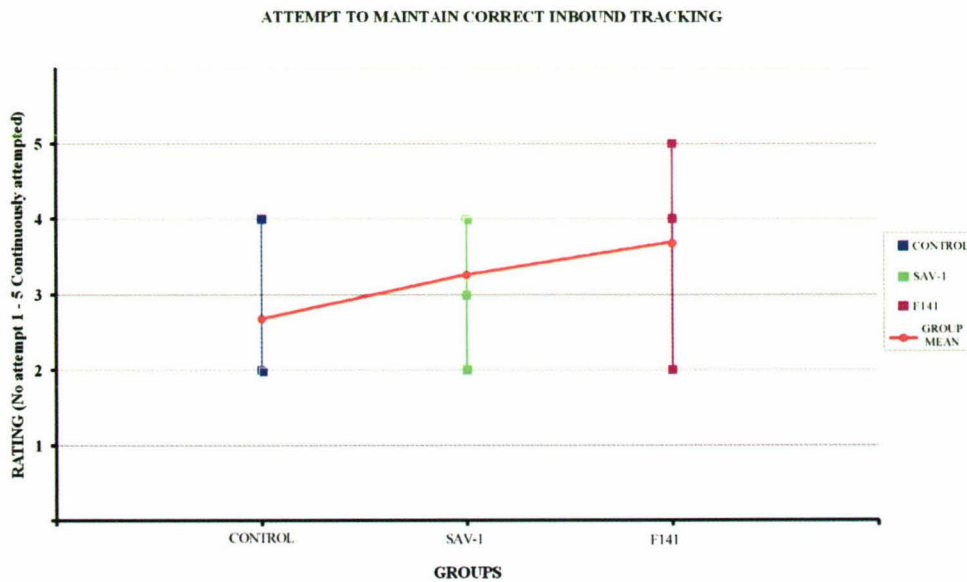


**Figure 35.**     Attempt to Maintain Correct Inbound Tracking (Individual and Mean Results).

### *Demonstrated an Improvement in Flying the Holding Pattern*

The greatest improvement in flying the holding patterns was judged to have come from the Control group with a mean score of 4.33 (Figure 36). The two simulator groups scored the same mean of 4.00. This indicates that the SAV-1 and F141 groups did not display a vast improvement during the lesson as they had already practised the procedure in the simulator and therefore there was not the ability to improve as much as the Control group.
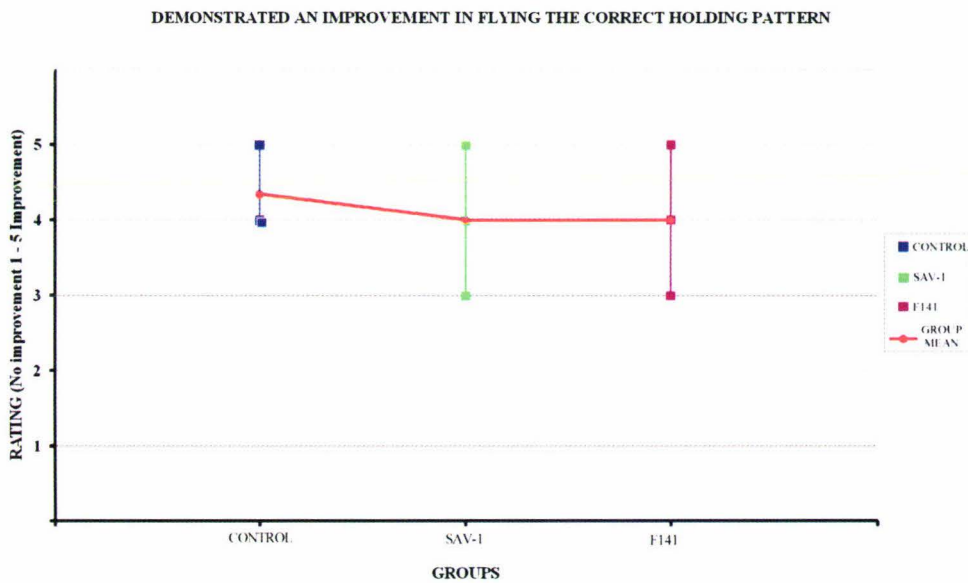


**Figure 36.** Demonstrated an Improvement in Flying the Correct Holding Pattern (Individual and Mean Results).

### *The Student's Understanding of the Holding Pattern Procedure*

The instructor judged that the SAV-1 and F141 groups had a good understanding of the holding pattern procedure and rated both groups with a mean rating of 4.00 (Figure 37). The Control group received a mean rating of 3.67 indicating that their understanding of how to fly and maintain the correct holding procedure, was not as comprehensive as the simulator groups.

THE STUDENT'S UNDERSTANDING OF THE HOLDING PATTERN PROCEDURE
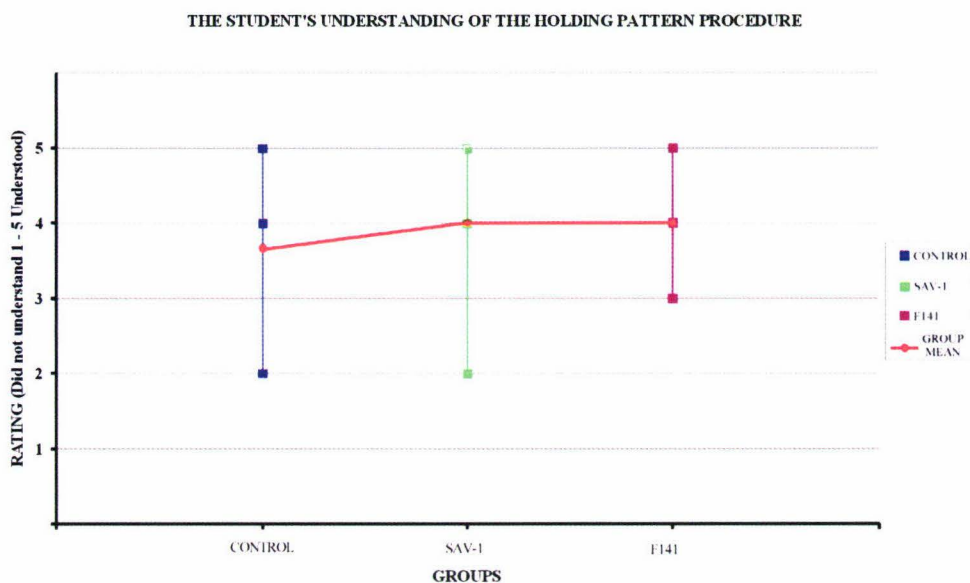


**Figure 37.** The Student's Understanding of the Holding Pattern Procedure (Individual and Mean Results).

## *Rate the Student's Performance*

The instructor was asked to rate the student's performance for the flight. All of the groups received mean ratings above the average score of 3.00 (Figure 38). The Control group received the highest rating of 4.00, the SAV-1 group's mean rating was 3.75, and the F141 group's mean rating was 3.67.

RATE THE STUDENT'S PERFORMANCE
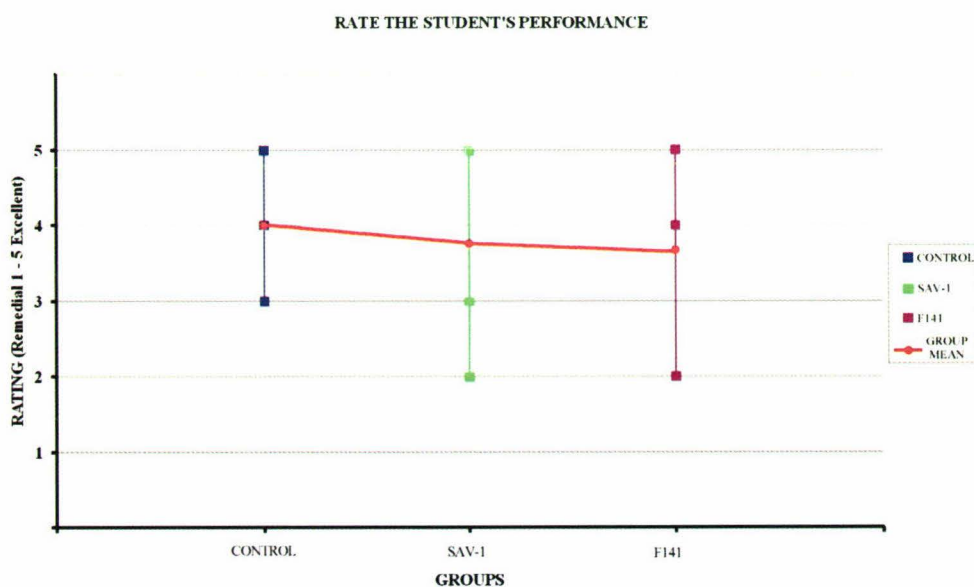


**Figure 38.** Rate the Student's Performance (Individual and Mean Results).

***Which Group Do You Think This Participant Belongs to?***

The last question of the Post-flight instructor questionnaire was designed to see if the instructor was able to place the student's performance in either the group with previous simulator training on the procedure, or the group with no previous simulator training. The instructor's overall success rate was 50%, meaning they were able to correctly place 5 of the 10 participants in the correct groups as mentioned above. The results generated from this question are inconclusive. They could be a consequence of chance, as much as they could be a consequence of the instructor's experienced judgement, as there would be a 50% chance of guessing correctly if a participant belongs to a simulator group or aircraft group. The incorrect placement of the students occurred in each of the two experimental groups and the control group. The Control group had two students judged to be from a group with previous simulator training, the SAV-1 group had 2 members judged to have had no previous training, and the F141 group had 1 member judged to have had no previous training. This could mean that some individuals performed better than they were expected to for their group membership and some individuals performed worse than was expected for their group membership.

## 4.5    Percent Transfer Results

The percent transfer equation (refer Equation 1, p. 14) was used to calculate the individual and group mean percent transfer for the SAV-1 and F141 groups. The percent transfer for all of the students who received prior training on a flight simulator was small but positive (Table 6). This positive transfer from the simulator to the aircraft ranged from 3.53% to 18.82%. The average percent transfer for the two simulator groups was 9.12% for the SAV-1 group and 10.19% for the F141 group. The F141 group therefore produced a slightly better percent transfer for the instrument holding procedure.

**Table 6.**     Percent Transfer Results for SAV-1 & F141 Groups.

| Participants | $Yc^*$ | $Yx$ | $Yc\text{-}Yx$ | $Yc\text{-}Yx/Yc$ | % Transfer |
|---|---|---|---|---|---|
| **SAV-1** | | | | | |
| 1 | 85 | 78 | 7 | 0.0824 | 8.24 % |
| 2 | 85 | 69 | 16 | 0.1882 | 18.82 % |
| 3 | 85 | 82 | 3 | 0.0353 | 3.53 % |
| 4 | 85 | 80 | 5 | 0.0588 | 5.88 % |
| **SAV-1 Mean** | 85 | 77.25 | 7.75 | 0.0912 | 9.12 % |
| **F141** | | | | | |
| 1 | 85 | 74 | 11 | 0.1294 | 12.94 % |
| 2 | 85 | 77 | 8 | 0.0941 | 9.41 % |
| 3 | 85 | 78 | 7 | 0.0824 | 8.24 % |
| **F141 Mean** | 85 | 76.33 | 8.67 | 0.1019 | 10.19 % |

\* Mean Control Group Flight Time

**SAV-1 = SAV-1 Experimental PC-based Simulator Group**

**F141 = F141 Experimental FTD Simulator Group**

## 4.6     Transfer Effectiveness Ratio Results

The TER equation (refer Equation 2, p. 16) was used to calculated the individual and group mean TERs for the SAV-1 and F141 groups. The TERs for all of the students who received prior training on a flight simulator were small but positive (Table 7). This positive transfer from the simulator to the aircraft equated to a reduction of flight time ranging from 3 minutes to 17 minutes, per hour of simulator training. The average TERs for the two simulator groups were 0.1366 for the SAV-1 group and 0.1557 for the F141 group, which are represented graphically in Figure 39 as the red group mean points. This equates to respective mean savings of 8 and 9 minutes, per hour of simulator training. The F141 group therefore produced a slightly better TER than the SAV-1 group for the instrument holding procedure.

**Table 7.**    Transfer Effectiveness Ratio for SAV-1 & F141 Groups.

| Participants | $Yc*$ | $Yx$ | $Yc-Yx$ | $X$ | $TER$ |
|---|---|---|---|---|---|
| **SAV-1** | | | | | |
| 1 | 85 | 78 | 7 | 55 | 0.1273 |
| 2 | 85 | 69 | 16 | 56 | 0.2857 |
| 3 | 85 | 82 | 3 | 56 | 0.0536 |
| 4 | 85 | 80 | 5 | 60 | 0.0833 |
| **SAV-1 Mean** | 85 | 77.25 | 7.75 | 56.75 | 0.1366 |
| **F141** | | | | | |
| 1 | 85 | 74 | 11 | 49 | 0.2245 |
| 2 | 85 | 77 | 8 | 58 | 0.1379 |
| 3 | 85 | 78 | 7 | 60 | 0.1167 |
| **F141 Mean** | 85 | 76.33 | 8.67 | 55.67 | 0.1557 |

\* Mean Control Group Flight Time

**SAV-1 = SAV-1 Experimental PC-based Simulator Group**

**F141 = F141 Experimental FTD Simulator Group**
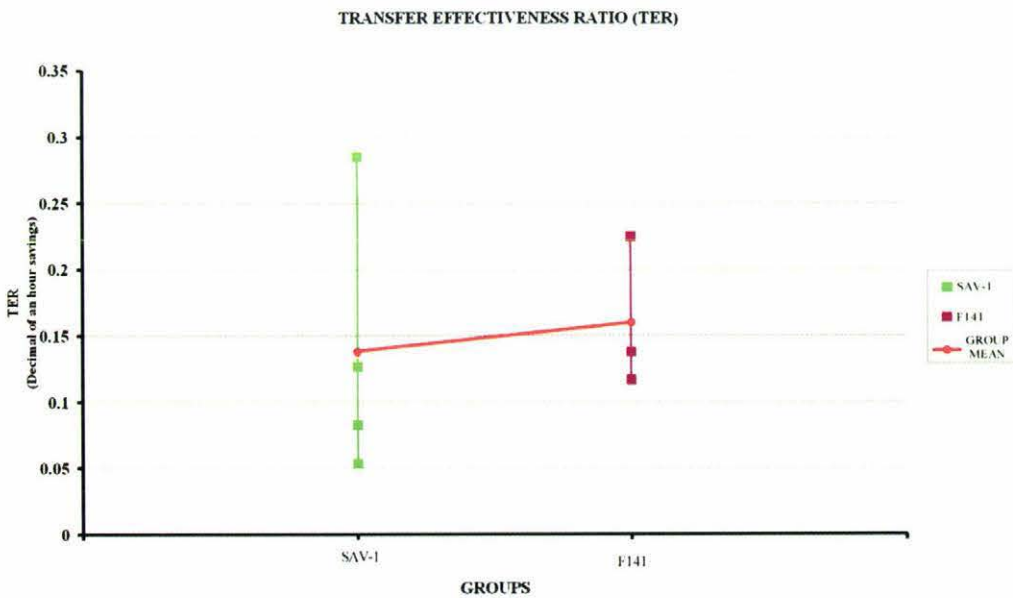


**Figure 39.**    Transfer Effectiveness Ratios for the SAV-1 and F141 Groups (Individual and Mean Results).

## 4.7    Cost Benefit Results

The Cost Benefit equation (refer Equation 4, p. 20) was used to calculate the financial savings that resulted from the use of the SAV-1 and F141 simulators for learning the NDB holding procedure. The individual flight times and TERs were used to calculate the individual Cost Benefits for the members of the two simulator groups. The hourly rates of the aircraft and simulators have had to be estimated for this study, as there were no specific rates available from Massey University. The hourly rate for a C172R aircraft is $160 per hour, which is older and less powerful than a C172SP, which has been given an estimated hourly rate of $170. The cost of the aircraft in Table 8 includes the hourly rate of $30 for the flight instructor. The SAV-1 PC-based simulator does not currently have an hourly rate. The estimated cost of the simulator to construct would be 10% the cost of buying a Frasca 141 FTD and therefore for the purposes of this study, the SAV-1 has been given an arbitrary hourly rate of $15, to account for purchase, running, and development costs. The cost of the SAV-1 simulator in Table 8 includes the hourly rate of $30 for the flight instructor. The hourly rate of the Frasca 141 FTD was unavailable, however a more complicated instrument flight simulator (the AST 300 multi-engine aircraft simulator) is charged at a rate of $100 per hour. Therefore, the Frasca 141 simulator was estimated to have an hourly rate of $50 for the purposes of this study. The cost of the Frasca 141 simulator in Table 8 includes the flight instructor rate of $30 per hour.

The Cost Benefit results revealed that the simulators generally cost the students extra expenditure for their training (Table 8). Only one of the students received a financial saving from the simulator training. The SAV-1 group cost benefit ranged from –$32.00 to $11.33. The F141 group cost benefit ranged from –$56.67 to –$28.67. The SAV-1 mean cost benefit of –$16.72 was less than half the cost of F141 group mean of -$45.33. These results reveal that the expected cost benefit from using simulator training prior to an aircraft instrument flight did not eventuate for this particular instrument holding procedure.

**Table 8.**     Cost Benefit Results for the Sav-1 Group and the F141 Group.

| Participants | $X$ (Hours) | *TER* | *Ca*\* | *Cs*\* | *Cost Benefit* \* |
|---|---|---|---|---|---|
| **SAV-1** | | | | | |
| 1 | 0.9167 | 0.1273 | 200 | 45 | -17.92 |
| 2 | 0.9333 | 0.2857 | 200 | 45 | 11.33 |
| 3 | 0.9333 | 0.0536 | 200 | 45 | -32.00 |
| 4 | 1.0000 | 0.0833 | 200 | 45 | -28.33 |
| **SAV-1 Mean** | 0.9458 | 0.1366 | 200 | 45 | -16.72 |
| **F141** | | | | | |
| 1 | 0.8167 | 0.2245 | 200 | 80 | -28.67 |
| 2 | 0.9667 | 0.1379 | 200 | 80 | -50.67 |
| 3 | 1.0000 | 0.1167 | 200 | 80 | -56.67 |
| **F141 Mean** | 0.9278 | 0.1557 | 200 | 80 | -45.33 |

\* Hourly Rates in NZ Dollars

SAV-1 = **SAV-1 Experimental PC-based Simulator Group**

F141 = **F141 Experimental FTD Simulator Group**

**Chapter Five**

**Discussion**

## 5.1 Introduction

This section discusses the implications of the results generated from this study, and their relevance to flight training organisations as well as making recommendations for future research in the area of flight simulators. The study set out to investigate the effectiveness of two different flight simulators when students were given prior training on the NDB instrument holding procedure. The literature provided an insight into the previous research that tested simulators for transfer of training, however there was limited research focussing on the comparison of simulators and the performance that resulted when subjects were tested in the aircraft. This study attempts to compare an approved FTD with a non-approved PC-based flight simulator, as well as confirm that there is a positive transfer of training to the aircraft.

## 5.2 Pre-flight Questionnaire

The Pre-flight Questionnaire was used to assess the students' previous PC simulator experience and determine their attitudes towards the use of PC simulators in their flight training. The questionnaire was also used to determine whether there could be covariates required for the flight data analysis to account for previous PC simulator experience and the possible effects that these may have on the outcome of the study.

The Pre-flight Questionnaire revealed that all of the participants had access to a home PC and 70% of them had a version of the Microsoft Flight Simulator program installed on their computer. This indicates that the home PC has become a more common piece of equipment in people's homes as the cost of computer technology has decreased and PC-based simulator software is easily accessible, affordable and can be used as a

game or a device for practising flying procedures while at home. 57.14% of those participants with a simulator game used a joystick to control the aircraft, while the remaining people used the keyboard or mouse. This indicates that control yoke and rudder pedals combinations may still be too expensive for home PC use, when cheaper joysticks are able to be used to good effect, even though they may not replicate the controls of many aircraft accurately.

It appears that the group of participants who have the PC simulators use them primarily as games as the extent of use was rather low and equated to an average of 1.56 hours per week. The questionnaire results also indicated that the simulator was below average as an effective training tool when used on the participant's home PC.

All of the participants had used a PC-based simulator for their training at their flight school. Although the amount of use of this simulator use varied among the students and on the whole appeared to be under-utilised, the students rated it as an effective training device and wanted to see more use of it for their flight training. The positive attitude towards the utilisation of the PC-based simulator is an important step towards making the training device effective (Rolfe, Cook, & Durose, 1986). They were also very positive about using the PC simulator for their flight training during their spare time, even if they were unsupervised.

The Pre-flight Questionnaire therefore revealed that the students did not have much experience with PC-based simulators for training at home, although they did have access to computers and most of they had a simulator game installed on them. They all had limited experience with a PC-based simulator at their flight school, but believed it was an effective training device, and they all wanted more PC simulator time in their flight training, which shows that they have a positive attitude to the utilisation of the training device. This Pre-flight Questionnaire did not reveal any significant differences between the independent groups used in this study.

## 5.3    Flight Data

The flight data did not produce any statistically significant differences between the groups, however there were expected trends apparent in the group mean results. The expectations were based on the findings of the previous transfer of training studies that were discussed in section 2.8 (p. 22). It was anticipated that there would be positive Percent Transfers and positive TERs for each of the simulators, and that the resulting performance of the members from the simulator groups would be similar and that both simulator groups would produce better performance results than the aircraft group.

The flight time, airborne time, training time, and practice time results indicated that the Control group mean had greatest elapsed time in all of these cases. The F141 group mean times were the lowest for all but the practice time, which was achieved by the SAV-1 group. This indicated that both simulator groups reached the performance criteria before the Control group and therefore the prior training helped to reduce the student's flight time. The F141 simulator group generally produced lower time than the SAV-1 group, which would be expected when comparing a CAA approved FTD to a PC-based simulator.

The mean total number of holds flown for each group revealed that the Control group flew the most, followed by the SAV-1 group and then the F141 group with the least number of holds. During the training period the Control and SAV-1 groups required the same number of mean holds, while the F141 required less holds before being required to fly the holding pattern with limited prompting from the flight instructor. The practice period revealed that the SAV-1 mean number of holds was the least and that the Control and F141 group required the same mean number of holds to reach proficiency in flying the NDB holding pattern. This indicates that the simulator groups required fewer training and total number of holds than the aircraft group, however once the students had learned how to fly

the holding pattern in the aircraft, only two to three practice holds were required to prove that they were proficient and consistent.

The maximum deviation from the reference altitude was the same for the Control and F141 groups, and the SAV-1 group had a slightly higher maximum deviation. The resulting mean maximums were relatively similar which would suggest that this is not a good indicator of group differences and that prior simulator training did not effect this element of the flight. This was unusual as prior simulator training was expected to help improve the student's ability to maintain a constant altitude while flying the holding pattern and in theory would have helped to reduce the maximum height deviation for the two simulator groups. This may indicate that the students' focus may have been directed more towards flying the holding pattern shape correctly, and the altitude may have become a secondary consideration.

The average deviation from the reference altitude was an indication of the participants' ability to maintain their altitude and attempt to regain this datum when the aircraft deviated from it. The SAV-1 group was the best of the groups, with a slightly better mean average deviation from the reference altitude than the Control group. The F141 group recorded the worst mean deviation, which was unexpected. It was believed that the prior training in the F141 simulator would have produced similar altitude deviation results as the SAV-1 group.

During the training period the group mean average deviation from the reference altitude was the similar for all groups, with the two simulator groups recording slightly better performance than the aircraft group. The similarity in height deviation may have been a result of the flight instructor's influence during this part of the flight. The NDB holding pattern requires that the aircraft is flown at a nominated altitude and the student would have been prompted by the instructor to regain the reference altitude once the deviation became greater than 100 ft.

The average deviation from the reference altitude during the Practice Period was largest for the F141 group. The Control group's mean was slightly better than the SAV-1 group's, however the difference was only 0.33 ft, which is minimal when considering the range of altitude deviation results. The larger mean deviation of the F141 group was unusual and was expected to have been closer to the SAV-1 group's performance.

The inbound tracking is an important element of the NDB holding pattern and indicates how well the overall pattern is being flown. The average inbound tracking angle from the reference inbound angle of 310° was least for the SAV-1 group, with the Control and F141 groups producing similar inbound tracking results. It was expected that the F141 group would have produced similar result to the SAV-1 group. During the training period the SAV-1 group had the best inbound tracking, with the Control group next, and the F141 group with the worst group mean. The results were the same for the groups during the practice period. The F141 group was expected to have produced similar tracking performance to the SAV-1 simulator group, however the overall inbound tracking of the F141 group was not substantially worse than the Control group.

## 5.4    Post-flight Questionnaire

The Post-flight Questionnaire was used to analyse the flight instructor's view of the three groups' relative performance during the flights. It was anticipated that pre-training on a simulator would be indicated by better performance ratings from the flight instructor for the members of the two simulator groups. Although there were no statistically significant group differences, the group means produced some interesting results.

The height holding or altitude maintenance is an important element of flying in general. To maintain an NDB holding pattern correctly the aircraft must maintain the assigned altitude and regain the altitude as soon as possible if it has been deviated from. The instructor rated the students

for their general height holding performance, with the Control group having the best group mean, the F141 group being the next best, and then the SAV-1 group having the lowest mean rating. When compared to the average deviation from the reference altitude results, the instructor's ratings of the groups' performances do not match. The SAV-1 group had the least average altitude deviation during the holding, but was rated the worst by the instructor, and the F141 group had the highest altitude deviation and received a higher rating than the SAV-1 group. The Control group was rated the best by the instructor for height holding, but actually had the second highest altitude deviation.

Once an aircraft has deviated from the assigned altitude, the pilot must make an effort to regain the desired altitude. The flight instructor rated the Control group as the group who frequently attempted to regain their assigned altitude, with the SAV-1 group next, and the F141 group showing minimal attempts to regain the assigned altitude. This is reflected in the average deviation from reference altitude results, which show the F141 group as having the greatest deviation and the Control and SAV-1 groups producing similar average altitude deviation.

The F141 group was rated as the group which attempted to maintain the correct inbound tracking the most, however their performance was not as good as the SAV-1 group which was rated as the second best group. The Control group was rated with the lowest score for attempting to maintain the correct inbound tracking and their actual tracking performance was similar to the F141 group.

Flight instructors often judge the success of a training flight by the student's improvement during the flight. The Control group demonstrated the greatest improvement to the instructor while flying the holding pattern, with the SAV-1 and F141 group receiving the same, slightly lower improvement score. This may be an indication that the two simulator groups had already learned the fundamentals of flying the holding pattern in the simulator. Therefore, there was not as much room for improvement

when flying the pattern in the aircraft, as there would be for the aircraft group who were required to learn the pattern with no prior simulator training.

During the flight the student was questioned by the instructor about where they thought they were in the holding pattern, when they were turning next, whether they were inside or outside of the holding pattern at the end of the outbound leg, how their inbound turn was progressing, what adjustments were required, and how their inbound tracking was progressing when compared to the required track of 310°. These questions were used to get feedback from the student and help the instructor assess the student's understanding of the holding pattern procedure. The SAV-1 and F141 groups received the same high score of 4 out of 5, which implied that they had a good understanding of the procedure. The Control group received a slightly lower rating than the simulator groups, which shows that they had more difficulty learning the procedure and their comprehension of the actions required to maintain the holding pattern successfully was not as good as the simulator groups.

The flight instructor was required to rate the student's performance at the conclusion of the flight. The Control group received the highest mean score, with the SAV-1 group a close second, and the F141 a close third. The mean ratings were all above average, which would indicate that the students were generally thought to have performed well during the flight, and that the lesson had been successfully taught to the students from each group. The Control group may have received the highest score for performance because they showed the best improvement and they had relatively good altitude maintenance and inbound tracking, even though they required a greater number of training holds to reach the required level of proficiency.

The final question of the Post-flight Questionnaire was included to ascertain whether or not the instructor could correctly judge the students'

group membership from their flight performance. The Control group had 2 members who performed better than expected and were incorrectly judged as belonging to a simulator group. The SAV-1 group had 2 members judged to belong to the aircraft group and the F141 group had 1 member incorrectly identified as being from the aircraft group. The incorrect placement of 5 of the participants was a sign that their performance was unexpected for their previous training. The students who performed well were expected to belong to the simulator groups and the students who did not perform as well were expected to belong to the aircraft group. The results from this question are however inconclusive, as deciding whether or not a student had received previous simulator training with a 50% success rate could have been a result of pure chance or it could have been the result of experienced judgement.

## 5.5    Percent Transfer

The percent transfer produced by the simulator groups were all positive indications of transfer from the simulators to the aircraft. They were however relatively small amounts of transfer. The average percent transfer for the SAV-1 group was 9.12%, and the F141 group produced a average percent transfer of 10.19%. This indicates that the skills learned in each of the simulators by the students were transferred into the aircraft.

The main disadvantage with the percent transfer results from this study is that conclusions about the effectiveness of the two simulators can not be made because there is no accounting for the amount of simulator time required to achieve these percent transfers (Roscoe & Williges, 1980). Additional training in the simulators was likely to increase the percent transfer of the individual participants and group means, but there was no way to determine how much additional simulator training is required to produce larger percent transfers. The main consideration when increasing the simulator training time is that the cost of the additional training may be more expensive than the resulting savings in aircraft flight time. Therefore the percent transfer equation is a simple measure of transfer, but does not

show the effectiveness of the simulators, and the TER provides a clearer indication of the degree of transfer from a simulator to the aircraft.

## 5.6 TER

The TERs produced by the simulator groups were positive, but relatively small. The average TER for the SAV-1 group was 0.1366, which equates to 8 minutes reduction of flight time for every hour of simulator training. The F141 group produced a mean TER of 0.1557, which equates to 9 minutes reduction of flight time per hour of simulator training. These results are indicative of the studies reviewed in section 2.8 (p. 22) of this thesis. Orlansky & Chatlier (1983, cited in Rolfe & Staples, 1986), indicated that previous studies using a wide range of simulators had produced TERs ranging from +1.9 to –0.4, with the average being +0.48. This indicates that the skills learned in each of the simulators by the students were transferred into the aircraft.

The results a study by Ortiz (1994, 1995), had shown that a PC-based simulator used to teach students to fly a simple instrument pattern produced an average TER of +0.48, which equated to 29 minutes in the aircraft, for every hour spent in the simulator. The NDB holding pattern procedure taught during this study is a complicated instrument procedure, and because of this, the simulator groups spent an average of 56 minutes receiving prior training in a simulator. This time allowed them to gain a good understanding of the fundamentals of maintaining the holding pattern, as well as practising with a crosswind effecting the holding pattern. This increased time spent in the simulator may have given the students a better understanding of the holding procedure, however it contributed to decreasing the TER. The transfer of training study by (Taylor et al., 1996, 1997, 1999) investigated the TER of a number of different instrument procedures, which indicated that the TER varied from +0.15 to +0.40. This study using complicated instrument procedures produced similar TER results as this NDB instrument procedure, with the TER varying from +0.05 to +0.29 for the SAV-1 simulator group and

+0.12 to +0.22 for the F141 simulator group. This confirms the positive TER of PC-based simulators and provides evidence that a PC-based simulator game has the potential to produce similar training outcomes as more expensive approved FTDs.

## 5.7    Cost Benefit

The cost benefit for each simulator was negative, which means that the prior training in the simulators generally cost the students an extra amount of money for their training. Only one student saved money from the simulator training. This was due to the small TER, the resulting small savings in flight time, and the relatively expensive flight simulator hourly rate, all of which contributed towards the negative cost benefit. The study conducted by Orlansky, Knapp, and String in 1984 (cited Pohlman & Fletcher, 1999), concluded that the use of full motion military flight simulators were cost effective if the TER is 0.20 or greater. The simulators used in this transfer of training study did not generate a high enough TER to meet the break-even point for the particular instrument holding procedure. The break-even point is the point where the savings in aircraft flight time is equal to the cost of the simulator time. Using the same hourly rates for the simulators, aircraft and flight instructor, as show in Table 8 (p. 82), the break even point for the SAV-1 simulator required a TER of 0.225 and the break even point for F141 simulator required a TER of 0.40. One member of the SAV-1 group achieved a TER of 0.2857 and financial savings of $11.33. The relative operational cost of the SAV-1 simulator and the C172SP aircraft, when compared to the relative operational cost of the Frasca 141 simulator and the C172SP aircraft show that there is a greater likelihood that the SAV-1 simulator will produce a cost benefit than the F141 simulator. Therefore to achieve a positive cost benefit, there needs to be an appropriate TER for the relative operational costs of the simulator and the aircraft. The greater the difference between the operational costs, the smaller the TER required to make the break even point, and the smaller the relative operational cost, the greater the required TER.

The Massey University ATP degree course allocates 60.2 hours simulator among the different phases of flying (Massey University, 2003). The initial simulator flights use the visual display of the SAV-1 simulator to teach help students with the basic visual handling aspects of flying an aircraft. The CAA approved FTDs are used later in their training for specific instrument flight procedures and the cost for this training is included in their university papers. Although the prior simulator training did not result in a cost benefit that covered the cost of the simulator, there is evidence that the SAV-1 simulator produced similar time savings as the CAA approved simulator. This means that if the less expensive SAV-1 simulator was used instead of the F141 simulator for instrument training, there would be a positive transfer and an overall cost savings, as the university paper costs could be reduced.

Many of the ATP course's simulator instrument hours are used towards gaining pilot licences and ratings, and require the hours to be flown in a CAA approved simulator. These hours are specified by the CAA and to substitute the hours flown in the F141 simulator for the SAV-1 simulator, the SAV-1 simulator would have to be certified for use by the CAA. This PC-based simulator my not receive FTD approval in its present state, however if the New Zealand CAA was persuaded to adopt the FAA rules which allow up to 10 hours of PCATD time to be logged towards an instrument rating (FAA, 1997), there would be an immediate financial savings for student pilots. There would also be opportunities to develop cheaper PC-based simulators, which have positive transfer of training and cost benefits. It is inevitable the CAA will eventually have to consider classifying advanced PC-based simulators as PCATDs or FTDs.

## 5.8    Limitations of the Study

There was no funding support for this study and the participants volunteered a small percentage of their allocated single engine time towards this research. Many for the students had over-flown their allocated hours and were therefore unable to be involved. The limited number of

students currently enrolled on the Bachelor of Aviation ATP degree programme and the large number of students who were unable to volunteer their time, resulted in a small sample size being used for this study. The implications of having a small sample size have already been discussed in section 4.4.2 (pp. 58-60). It is important to note that although the minimum sample size required to achieve a 95% power for detecting flight time group differences was 42, to maintain this probability of finding the group differences when measuring other flight data variables the number of participants required was considerably higher. Similar studies to this one by Taylor et al. (1996, 1999) had sample sizes of 92, 74, and 27, which produced some significant statistical results with respective powers of 87%, 81% and 80%. These results were based on the flight times of a control group and a single experimental group. This shows that for a study with three independent groups, a sample size between 117 and 285 would be required to ensure that the measured flight variables detect group differences at a 95% power. This study had limited resources available, and an external funding source could have helped to subsidise the aircraft flight time and which may have resulted in a greater number of participants. A larger sample size would have been more likely to discover significant group differences resulting from prior simulator training.

The intended beginning of the research was delayed for a month while technical problems were sorted out with the GPS tracking system. A GPS aerial was ordered from a local New Zealand company, which unfortunately was unable to deliver the product within the required timeframe. As a last resort measure an aerial was purchased from Australia and flown by overnight airfreight to allow the aircraft flight testing to begin. Five different GPS tracking software programmes were trailed for this study. Some of them having to be purchased while others were freeware programs found on the Internet. The GPS TrackMaker version #11.8 software was chosen for this study because of the ease of recording tracking data. This program was not specifically designed for aviation use, and therefore not capable of recording all facets of the flight and was not able to replay the flight data like a video recording. An ability

to do so may have allowed for more flight data and a closer analysis of the performance of each participant during their flight.

The research was conducted at the end of the year following their end of semester exams. This was period of time when the students were not required to study academic papers and were able to concentrate on flight training. Three of the participants were unable to complete their flights before the end of the year, as they were booked on overseas flights. Two of the students were required to wait until for confirmation that they had successfully completed the previous semester of flying before they could continue on their flying schedule. Therefore of the ten students, half of them were unable to conduct the NDB instrument flight in aircraft until the New Year, and as a result there was an approximate wait of four weeks for these participants between conducting their simulator flight and their aircraft flight. This was unsatisfactory for creating reliable data during an experiment, but unavoidable under the circumstances.

There were also time pressures to conduct the recruitment, training, and flying of participants within a five month period to allow the completion of this thesis in a timely manner. This limited the number of students that were eligible to take part in the study. Conducting the research over a longer period would have allowed for more participants as new intakes began their training and as a result more research data would have been gathered. This would have also required more resources and a greater time commitment from the people who had volunteered to help with this study.

## 5.9    Conclusions and Recommendations

This study intended to investigate the transfer of training of flight simulators with the hypotheses that were stated in section 2.9 (p. 25). The results gathered during the flight training process give some indication as to whether or not these suggested hypotheses are correct, however they can not be considered as conclusive because there were no statistically significant group differences in the results.

The prior instrument training of the NDB holding pattern on a PC-based SAV-1 simulator or the F141 simulator resulted in shorter flight times to proficiency for the simulator groups, when compared to the Control group which trained solely in the aircraft. The F141 group was generally the better of the two simulator groups with shorter mean times for all but one of the timed parameters.

There were small but positive percent transfers and TERs for students who received prior training on a PC-based simulator or an FTD. This demonstrated that there was a positive transfer of training to the aircraft for both simulators. The resulting TERs were similar for both simulators with the SAV-1 saving 8 minutes of flight time per hour of simulator training, and the F141 saving 9 minutes.

The students who trained on the SAV-1 PC-based simulator produced aircraft flight performance mean results that were generally better than the F141 and Control groups. The F141 group produced aircraft flight performance mean results that were generally worse than the SAV-1 and Control groups. This shows that the SAV-1 PC-based simulator is an effective training tool and produces flight training results similar to more expensive approved FTDs (Homan & Williams, 1998).

Students who received prior training in a flight simulator were not judged by the flight instructor to have displayed better performance while flying the instrument holding procedure in the aircraft. The Control group was judged to have performed better than the simulator groups in the areas of height holding, attempting to regain the assigned altitude, demonstrating an improvement in flying the holding pattern, and was given an overall higher performance rating than the simulator groups. The simulator groups were rated by the flight instructor as being better at maintaining the correct inbound tracking during the holding, and having a better understanding of the holding pattern procedure.

The F141 simulator group mean was the lowest for the time parameters, indicating that the group achieved the required criteria for the NDB holding pattern before the other groups, and resulting in the greatest flight time savings. The SAV-1 group produced the best overall performance and had a mean flight time savings similar to the F141 group. Both simulator groups had a better understanding of the holding pattern than the Control group, which took the longest time to achieve the performance criteria and produced relatively good flight performance when compared to the two simulator groups.

The SAV-1 simulator produced good performance results and time savings, had a small but positive TER, and was the cheaper of the two simulators to purchase, maintain and upgrade. For these reasons the SAV-1 simulator should be developed further, including more modern controls, faster graphics cards and a functional radio stack with instrument dials and knobs that can be used by the student to set instruments and radio station frequencies. The upgrades mentioned will make the simulator more user friendly and should enhance the transfer of procedural based skills, as well as motor-skills. The SAV-1 simulator should be included more in the instrument training phase of the Massey ATP degree program, even though it is not approved for logging time towards flight licences, as it is still capable of producing positive training results and reducing the overall costs of a student's flight training. The CAA should be consulted with reference to the certification of PC-based flight simulators for the logging towards flight licences, either as approved PCATD similar to those currently being used in the United States, or even gaining certification as a generic FTD.

Flight training organisations should be encouraged to develop PC-based simulators for their flight training programs and because of the substantial reduction in capital outlay when compared to an approved FTD. The training organisations should have multiple PC simulators to increase the availability for students, and also allow the simulators to be networked so

that the students are able to interact with each other in the same virtual environment.

## 5.10 Areas for Future Research

The use of PC-based simulator games requires further study, with a larger sample size to confirm that there are significant differences between the performance of students who receive prior simulator training and those students who learn the instrument lesson in the aircraft.

Different instrument flight tasks should be taught using the same independent group method as used in this study, to determine that PC-based simulators and FTDs produce positive transfer of training and flight time savings. This should include all of the instrument lessons that are required for pilot licences and ratings, which are currently taught in approved FTDs. This will help to determine if there are particular instrument lessons that are transfered to the aircraft better than others and may allow for training organisations to use PC-based simulators and FTDs in conjunction with each other to maximise the training benefits for the student pilot.

Further cost benefit analysis needs to be conducted with the focus on the areas of comparison costs of approved FTDs and PC-based simulators. The results of this study indicated that for the NDB instrument holding procedure the TER needed to be greater than 0.225 for the SAV-1 and greater than 0.40 for the F141 to surpass the break-even point. This would appear to make the F141 uneconomical for training on complex instrument tasks, however this is not to say that other instrument tasks will not produce substantial savings, especially when the Massey University ATP course has 60.2 simulator hours allocated (Massey University, 2003). The cost benefit analysis should take into account the reduction of simulator hours required to be flown in a FTD that could be flown in a PC-based simulator, as well as the potential savings in flight time costs. This cost

benefit analysis should also include the direct savings to the student, as well as the operational cost savings for the training organisation.

The NASA Task Load Index (TLX) is used to assess the participant's cognitive workload when undertaking complicated tasks such as flight manoeuvres. This is a pre-flight / post-flight comparison of the students own judgement of their normal idea of workload, compared to the workload that they experienced during the flight. Dennis and Harris (1998) conducted a study to determine if prior simulator training helps to lower mental workload when flying a procedure in the aircraft. The same instrument pattern used by Ortiz (1995, 1996) was used in this study and the participants were trained on a PC-based simulator with Microsoft Flight simulator 4.0 installed on it. The results showed that the experimental simulator group performed the instrument pattern better than the aircraft control group, and their mental workload was significantly lower. The researchers recommended further studies using PC-based flight simulators with more complex instrument flight procedures. The NASA TLX questionnaire should be used in transfer of training studies similar to this thesis to investigate whether mental workload can be reduced in the aircraft when flying a complex instrument procedure, by using PC-based simulators for pre-training on the procedure. The prediction is that those students that receive prior simulator training are likely to have lower mental workload than those students that learn the procedure in the aircraft.

The flight instructor is an important element in effective flight training, but a resource that is often mismanaged  (Caro, 1988). If students conducted some simulator flights training unsupervised, this would allow the instructor to be used more productively in the aircraft. Research should be conducted into the relative performance of students who receive supervised flight instruction on PC-based flight simulators and FTDs, when compared to students who receive unsupervised learning on the same simulators when given written instructions on how to complete a simulator lesson. The resulting flight performances, TERs and flight time

savings should indicate whether or not flight instructors are required for all facets of instrument flight training. The future of flight simulation may become one that is increasingly dominated by cheaper PC-based simulators that do not require the full-time supervision of a flight instructor.

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# Glossary

| | |
|---|---|
| **ADF** | Automatic Direction Finder Aircraft Navigation Instrument |
| **ATP** | Airline Transport Pilot |
| **ATPL** | Airline Transport Pilot Licence |
| **C172SP** | Cessna 172 SP aircraft |
| **CAA** | Civil Aviation Authority |
| **CPL** | Commercial Pilot Licence |
| **F141** | Frasca 141 Simulator |
| **FAA** | Federal Aviation Authority |
| **GPS** | Global Positioning System |
| **KPH** | Kilometres per hour |
| **KTS** | Knots |
| **LOFT** | Line Orientated Flight Training |
| **NASA** | National Aeronautics and Space Administration |
| **TLX** | Task Load Index |
| **NDB** | Non-directional Beacon Ground Navigation Transmitter |
| **NZ** | New Zealand |
| **MEIR** | Multi-engine Instrument Rating |
| **PC** | Personal Computer |
| **PCATD** | Personal Computer Aviation Training Device |
| **PPL** | Private Pilot Licence |
| **SAV-1** | Personal Computer Based Flight Simulator |
| **USA** | United States of America |
| **VHF** | Very High Frequency |
| **VOR** | VHF Omni-Directional Radio Range |

# Appendices

## Appendix A

## Holding Pattern Mass Brief



**Mass Brief**

**IFR Holding Patterns & Procedure Turns**

Massey University

aviation

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**Objective**

- To learn the procedures required to enter and fly NDB holding patterns and procedure turns

Massey University

aviation 1

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**Considerations**

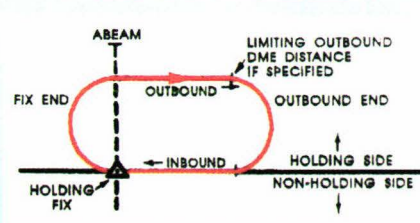**What is a holding pattern?**

- A manoeuvre designed to keep an aeroplane within specified airspace, whilst waiting for further clearance from ATC.

- Is a delaying action in a racetrack pattern.

Massey University

aviation 2

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- Onwards flight stops until aeroplane is cleared to proceed

- **Delay due to** → Other aircraft holding
  → Weather at destination
  → Aircraft on the runway (blown tyre etc)

Massey University

aviation 3

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**Standard Holding pattern**



Massey University

aviation 4

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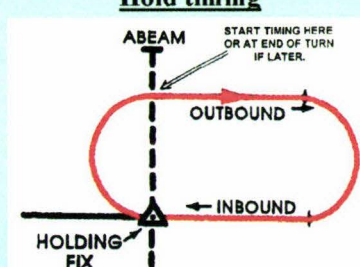
- Limiting speed 170kts for propeller driven aircraft up to FL140.

- All turns to be made at a bank angle of up to 25° or at rate 1 (3°/sec), whichever requires less bank.

- Outbound timing begins at end of turn, or abeam the fix, whichever occurs later.

Massey University

aviation 5

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**Hold timing**



Massey University

aviation 6

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- All procedures show "dead reckoning" tracks, not headings. Pilots should maintain track by making allowance for known wind

  ie apply corrections to both heading and timing whilst entering the hold.

- Outbound leg can be DME limited

Massey University

aviation 7

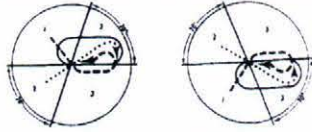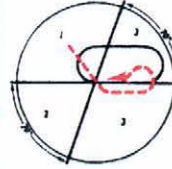**Appendix A Continued**

## Holding pattern entry

- Enter according to heading, in relation to the 3 entry sectors shown below.



- There is a zone of flexibility of 5° on either side of sector boundaries

## Parallel entry (Sector 1 procedure)



a) Having reached fix, turn a/c onto outbound <u>heading</u> for correct period of time, or until reaching limiting DME distance.

b) Turn onto the holding side to intercept the inbound track or return to fix.

c) On the second arrival over the fix, the a/c is turned to follow the holding pattern.

## Offset entry (Sector 2 procedure)

a) Having reached fix, a/c is turned onto a heading to make good a track, making an angle 30° from the reciprocal of the inbound track, on the holding side.



b) a/c flies outbound for correct period of time or until reaching limiting DME distance.

c) a/c is turned to intercept the inbound holding track

d) On the second arrival over fix, a/c is turned to follow the holding pattern.
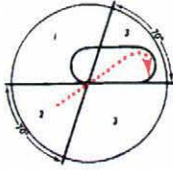
## Direct entry (Sector 3 procedure)
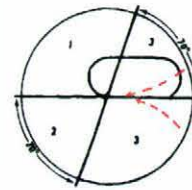


Having reached the fix, the aircraft is turned to follow the holding pattern

## DME arc entry/Non beacon fix entry

- Having reached the fix, aircraft are required to enter the holding pattern using sector 1 or sector 3 procedure.
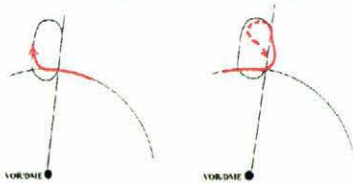


## Entry procedure continued

**Time/Distance outbound (Sector 1 and 3 entries)**

- Still air time for flying outbound entry heading should not exceed 1 minute if below FL140. If DME is available, outbound leg may be flown to a limiting DME distance, if one is specified.

## Holding pattern procedures and timing
## Still air conditions

- After entering hold, on second and subsequent arrivals over the fix, turn to fly the outbound track!

- Continue outbound for one minute or until reaching the limiting DME distance.

- Turn so as to realign the aircraft on the inbound track.

## Holding procedures and timing
## Wind Effect

- Allowance must be made by the pilot in heading and timing to compensate for known wind.

- Make use of 2000ft wind forecast. Also use DME g/s vs IAS as well as the crab angle whilst enroute to the hold.

- Double the inbound drift angle when working out the outbound drift angle. ie 10° port drift inbound = 20° starboard drift outbound.

- Drift angles are normally restricted to 30°.

- Inbound leg should be 1 minute, so adjust outbound leg accordingly ie    +1 second for each kt of headwind
    -½ second for each kt of tailwind

## Precautionary holding

- To help ATC produce conflict free flight paths ie, "Maintain 7000ft precautionary hold Waiuku".

- Precautionary hold may be cancelled before reaching the fix. If not cancelled, aircraft must join pattern with expected onwards clearance time of actual time plus five minutes.

## Reversal turn procedures

- A reversal turn is a procedure used to reverse the direction of flight.
- Commonly used when both a holding pattern and an approach procedure are on the same side of a navigation aid.
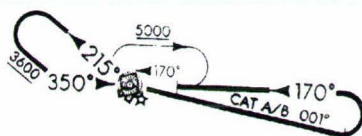


## 80° Procedure turns

- Consists of a specified outbound track and timing from the facility or fix, an 80° turn away from the outbound track, followed by a 260° turn in the opposite direction to intercept the inbound track.
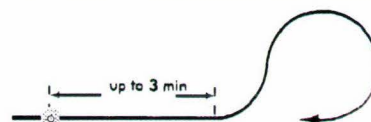


## 45° Procedure turns

- Consists of a specified outbound track and timing from the facility or fix, a 45° turn away from the outbound track for 1 minute from the start of the turn (for category A and B aircraft).
- Followed by a 180° turn in the opposite direction to intercept the inbound track. An 80° procedure turn may also be used when a 45° procedure turn is shown.

## 45° Procedure turns continued...
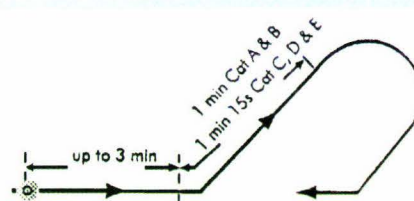


## Procedure turn example
## Paraparaumu
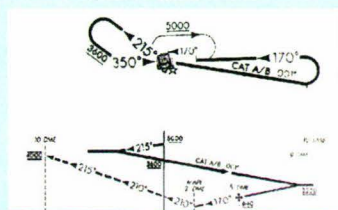


## Human Factors

- Self briefing of procedures to be flown.

- Wind awareness.

- Aviate, navigate, communicate.

# Appendix A Continued
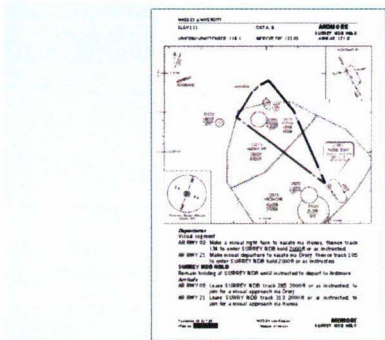


Appendix A



Appendix B



Appendix C

**Figure 40.** Aeronautical Map of South Auckland. (The red lines show the departure and arrival tracks required between Ardmore Airfield and the Surrey NDB. The Surrey NDB holding pattern is also highlighted in red).

## Instrument Plate for Holding at Surrey NDB

MASSEY UNIVERSITY

| ELEV 111 | CAT A, B | **ARDMORE** |
| --- | --- | --- |
| | | **SURREY NDB HOLD** |
| *UNICOM/UNATTENDED: 118.1* | *MERCER TRF: 133.05* | *AWIB AR: 121.0* |
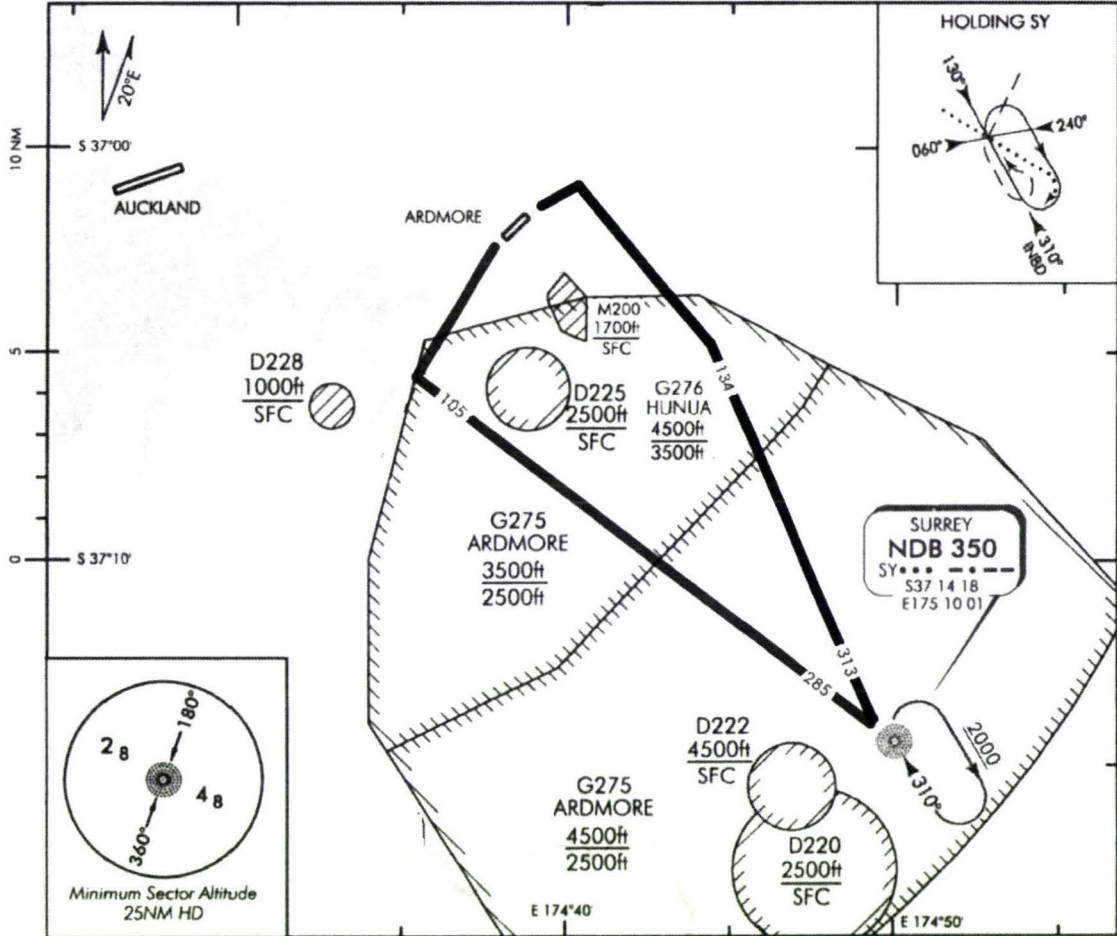


### Departures
**Visual segment**

AR RWY 03     Make a visual right turn to vacate via Hunua, thence track 134 to enter SURREY NDB hold <u>2000</u>ft or as instructed.

AR RWY 21     Make visual departure to vacate via Drury, thence track 105 to enter SURREY NDB hold <u>2000</u>ft or as instructed.

### SURREY NDB HOLD
Remain holding at SURREY NDB until instructed to depart to Ardmore.

### Arrivals

AR RWY 03     Leave SURREY NDB track 285 <u>2000</u>ft or as instructed, to join for a visual approach via Drury.

AR RWY 21     Leave SURRY NDB track 313 <u>2000</u>ft or as instructed, to join for a visual approach via Hunua.

**Appendix D**

## Pre-flight Questionnaire

1.  Do you have access to a Personal Computer at home?        Yes / No

2.  Do you have a flight simulator program installed on it?        Yes / No

3.  Which flight simulator program(s) do you have?

    ..........................................................................................................................

    ..........................................................................................................................

4.  Why did you purchase this(these) particular flight simulator program(s)?

    ..........................................................................................................................

    ..........................................................................................................................

    ..........................................................................................................................

5.  Do you have a joystick or control yoke and rudder pedals for your PC?

    Please specify        Joystick

                          Control Yoke

                          Rudder Pedals

                          Other.................................

6.  To what extent do you use your home PC flight simulator program for your flight training?

    (Not very often)    1    2    3    4    5    (Very often)

7.  How many hours per week, on average, would you use your PC flight simulator?

    ..................(hours/week)

8.  To what extent has your home PC simulator program helped your flight training?

    (Not effective)    1    2    3    4    5    (Very effective)

9.  To what extent have you used PC-based flight simulators at your flight training school?

    (Not at all)    1    2    3    4    5    (Extensively)

10. To what extent do you think the PC-based flight training device that you used was effective?

    (Not effective)    1    2    3    4    5    (Very effective)

11. To what extent would you like to see more PC simulation in your flight training?

    (No PC simulation)    1    2    3    4    5    (Extensive PC simulation)

12. To what extent would you use PC simulators if they were available for use during your spare time at your training school?

    (Never)    1    2    3    4    5    (Frequently)

## Post-flight Questionnaire

1......... Height holding in general

                 (Not well done)    1    2    3    4    5    (Very well done)

2......... Attempted to regain assigned altitude

                 (no attempt)    1    2    3    4    5    (continuously attempted)

3......... Attempted to maintain correct inbound tracking

                 (no attempt)    1    2    3    4    5    (continuously attempted)

4......... Demonstrated an improvement in flying the correct holding pattern

                 (no improvement)    1    2    3    4    5    (improvement)

5......... Demonstrated an understanding of holding pattern procedure

                 (did not understand)    1    2    3    4    5    (understood)

6......... Rate the students performance based on your expectations of a student learning to fly this procedure

                 (Remedial)    1    2    3    4    5    (Excellent)

7......... Which group do you think this participant belongs to...?

          F141 Simulator / SAV-1 Simulator                No previous Simulator training

**Appendix F**

**Table 9.**     Means and Standard Deviations for Flight Results.

| Variables | Groups* | Mean | Std. Deviation | N |
|---|---|---|---|---|
| **Flight Time (Minutes)** | Control | 85.00 | 9.54 | 3 |
| | SAV-1 | 77.25 | 5.74 | 4 |
| | F141 | 76.33 | 2.08 | 3 |
| | Total | 79.30 | 6.91 | 10 |
| **Airborne Time (Minutes)** | Control | 71.00 | 7.21 | 3 |
| | SAV-1 | 66.25 | 6.40 | 4 |
| | F141 | 61.67 | 3.79 | 3 |
| | Total | 66.30 | 6.55 | 10 |
| **Flight Training Time (Minutes)** | Control | 21.67 | 9.81 | 3 |
| | SAV-1 | 20.00 | 4.97 | 4 |
| | F141 | 16.33 | 3.21 | 3 |
| | Total | 19.40 | 6.08 | 10 |
| **Flight Practice Time (Minutes)** | Control | 14.00 | 3.46 | 3 |
| | SAV-1 | 11.75 | 2.75 | 4 |
| | F141 | 12.33 | 2.08 | 3 |
| | Total | 12.60 | 2.67 | 10 |
| **Total Number of Holds Flown in the Aircraft** | Control | 6.67 | 1.15 | 3 |
| | SAV-1 | 6.50 | 1.00 | 4 |
| | F141 | 6.00 | 1.00 | 3 |
| | Total | 6.40 | .97 | 10 |
| **Number of Training Holds Flown in the Aircraft** | Control | 4.00 | 1.73 | 3 |
| | SAV-1 | 4.00 | .82 | 4 |
| | F141 | 3.33 | .58 | 3 |
| | Total | 3.80 | 1.03 | 10 |
| **Number of Practice Holds Flown in the Aircraft** | Control | 2.67 | .58 | 3 |
| | SAV-1 | 2.50 | .58 | 4 |
| | F141 | 2.67 | .58 | 3 |
| | Total | 2.60 | .52 | 10 |

**\* Groups**

**Control = Aircraft Control Group**

**SAV-1 = SAV-1 Experimental PC-based Simulator Group**

**F141 = F141 Experimental FTD Simulator Group**

**Table 9. Continued.**     Means and Standard Deviations for Flight Results.

| Variables | Groups* | Mean | Std. Deviation | N |
|---|---|---|---|---|
| Maximum Deviation from Reference Altitude (Feet) | Control | 200.00 | 100.00 | 3 |
| | SAV-1 | 215.00 | 66.08 | 4 |
| | F141 | 200.00 | 100.00 | 3 |
| | Total | 206.00 | 77.20 | 10 |
| Average Deviation from Reference Altitude (Feet) | Control | 70.83 | 27.42 | 3 |
| | SAV-1 | 67.87 | 21.56 | 4 |
| | F141 | 83.59 | 37.09 | 3 |
| | Total | 73.48 | 26.04 | 10 |
| Average Deviation from Reference Altitude During the Training Period (Feet) | Control | 68.42 | 32.09 | 3 |
| | SAV-1 | 67.55 | 18.79 | 4 |
| | F141 | 66.97 | 28.58 | 3 |
| | Total | 67.64 | 22.99 | 10 |
| Average Deviation from Reference Altitude During the Practice Period (Feet) | Control | 77.49 | 18.15 | 3 |
| | SAV-1 | 77.82 | 25.78 | 4 |
| | F141 | 107.08 | 72.16 | 3 |
| | Total | 86.50 | 40.66 | 10 |
| Average Inbound Tracking Angle from Reference Inbound 310° (Degrees) | Control | 7.61 | 1.77 | 3 |
| | SAV-1 | 6.37 | 2.21 | 4 |
| | F141 | 7.63 | 2.88 | 3 |
| | Total | 7.12 | 2.14 | 10 |
| Average Inbound Tracking Angle from Reference Inbound 310° During the Training Period (Degrees) | Control | 7.89 | 4.19 | 3 |
| | SAV-1 | 6.18 | 3.15 | 4 |
| | F141 | 8.92 | 2.09 | 3 |
| | Total | 7.51 | 3.11 | 10 |
| Average Inbound Tracking Angle from Reference Inbound 310° During the Pactice Period (Degrees) | Control | 8.45 | 4.22 | 3 |
| | SAV-1 | 6.21 | 1.87 | 4 |
| | F141 | 8.89 | 4.14 | 3 |
| | Total | 7.68 | 3.25 | 10 |

**\* Groups**

**Control = Aircraft Control Group**

**SAV-1 = SAV-1 Experimental PC-based Simulator Group**

**F141 = F141 Experimental FTD Simulator Group**

**Table 10.** Means and Standard Deviations for Post-flight Questionnaire.

| Variables | Groups* | Mean | Std. Deviation | N |
|---|---|---|---|---|
| 1. Height holding in the aircraft in general | Control | 3.67 | 1.528 | 3 |
| | SAV-1 | 2.75 | 1.500 | 4 |
| | F141 | 3.00 | 1.000 | 3 |
| | Total | 3.10 | 1.287 | 10 |
| 2. Attempted to regain assigned altitude in the aircraft | Control | 3.33 | 1.528 | 3 |
| | SAV-1 | 3.00 | 1.155 | 4 |
| | F141 | 2.67 | 1.155 | 3 |
| | Total | 3.00 | 1.155 | 10 |
| 3. Attempted to maintain the correct inbound tracking in the aircraft | Control | 2.67 | 1.155 | 3 |
| | SAV-1 | 3.25 | .957 | 4 |
| | F141 | 3.67 | 1.528 | 3 |
| | Total | 3.20 | 1.135 | 10 |
| 4. Demonstrated an improvement in flying the correct holding pattern in the aircraft | Control | 4.33 | .577 | 3 |
| | SAV-1 | 4.00 | .816 | 4 |
| | F141 | 4.00 | 1.000 | 3 |
| | Total | 4.10 | .738 | 10 |
| 5. Demonstrated an understanding of the holding procedure in the aircraft | Control | 3.67 | 1.528 | 3 |
| | SAV-1 | 4.00 | 1.414 | 4 |
| | F141 | 4.00 | 1.000 | 3 |
| | Total | 3.90 | 1.197 | 10 |
| 6. Rate the student's performance based on your expectations of a student learning to fly this procedure | Control | 4.00 | 1.000 | 3 |
| | SAV-1 | 3.75 | 1.500 | 4 |
| | F141 | 3.67 | 1.528 | 3 |
| | Total | 3.80 | 1.229 | 10 |

**\* Groups**

**Control = Aircraft Control Group**

**SAV-1 = SAV-1 Experimental PC-based Simulator Group**

**F141 = F141 Experimental FTD Simulator Group**