

**INVESTIGATING THE CONFIGURATION OF A FLIGHT TRAINING
DEVICE FOR VISUAL FLIGHT RULES NAVIGATION**

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ABSTRACT

The acquisition of pilot navigational skills utilising visual landmarks is a crucial skill that is required as part of Visual Flight Rules navigation towards obtaining a Private Pilot License. Due to the high cost of pilot training simulators, industry has identified a need for research in efficient utilisation of low-end, low cost personal compute flight simulators to assist in developing pilot skills.

Analysis of the effectiveness of the use of such personal computer simulators depend on proper configuration determined by measurable errors to define simulator fidelity. To date, research has shown that the configuration of these simulators appears to have been done in an ad-hoc fashion and not in a scientific fashion. Therefore, the problem that needed to be solved was how to effectively configure such simulators.

This thesis research attempted to solve this problem and present the process for effectively configuring a personal computer simulator, or flight training device, capable of successful Visual Flight Rules navigation.

The simulator was configured utilising a process that followed an interpretation of the Design Science research method, and an error correction model to determine the errors in the simulator configuration. This was done by comparing two probability distributions to measure the maximum error variable distance in order to configure a simulator suitable for the acquisition of Visual Flight Rules navigation piloting skills required for obtaining a Private Pilot Licence in Australia. This error identification method was then used to indicate simulator configuration efficiency and fidelity in order to achieve a minimum suitable configuration and setup.

Further application of the findings of this research could potentially lead to the configuration of different types of non-aviation simulators, in particular Part-Task-Trainers and other training devices, including Virtual Reality Augmented Reality devices utilising various types of platforms such as Windows, Apple, and Android.

STATEMENT OF AUTHORSHIP

I hereby declare that this thesis is entirely my own work. Whenever material containing text, graphics, ideas, opinions and statements of other people was used, these were cited and acknowledged within my own text.

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William Harvey

STATEMENT OF ETHICS APPROVAL

Principal Researcher:	A/Prof Andrew Stranieri
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Quote the Project No: B17-023 in all correspondence regarding this application.

Please note: Ethics Approval is contingent upon the submission of annual Progress reports when applicable and a Final report upon completion of the project. It is the responsibility of researchers to make a note of the following dates and submit these reports in a timely manner, as reminders may not be sent out. Failure to submit reports will result in your ethics approval lapsing

REPORTS TO HREC:

An annual report for this project must be submitted to the Ethics Officer by:
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Report templates can be found at:

<http://federation.edu.au/research-and-innovation/research-support/ethics/human-ethics/human-ethics3>

Fiona Koop
Ethics Officer
20 April 2017

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CHAPTER 1

INTRODUCTION

This chapter introduces the study, identifying the research aims and research questions, the research contribution, scope, limitations, and provides an introduction to Flight Training Device (FTD) simulators. The chapter reviews the literature regarding the application of commercial and consumer flight simulations, and FTD's for training purposes, looking at some emerging geographical terrain and land-object personal flight simulation software developed by various software developers for Microsoft Flight Simulator X. This includes the 3D-Graphical rendering processes and the quality and accuracy of the simulated terrain and geographical landmarks. Terrain, textures and other land-objects are evaluated to determine how accurate and useful the sceneries are for real Visual Flight Rules (VFR) flying whereby pilots fly and navigate mainly by using visual ground reference points instead of relying on instruments.

1.1 Introduction

The training of military, commercial and general pilots has evolved into a highly professional and structured process, all utilising simulations to train a wide range of pilot skills, including “basic stick-and-rudder skills” (Stark, 1998). As a result, aviation authorities globally regulate pilot training through traditional training methods utilising flying schools and approved flight training centres with suitably qualified flight instructors. These typically include an initial training phase in which student pilots attend a flying school where the training covers a combination of theory and practice. The theory component is usually done in a classroom environment, whilst the practical component is done flying an aircraft under the supervision of a flight instructor (CAA, 2018, CASA, 2010). The effectiveness of these methods has been proven by a low accident record in the aviation industry. According to Khatwa (2000), accidents in aviation in the past 100 years were statistically rare events with an average of 1.5 accidents per every 1 million flights. More recently, Ranter (2017)

estimates 1 fatality per 7,360,000 flights. However, Craig (2000) claims that therefore, that there is a need to explore methods to increase the proficiency levels of private pilot training.

Youson (2001) stated more than a decade ago that greater emphasis is being placed than in the past on computer-aided training within the aviation industry, and that successive generations of aircraft have become easier to fly, referring to the trend for replacing mechanical linkages with fly-by-wire systems. “Fly-by-wire” is described by (Sutherland, 1968) as a system that replaces conventional manual flight controls of an aircraft with an electronic interface. At the same time pilot training devices have developed a greater degree of sophistication, often by sharing fly-by-wire algorithms with real aircraft systems. Salas et al (1998) and Brannick et al. (2005) studied the effectiveness of flight simulators, and simulator fidelity in aviation training. They concluded that there is a misconception that “high-fidelity simulators do not ensure training success.” (p.202). This view is shared by Flexman & Stark (1987) that “complete physical fidelity is rarely required for effective training and transfer” (p.1031). To this end, Salas et al argues that the level of fidelity should be determined by the level needed to support learning on the tasks. (p.202). The above indicate that high-end simulators do not necessarily offer more fidelity than low-end simulators to improve training. The net result would then be pilots with better training flying fewer demanding aircraft, and nineteen years later in 2020, adaptation of computer aided on low-end FTD simulators training is still lagging behind advances in technology. Therefore, it could be argued that the use of low-end simulators could have the potential to improve aviation safety through further simulator training on FTD devices.

Therefore, the use of low-cost simulators, defined as a Flight Training Device (FTD) utilising a low-cost computer-based platform with additional controls, has become popular as is evident by their popularity with flight enthusiasts and some flying organisations. This type of simulator is also known as a Level 4 Flight Training Device (FAA, 1994). In Australia many flying schools do not

formally use any such FTD devices within their Private Pilot training syllabus despite the body of evidence showing that low-grade simulation during the initial stages of flight training is beneficial for military and commercial aviation. An example of the adoption of FTD devices by the Royal Australian Air Force to support the recent acquisition of new PC-21 training aircraft to replace the outgoing PC-9 aircraft. (Commonwealth of Australia, 2016). By incorporating such software into the flying training syllabus, it could be of benefit for trainee pilots to enhance skill acquisition, and flying schools could offer a flight simulator training device that could be used to teach certain VFR flight procedures, and there is a body of evidence supporting the use of low-fidelity simulators as an alternative to high-cost simulators for training. (Beringer, 1994; Dennis & Harris, 1998, Jentch & Bowers, 1998, Koonce & Bramble, 1998, Harvey, 2006, O'Hare & Wright, 2015) Pingali & Newman, 2017, Rewiti et. al 2017, Wahl, 2019)

This thesis does not argue that simulators are a replacement for flight instruction in the air, but that the objective of low-cost simulation should be to aid in maximizing the quality of instructional time in the air. Using personal computer technology for aiding pilot training is therefore a motivator in exploring the possibilities FTD devices offer, and a need exists for a suitable and cost-efficient flight simulation to benefit the general aviation sector (Bradley & Abelson, 1995, Rewiti et al, 2017).

However, the problem to be solved is how to configure such FTD training simulators to best support pilot training as there are many variables and options that can be set as is illustrated in the following examples of simulator configuration research:

- Allen et al (2003) compared a driving simulator training system across 3 different simulator configurations, including a desktop system with a single narrow field-of-view display, a desktop system with wide field of view display, and a cab with wide field of view display. That study showed that a PC-based platform is easy to administer in school classroom

environment as well as in laboratories for training purposes to simulate real-world environment situations.

- Hayes et al. (2009) configured a flight training simulator and found that measuring the effect of simulator fidelity was hampered by two factors: (a) the deficiency of detailed reporting of simulator configuration parameters, and (b) the lack of a validated taxonomy of flight tasks. The latter compelled the assessment of fidelity information on a task-by-task basis. The only two variables used to evaluate visual imaging systems were total field of view (FOV) of the system and use of Computer Graphic Interface (CGI) technology. They state that “A more thorough evaluation, such as determination of configuration requirements, would be more helpful but is not possible from the information available” (p71)
- A commercial enterprise, CarpAir (2003), utilised a simulator using Microsoft Flight Simulator 2004 as the simulator software platform, with a fully featured Virtual Cockpit across three 17" monitors to provide increased situation awareness, claiming that in their experience this technology provides greater realism due to the fact that the simulator pilot can have a larger field-of-view of the cockpit and surrounding scenery.
- Harvey (2006) configured a basic FTD utilising a computer with 1 monitor, a flight yoke, pedals and Microsoft Flight Simulator 2004 to compare the flight simulator land and object scenery, aircraft and cockpit instrumentation graphical environment with the real-world and found that the technologies present potential training possibilities for VFR pilot training by offering very realistic representation of the actual aircraft and real-world scenery. Results from this study highlights the relevance of the scenery realism being potentially sufficient to facilitate VFR navigation using a FTD.

Therefore, there is a need for a method to measure the navigation error and to configure a FTD suitable for VFR navigation in a way to minimise navigation errors. For this thesis, a research method was chosen based on Design Science (as discussed in Chapter 4) in order to find a solution to optimally configure a FTD suitable for VFR navigation. The FTD simulator configuration was

refined iteratively to the point where a minimal suitable configuration to meet the defined Learning Objective (LO) was established. A modified interpretation of the KS-Test was used to measure the simulator configuration. This process, as described by Chakrabarti. (2019), was used to decide if a sample comes from a population with a specific distribution and is explained in more detail in Chapter 4.

For the purposes of this thesis, the simulation software chosen as the basis to determine if a suitable FTD simulator can be configured as described by Chakrabarti (2019), was Microsoft Flight Simulator X. (Microsoft, 2006). This was chosen since the software is highly configurable and customisable for VFR scenery generation as it was important that visual landmarks and objects could be accurately represented within the FTD simulator environment. For the purposes of this study, visual landmarks are defined as any man-made object or natural landscape feature that can be used to identify a route for flying visually. These include objects such as buildings, rivers, coastline, islands, towns, and other identifiable features that can be identified as waypoints. A waypoint is a term to identify a specific co-ordinate of a location as defined by a GPS or object.

1.2 Research Aims

To gain a Private Pilot Licence in Australia and other countries such as New Zealand, acquiring navigational skills with the use of visual landmarks is a crucial skill to be learnt as part of Visual Flight Rules (VFR) training. To aid in achieving this skill, the use of low-cost computer simulation technologies is gaining popularity to teach VFR navigation skills in various flight training institutions and universities (Griffith University, 2019). However, an analysis of the effectiveness of simulation-based training requires navigational error to be systematically measured. In this thesis, a model for the determination of error was identified, and then applied to identify a suitable configuration for a FTD suitable for acquiring VFR navigation skills, with the study aims as described as follows, and further detailed in Chapters 4, 5 and 6:

1. To identify a method for configuring a FTD simulator suitable for successful VFR navigation;
2. To determine an error model to indicate the FTD configuration effectiveness, and
3. To present a minimum FTD configuration suitable for VFR navigation.

1.3 Research Questions

Supporting the research aims, the specific research questions for this study of this thesis were:

1. What is a suitable procedural method for configuring a Flight Training Device suitable for acquiring VFR navigation skills?
2. What is a suitable algorithm for an error measurement model to determine the effectiveness of a navigation FTD simulator?
3. What is the minimum Flight Training Device configuration required for successful VFR navigation?

To contextualise this study, it is to be noted that it aims to contribute to the field of Information Technology and applied to an industry example of flight navigation utilising a FTD simulator consisting of a combination of computer hardware and software. This placed the field of study mainly within the field of Information Technology and *not* Aviation. Therefore, the literature, research methodology and scope remained focussed on the field of Information Technology.

1.4 Contribution to VFR FTD Simulation Navigation

In this thesis, a model for the determination of flight navigation error was identified, and then applied to identify a suitable configuration for a FTD for acquiring VFR navigation skills. The thesis presents the following contributions to improving VFR FTD Simulation Navigation as is further discussed in Chapter 7:

- a. *A Process* using a Design Science interpretation applied to identify a method for configuring a FTD simulator suitable for successful VFR navigation.
- b. *An Error Measurement Model* based on gross error calculation by using a smaller data sample set instead of a large data set utilising patterns of small errors to indicate configuration efficiency.
- c. *A FTD Navigation Simulator Configuration* suitable for VFR navigation. Besides the use of FTD devices that have limited hardware and software configurations require an understanding of the configuration process to be effective. It is the intent of this study to present configuration methods that would be suitable for satisfying the requirements of a VFR Navigation FTD.

1.5 The Use of Flight Simulators

To make flight simulation technologies relevant and useful within the real flying environment, the challenge was to bridge the gap between simulation and reality by recreating the experience as close to reality as is possible, and to make the participants forget that the experience is simulated. Therefore, the FTD simulator focus needed to be on areas where the real experience could be emulated with a simulator which does not offer an accurate representation of a real cockpit since the FTD simulator is not an accurate replica of the aircraft cockpit used. The FTD simulator should also be capable of familiarising the pilot with procedures and processes that the pilot could take into an actual aircraft with the intent to focus more on the task of flying and maintaining situational awareness. The term situation awareness was adopted to describe the “processes of attention, perception, and decision that together form a pilot’s mental model of the current situation.” (Endsley, 1995)

There are also potential issues with utilising low-end desktop simulators relevant to this thesis: limited field of view, the absence of vestibular cues and aerodynamic forces, and the potential negative impact of low frame-rates(Drake & Abelson 1995). Research done by Norman & Grierson

(2012) showed that any advantages gained by adding a high-fidelity simulator with full-motion are very limited, and furthermore Bradley & Abelson (1995) discovered that when the output of a desktop flight simulator is projected on a large screen using a data projector, strong sensations of motion are induced through visual cues. The conclusion was therefore made that a low-end simulator configuration could be effective, and that further exploration in this area would be beneficial.

Literature in the fields of commercial, military and space aviation all indicate the usefulness of using a FTD flight simulators for training pilots. (Brannick 2005; D'Allessandro 2007; De Montalk 2008; Dennis & Harris 1998; Estock et al. 2008; Bills et al. 2010). However, the use of FTD simulators for private general aviation is relatively new, and utilisation of the technologies available to assist in acquiring the required skills is not uniformly accepted in the aviation industry. (Appendix 1)

Besides the use of FTD devices that have limited hardware and software configurations require, an understanding of the configuration process to be effective, and this thesis presents a configuration method that would be suitable for satisfying the requirements of a VFR Navigation FTD.

1.5.1 Commercial Full Motion Flight Simulators

It is generally accepted in industry that during commercial pilot training a full motion flight simulator built to replicate a full-scale aircraft cockpit in every detail is used as part of the formal training process to achieve and improve pilot proficiency levels (Kincaid et al. 2003, Craighead et al. 2007, May et al. 2010, Boril et al. 2015, Farmer et al. 1999, Judy 2018). This is further evident in the widely based use of full motion simulators by all major airlines. However, these commercial simulators are expensive to acquire and maintain. As an example, the Boeing 737, 747 and 777 simulators used in all the major airlines cost millions of dollars. (Qantas, 2019) A training session on the Qantas Boeing 747 simulator lasting typically around 1.5 – 2 hours is around \$1500 per session, a very expensive enterprise and reserved for a select few. For the rest of the flying

community, and specifically general aviation, there are very few simulators available to assist in training and in maintaining proficiency levels for private pilots. In Australia, many flying schools do not formally use any type of FTD simulator for private pilot training. Therefore, FDT simulators have not yet had a significant impact on the training of general aviation pilots, even though there is evidence for the potential for learning aviation skills through virtual environments. (O’Hare, 2001). The main reason for the lack of utilisation of desktop flight simulators is the perceived impact of hardware limitations on flight realism, and typically that low-end non-motion simulators have certain limitations within the aviation industry, specifically the aviation government regulating body CASA.

These commercial simulators do not require configuration as they are built to duplicate actual aircraft cockpit configurations. Full motion simulators are not usually configured for VFR flight training due to the high-altitude environment that Instrument Flight Rules operate in (Typically 30,000 – 45,000’)

1.5.2 Computer Aided Flight Training Simulation Devices

According to Craig (2000), the use of flight simulation training devices that are not full-motion or accurate replications of aircraft cockpits in full detail to assist student pilots during their training is useful in several potential areas. He identified four methods to observe pilots and their decision-making tendencies, namely:

- The classroom environment
- Computer-assisted instruction
- Flight simulation, and
- Flight in an actual airplane (pp29-30).

The classroom method usually involves a retrospective look at decisions made by pilots who were previously in accidents this method involves recreating the decision sequence that led up to the accident. This “learn from the mistakes of others” method is better than nothing, but it does not feel

very real to the pilot. There are also some terminology issues that have developed over the years in the world of ground simulation and Craig stated that the use of the term ‘flight simulator’ has become misunderstood. Instead, he argued that an airplane simulator

“must be a full-sized exact replica of a specific type, make, model, and series airplane cockpit. It must have computer software programs that are necessary to represent the airplane in ground and flight operations. It must have a visual system that provides an out-of-cockpit view and a force (motion) ‘cueing’ system that at least provides cues around the three axis of airplane control” (p30).

The above is referred to as full-motion simulators have a price tag starting of millions of dollars, which makes the use of flight simulators prohibitive outside of military and airline training centres. Consequently, general aviation pilots are more likely to use what is now being called a Flight Training Device (FTD). Furthermore, recent research has explored utilisation of various aspects of low-end flight training devices and determined that there is enough potential in these technologies to explore relevance in the training of general aviation pilots. (Pingali & Newman, 2017, O’Hare & Wright 2015, Newman 2014, Rewiti et al. 2017)

A more affordable simulator device layout can be inside an enclosed cockpit or arranged as an open flight deck and this device can be a FTD, and does not have to duplicate any specific airplane, and visuals are not required. This category of training device has been known by many names in the past, and this has led to some confusion. Cockpit procedural trainers (CPT), cockpit systems simulators (CSS), ground trainers (GT), and fixed base simulators (FBS) all now fit under the FTD category – collectively known as Computer Aided Flight Training Devices. Before any machine can be used in the training of pilots, it must be approved by the relevant aviation authority. The research for this thesis could apply to the type of simulator as described, and present future research

opportunities, but was not the main focus, focussing instead on desktop flight simulators due to the cost factor and configuration options.

1.5.3 Desktop Flight Simulators

As mentioned, in Australia the Civil Aviation Standards Authority (CASA) has been slow to recognise or approve the use of FTD computer flight simulators using consumer personal computer training devices for Private Pilot training. Over the past 2 decades the Microsoft Flight Simulator software has been supplemented by many third-party software developers, resulting in a flight simulation suite focused on being as realistic as possible to simulate the real world in aviation. However, the measure of how realistic the software is in relation to the actual flying environment is integral to its' usefulness as a training tool. It is therefore important that a framework be established to identify and measure the critical factors that need to be satisfied within the aviation parameters in which to measure the software's realism.

Since Microsoft Flight Simulator is one of the main commercially affordable simulators used today by many flight simulator pilots, real pilots, and third-party developers, this research focussed on the capabilities and features of this simulator. There are other civilian flight simulators available, for example X-Plane and Pro-Pilot, but this research excluded those due to the limitations in configuring the software. Herd (2001), in his review of Microsoft Flight Simulator, stated that latest version of Microsoft Flight Simulator scenery mesh is so accurate that he could fly around in the simulator world identifying many places he knew.

Jacobs (2005) stated that a “flight simulator with a few add-ons available from the many third-party designers, should be capable of giving a pilot familiarity with operations and familiarization towards a private pilot's license.” To enhance the default commercially available flight simulator software, third party software applications are available to assist Student Pilots in many areas of aviation, and

in Australia software for Visual Flight Rules (VFR) and Night Aeronautical Instrument Planning Systems has been developed by various commercial software developers such as Aerosoft Australia. (CarpAir, 2003).

This indicates a level of realism that could potentially be enough to allow VFR flight in a FTD simulator. To further add to the realism of Microsoft Flight Simulator, third party software developers have developed scenery products that enhance the realism of scenery and buildings to the point where they can be very closely compared to the real world. (Appendix 2)

Research from Thomas (2018) validated the potential of using home personal computer scenario-based simulation for instrument currency. Flight simulation for private pilots has become more affordable due to the technological advances in personal computer hardware and flight simulation software, and consequently some international Aviation Authorities and flying schools have already recognised the impact of these new technologies on private pilot training and incorporated these technologies into the formal private pilot syllabus. While it is true that these technologies have limitations, they offer an affordable and viable flight simulation environment that could be valuable for private pilot training.

Davis (2004) referred to the fact that flying schools and clubs offer “initial pilot training and qualified pilots to practice and hone their flying skills.” (p22). An example of such a FTD simulator Microsoft Flight Simulator 2004 provides a fully featured 'Virtual Cockpit' across three 17" TFT screens providing “incomparable” situation awareness. This technology provides greater realism since the simulator pilot can have a larger field-of-view of the cockpit and surrounding scenery. It is to be noted that research by Myers & Mullind (2018) indicate that flight simulation cannot replace real aviation - only supplement.

1.5.4 The Flight Training Device (used in this Study)

The FTD simulator used for this study needed to be determined before the configuration process could be undertaken. Therefore, it was important and relevant to gain an understanding of the relevant available hardware and software technologies that could be utilised for the FTD simulator.

The Hardware and Software

Flight simulation aims to find a compromise between realism and safety, so even though participants know that it is a simulation and that there is no real danger, the experience and the stress of a realistic simulator session tend to suggest that it is real enough “to be terrifying” (Lehrer, 2011)

Figure 1 shows a comparison between the real Cessna 172 cockpit panel (left image) and the FTD simulator panel (right image) used in this study. The obvious difference is the fact that the simulator panel is displayed on the computer monitor, and therefore only partially visible, whereas a life-size replica of the actual Cessna 172 cockpit is presented in the real panel.



Figure 1 Cessna 172 Glass vs Analogue Cockpit Panel

Additionally, all the switches within the simulator need to be manipulated through a mouse and/or keyboard, whereas the real cockpit switches are actual rocker switches. The absence of additional hardware affects the overall realism of the simulation as it has an impact on the feel of the flight controls and aircraft motion effects, and the transition from an advanced glass cockpit to a conventional analogue cockpit is an issue as identified by Wright & O'Hare (2015). There have been other studies in this area, and (Haslbeck & Hoermann, 2016; Whitehurst & Rantz, 2011; and Pingali & Newman, 2017) conducted experiments to compare pilot eye scanning patterns in different types of cockpit configurations.

The results from the above research show that when making a transition to an aircraft with an analogue cockpit, the scanning patterns were significantly different. Their findings showed that VFR pilots' eye scanning preferred an analogue display, whereas pilots who fly mainly with instruments under Instrument Flight Rules (IFR) preferred the Glass cockpit display. These findings were considered during this research and the resultant impact on the realism is therefore acknowledged. The decision was therefore taken to only use the traditional cockpit instrument layout using a computer monitor for this study, because Newman (2016) shows that pilots who have trained on analogue instruments find it easy to become accustomed to the digital cockpit, and that when the situation is reversed, the extra mental load going from digital to analogue can cause problems.

The third issue was how the simulation loaded the virtual environment whilst in flight. This phenomenon was described by Zyskowsky (2003) as Terrain/Sim Interaction. He explained that a major problem with any simulation is the interaction between a simulated object and the world in which it is simulated. This was mainly due to limitations in hardware as it is not possible to load the entire world's scenery into the simulator during flight. The simulator always must know where on the geographic grid the aircraft is, and then load the appropriate scenery for that area. This creates

strain on the hardware, resulting in reduced performance. To counter this, certain sacrifices must be made to realism to maintain acceptable simulator performance. Therefore, only the scenery detail relevant to the navigational exercise was loaded into the simulator.

1.6 A suitable FTD for VFR Navigation

A Private Pilot Licence (PPL) is the minimum licence required by law to be able to fly an aircraft legally and is mostly used for recreational or general aviation. The licence that follows the PPL is the Commercial Pilot Licence (CPL), and is primarily focussed on commercial aviation. It is the minimum licence required to work and fly for remuneration. (CAA, 2018; CASA, 2010). This thesis focussed on VFR exclusively since all pilot training in the initial training is primarily focussed on VFR for the Private Pilot Licence which relies heavily on visual references for flying. Since the use of simulators have been successfully proven within the commercial and military aviation sectors, the success of these simulators can now be translated into the field of general aviation through appropriate simulation technologies as stated above. Later research done by Taylor et al. (2005) showed that using a flight training device (FTD) is effective in teaching basic instrument tasks to private pilots, and that actual flying hours (around four hours) could be reduced during training.

(Brannick et al., 2005; D'Alessandro, 2007; De Montalk, 2008; Dennis & Harris, 1998; Estock et al., 2008; Heerkens, 2002) show that low-grade simulation during the initial stages of flight training is beneficial for the acquisition of many skills in military and commercial aviation, including navigation skills. Realism is presumed to be important for pilots training for a PPL because these trainees are expected to navigate using Visual Flight Rules that reference visible landmarks such as cliffs and man-made objects such as buildings. Despite this, O'Hare (2001, 2015) demonstrated that low-grade simulation can be effective for pilot training. Similarly, Rewiti et al. (2017) indicates enormous potential for learning aviation navigation skills through virtual environments.

As mentioned earlier, the research done by Taylor et al. (2005), Rewiti et al. (2017) and Pingali & Newman (2017) showed that using a flight training device (FTD) is effective in teaching basic instrument tasks to private pilots. Rewiti et al. (2017) further explored whether a full cost flight training device was significantly better for simulator training than a low-cost PC-based Aviation Training Device. They found no overall evidence that an CAFTD performed better than a FTD when used to train pilots to “perform a VFR re-join procedure (flying pattern around an airport in preparation for landing); there was no evidence of a significant difference in pre-test/post-test change scores between the FTD group and the PCATD group”. Specifically, while there was strong evidence of the effectiveness of training compared to no training on these variables, there was “no evidence of a difference in efficacy of FTD vs. PCATD training. This implies that VFR task training (e.g.: Overhead Re-join Procedure) was just as effective when completed on the low cost PCATD as it was on the certified FTD.” These findings are important for this thesis, as they emphasise the potential use of a FTD as a VFR pilot training aid.

1.6.1 Simulator Fidelity

For any simulator to be useful in preparing for the real environments, it must satisfy fidelity requirements, and as such simulation has traditionally been defined as ‘the degree to which the simulator replicates reality.’ Vonthoff (2017), using this definition, simulators are labelled as either ‘low’ or ‘high’ fidelity depending on how closely they represent ‘real life’. He also stated that, ideally, every simulation would be high fidelity and would replicate as precisely as possible the real-world application, but that is an unrealistic expectation. The realistic view is that fidelity is almost always a trade-off between the degree of fidelity required and the simulator cost.

The term “simulator fidelity” is further described in Wahl (2019) “to indicate the degree of physical resemblance between a computer-created simulated environment and a real work environment” (p32). (Hontvedt and Arnseth 2013; Liu et al. 2009) further describes in Wahl (2019) that fidelity “is characterised as high or low depending on how immersive or complex the simulations are

perceived”...and ... “The degree of fidelity increases as the simulated environment becomes more like the physical work environment.”. (p32). In addition, the term simulator fidelity can also be described with multiple subcategories, for example physical fidelity, functional fidelity, or task fidelity (Liu et al.2009)

As stated, the use of flight simulator applications on personal computers has not had widely accepted formal impact on the training of general aviation pilots, even though there is enormous potential for learning aviation skills through virtual environments using an FTD simulator. (Pingali & Newman, 2017; O'Hare, 2001; Rewiti et al, 2017)

The potential issues utilising low-end desktop simulators relevant to this study were: limited field of view, the absence of vestibular cues and aerodynamic forces, and the potential negative impact of low frame-rates. (Drake & Abelson, 1995) Research done by Norman & Grierson (2012) showed that any advantages gained by adding a high-fidelity simulator with full-motion are very limited, and furthermore Bradley & Abelson. (1995) discovered that when the output of a desktop flight simulator is projected on a large screen using a data projector, strong sensations of motion are induced through visual cues. The conclusion was therefore made that a low-end simulator configuration could be effective, and that further exploration in this area would be beneficial.

For a FTD to be used as a flight simulator, (Drake & Abelson 1995) described a basic desktop flight simulator as representing flight instruments graphically with a straight-ahead view utilising control inputs provided through a mouse, joystick, and flight yoke. A VFR simulator also requires more computing power to render scenery due to the requirement to render the scenery accurately enough to facilitate navigation using visual references.

Therefore the biggest factor that sets an FTD apart from a conventional flight simulator is the extent to which an FTD can achieve fidelity and the conclusion may therefore be drawn that a FTD

simulator could be effective if a suitable configuration is determined, and that further exploration in this area would be required.

1.6.2 Configuring a FTD Simulator

The issue of understanding simulator design (configuration) has enormous potential for learning aviation skills through virtual environments, and there is a need for further research aimed specifically at the effects of simulation interface design on concept learning. (O'Hare, 2001; Williams, 2003). The impact of the configuration of a flight simulator needs to be explored to determine if proficiencies can be improved utilising a low-end simulator. (Hays, 1989). To this end it is imperative that the simulator configuration can effectively merge the simulator design, configuration and subsequent effectiveness in achieving the required proficiencies.

FTD simulator configurations need to be able to effectively merge the simulator design, configuration and subsequent effectiveness in achieving the required proficiencies. The configuration of a flight simulator generally includes:

- A flight deck replicating the aircraft controls, equipment, observable indicators, and controls.
- The pilot seating position allowing the occupant to achieve the design “eye position” established for the airplane being simulated.
- Electronically displayed instruments and instrument panel layouts that are dimensionally correct with differences, replicating those of the airplane including full instrument functionality and embedded logic including: resolution, colours, luminance, brightness, fonts, fill patterns, line styles and symbology. (FAA,1994)
- Flight simulation software to represent the virtual world for the simulator

(Harvey, 2006) compared the scenery in the virtual world within the real world and showed that the simulation software compared very well to the real-world scenery, and that real aviation charts could be used when using the simulation software. That study showed that personal computing flight

simulation software has evolved to a level of complexity and accuracy such that it could be used in the training and maintenance of piloting skills of private pilots.

(Pingali & Newman, 2017) utilised cockpit configurations to look at how novice and experienced pilots look at digital and analogue cockpit instruments during daytime VFR flight with emergencies and unusual attitudes, and then repeating that under instrument conditions. The study did not investigate whether simulator training is comparable to other types of training. However, findings from research done by (Newman, 2014) indicated a notable difference in the way pilots perceive information.

This thesis focussed on finding a suitable method for configuring a FTD simulator, and presents a process along with an error method as discussed in Chapters 3 and 4.

1.6.3 Flight Simulator Scenery Realism

This thesis focussed on the configuration of a FTD simulator suitable for VFR navigation. As such, the relevance of realistic scenery generation is important to facilitate this task successfully, and to understand how these technologies are able to create the level of realism required for VFR navigation in a FTD.

Lateef (2010) found that flight simulations can also create a level of anxiety that affects the pilot's performance or participation, and it is impossible to genuinely recreate authenticity in a simulated environment. This is relevant to flight simulation as the simulator environment needs to accurately represent actual flight environments to develop and increase piloting proficiencies in a safe setting. In the attempt to increase simulator realism, students also need to be guided throughout the simulation, and learning needs to be graduated. Because simulation setup costs can be significant, this needs to be considered during any simulation design and setup. Lateef further stated that simulator facilitators sometimes need to invest significant time learning the tools required to develop a simulation to track and structure activity, and to monitor and communicate with students during

simulations. For the purposes of designing a cost-effective flight simulator, it is therefore also imperative that an efficient simulator configuration is identified that will balance the requirements of learning piloting skills and flight simulator cost.

Therefore, there is a gap between the technologies and the adoption in the field of available FTD flight simulators suitable for private pilot training is clear, Craig (2000) stated that "...as computer technology has exploded, many industries have jumped on the bandwagon and uses (sic) include flight simulation." He added that during "the time since the 1970s, flight simulation has gone from a GAT (General Aviation Trainer) to full-size, holographic, multiple-axis motion marvels. The flight simulators of today are so real in every respect that it has become common place to do 100 percent of the required flight training in them." (Craig, 2000, pp27-28)

These flight simulators offer complete start-to-finish flight scenarios. Researchers have taken advantage of this, and general aviation has been left out in the process. With each improvement in the computer/simulator technology, the price of these technologies has increased, and general aviation had been priced out of the flight simulation market. Therefore, researchers seeking a device that would be closest to the real thing followed the technology up the scale. Since the airlines and military institutions capable of affording these devices, researchers were drawn to airline training centres and military bases, and away from general aviation airports and its pilots (Craig, 2000, p29).

This view is therefore important to this study as it highlights the fact that research in the area of private pilot training has until now been limited, and as such identified a gap to be researched in this field. If the use of flight simulators for the commercial pilot has been as successful as stated by (Craig, 2000) in improving safety and pilot responses, then the same could be true for the Private Pilot, and low-grade simulation during the initial stages of flight training is beneficial for the acquisition of many skills in military and commercial aviation, including navigation skills.

(Brannick et al., 2005; D'Alessandro, 2007; De Montalk, 2008; Dennis & Harris.; 1998, Estock et al., 2008; Heerkens, 2002). These studies highlight the importance of maintaining aviation safety standards in the use of FTD's if these are to be taken seriously for flight training purposes,

Low-grade simulation typically executes on a Personal Computer with flight simulator software that does not have the immersiveness or realism of virtual reality simulation on computationally powerful computers. Realism is presumed to be important for pilots training for a Private Pilot License (PPL) because these trainees are expected to navigate using Visual Flight Rules that reference visible landmarks such as cliffs and towers. Despite this, (O'Hare, 2001, 2015) demonstrated that low-grade simulation can be effective for pilot training. Similarly, (Rewiti et al, 2017) indicated enormous potential for learning aviation navigation skills through virtual environments.

1.7 Relevance to Real Aviation

It is important to highlight the relevance of flight simulation to real aviation, and how it can be adopted for pilot training. With the level of complexity of the technology, and with the cost of PC hardware and software becoming more affordable, it is possible for more people to add hardware and software to their low-end PC flight simulator. Today the cost of hardware that is capable of recreating realistic force feedback sensation is in the vicinity of \$200 - \$300. This is certainly a feasible cost for the serious flight simulation enthusiast. However, affordable rudder pedals do not have the same haptic input, and those that do are expensive.

In addition, the advances of computing processing power, and the falling cost of computers themselves, give computing power capable of handling complex algorithms and fast screen refresh rates. This can then be utilised with the software programming. However, (Deitz, 1990) stated:

“Although the computer is more powerful than just about any other tool used by engineers, it has not yet overcome a critical limitation of most of the tools it has displaced: the inability to render 3-D objects via a 2-D medium.”

This is unfortunately a limitation that has a significant impact on the flight simulation realism since the 360-degree field of view is absent when the simulator world is only shown through one computer monitor. However, it is possible to partially overcome this problem by placing a series of three to five monitors around the seat of the simulator station, thus increasing the field of view to approximately 180 degrees. Each monitor would be able to display a part of the world in real time to extend the field of view. (Dietz, 1990)

(Sullivan, 1998) conducted a study to describe an initial experiment to determine if experienced helicopter pilots could effectively navigate using this system and if their performance was reasonably similar to their performance in an actual helicopter pilot. The study concluded that the “...Virtual Environment appears to be a viable approach to appended training for helicopter simulation – possibly for vehicle simulation in general. We believe the primary advantages of this apparatus are (1) its ability to simulate a stressful environment, (2) its close approximation of the real-world task, (3) its small footprint, (4) its low cost, and (5) its potential for use in a deployed setting.”

Lennerton (2004) explored the creation of a trainer that places the pilot in an immersive and familiar environment to exercise myriad piloting tasks as faithfully and as rigorously as in actual flight, with the aim to assess the viability of an chromakeyed augmented virtual environment (ChrAVE) trainer embedded into a helicopter for use in maintaining certain perishable skills, specifically to address the task of helicopter low-level land navigation. The study recommended that to migrate the outside view and instrument panel, rendering to a single CPU is required.

The above indicate the potential for the current scenery level of realism available in current desktop flight simulators to be used for VFR navigation, especially with the available add-on scenery technologies as discussed in the next chapter and in more detail in Appendix 3. Only one flight simulator and associated scenery enhancements was selected for this thesis (Microsoft Flight Simulator X), but it is to be noted that there is a myriad of other such flight simulator applications available which offer similar features. The notable exception to these technologies is Virtual Reality (VR) and Augmented Reality (AR) technologies. Further research in utilising these technologies would offer new possibilities to further enhance the level of realism. For this thesis, these were excluded.

1.8 Limitation of the Study

Due to the nature of the real aviation environment, there are several limitations that needed to be considered during the research process, in the analysis of the final results. This was mainly because flight simulation takes the pilot out of the sky and into a safe, controlled simulated environment and the overall impact on realism due to the lack of sensory motion input. Therefore, it was not possible in this thesis to test if these skills transfer to a real aircraft as it was a requirement that the selected participants were not trained pilots. Additionally, there were anticipated variables with the flight not included in determining successful VFR navigation, as they were deemed not relevant to the learning objective:

These were:

- a. Aircraft height. The participant had issues remaining at a constant height and attempted to fly at a lower altitude to attempt to have greater visual reference of the ground. This did not result in seeing more because the detail level setting was minimum as height difference will only assist when flying higher – not lower.

- b. Aircraft speed: The participant did not keep a constant speed. This was because of varying height and not focussing on the instruments enough.
- c. Simulator experience: This caused the participant to make several height, speed and course adjustments. This is simply due to a combination of simulator sensitivity and experience in handling the simulator controls. By adjusting the sensitivity of the controls, it would compensate for this issue. (Note: This results in less accurate setting of the flight controls in relation to actual real-life flight controls. However, if required this can also be adjusted to improve flight control integrity, but in this instance the only focus was on the ability to successfully navigate.

1.9 Conclusion

This chapter introduced the study, identified the research aims with research questions, research contribution, scope, limitations, and an introduction to a Flight Training Device (FTD). The chapter further focussed on the flight simulator software technologies used as basis for the FTD used in this study. The next Chapter will discuss areas of pedagogical strategies for adult learners in simulation training, as well as identifying a suitable evaluative framework for the research. This included defining which skills required for private pilot training can be developed with the use of the simulator as well as a model for flight simulation training and considers the use of flight simulation software within the identified field and scope of this study.

CHAPTER 2

PEDAGOGICAL STRATEGIES FOR ADULT LEARNERS IN SIMULATION TRAINING

2.1 Introduction

This chapter discusses pedagogical strategies for adult learners in simulation training and identifies a suitable evaluative framework for the research. This includes identifying which skills are required for private pilot training can be developed with the use of the simulator, as well as a model for flight simulation training and considers the use of flight simulation software.

2.2 Pedagogical Strategies for Adult Learners in Simulation Training

Further to the discussion of the technologies relating to configuring a FTD simulator, it is important to consider how the required skills need to be taught with a FTD simulator. Since the assumption can be made that pilots are adult learners, the definition of Belletti & Mihall (1999) of adult learning methods as ‘andragogy’ derived from the Greek word ‘aner’ meaning man, and not boy can be adopted for this thesis.

They identified adult-learning principles as follows:

- “Focus on real-world problems;
- Emphasise how the learning can be applied;
- Relate the learning to the learners’ goals;
- Relate the material to the learners’ past experiences;
- Allow debate and challenge of ideas;
- Listen to and respect learners’ opinions; and
- Give learners control.” (p1)

Coupling the above within the field of training of adults in a simulation-training environment, “a simulation is a serious attempt to accurately represent a real phenomenon in another more malleable form” (Vogiatzis, 2005), and the term “simulation” can be defined as the artificial representation of a complex real world process with sufficient fidelity to achieve a particular goal, such as in training or performance testing, and identified four types of computer-based simulators:

- Screen-based text simulators;
- Screen-based graphical simulators;
- Mannequin-based simulators; and
- Virtual reality simulators. (Doyle, 2002, p1).

This study dealt with a low end FTD simulator where the simulator creates a virtual world that represents the real world. The assumption that the more realistic the experience, the more successful the simulator would be as a training tool is controversial, as commercial flight simulators do not require high fidelity realism to be a successful training tool as is discussed previously on p22. However, (Laurillard, 2002) stated that a simulator should be based on a model suitable for training and “... a simulation is possible for anything that can be implemented as a model relating two or more parameters, where changes to one parameter produce changes in another”. (p32) A simulation also stands or falls with the quality of its model, and the learning and competing elements of a flight simulator make the experience more engaging. Since the simulator is very complicated, different tools and frameworks for constructing simulated learning environments exist. (Pennings, 2004)

sum

To further highlight the need to make the simulator experience more engaging and interesting, Roge & Laba (2003) found that a learner activity involving only hypertext links or answering multiple choice questions is not sufficient for improving human training environments. This view holds that the learner needs to be engaged in problem-solving activities involving real interactivity through a virtual reality simulator (p1).

Adding to this theory, (Quak et al, 2015) argued that “higher-order representations of the external world built from memorized information have been shown to influence visual processing, and complex representations (thereof) seem to be formed in working memory, consisting of the integration of several independent representations that can be sensory, and short- or long-term memory activations.” Depending on task requirements either just the simple modal representation or the complex high-resolution binding of several features at once will become active.

The simulation software for this study is designed with an interface that resembles the cockpit instrument panels from several aircraft. This study looked only at the cockpit panel of the Cessna 172 (Referred to in Figure 1) since this is the aircraft most widely used for private pilot training in Australia. The simulation software interface allowed the user to interact with the instruments and allowed various outside views of the virtual world around the aircraft. The simulation software for this research used an intuitive virtual cockpit interface that closely followed the SimPLE model as identified by Rose et al. (1998)

Simulation-modelling software presents diverse functionality that can be used to accomplish various types of projects. Atolagbe et al. (1997) stated that the “pedagogical environment for simulation modelling involves classroom activities and mastering a core set of contents”, and that “classroom activities should expose the adult learner to intuitive aspects of simulation modelling and the knowledge embedded into practice.” (p1396). This model of learning could be useful within the scope of this study with an exercise comparing an actual flight with a simulated flight. Additionally, (Williams, 2003) examined the major features of a simulation learning environment, and identified a framework that places the simulation interface design at the centre of interactive learning, mediating as an information flow portal between human cognition and a programmed model (p1). This approach from Williams is appropriate for this study and is discussed in more detail below.

The meaning of simulation is often used in the context of the beneficial use of the technology, and any system can be simulated in computer-based learning, if its relevant attributes can be expressed in terms of an algorithm model. This model may be based on the “real world” or fantasy (p2). As a result, Williams identified a simulation as a “modelled interactive environment that reflects particular attributes of another system.” (p2) Williams specifically referred to Microsoft Flight Simulator as an example of such a simulation.

De Jong (2002) proposed 4 requirements for instructional use of simulations. These are:

- The presence of formalised, manipulatable underlying models;
- The presence of learning goals;
- The elicitation of specific learning processes; and
- The presence of learner activity. (De Jong, 2002)

These requirements are relevant to this thesis since it was important to identify a clear learning goal or learning objective (LO), based on specific learning process utilising a formalised model of learning. In this context, a cognitive approach in which immersion is created through sensory stimulation has been identified by Zyda (2005), indicating that this must involve a pedagogical approach where the activities must educate or instruct and impart knowledge and skill (pp26-29). Kirkpatrick (cited in (Doyle, 2002)) identified four levels of evaluation of teaching programs, involving four kinds of measurement. These are Reaction, Learning, Behaviour and Results. The simulation software used in this study supports all the above features for instructional use as specified by Kirkpatrick.

2.3 Pedagogical Framework for Flight Simulation Training

Innovative research has been done to teach real world environments through games simulation as a pedagogical approach. (Aldrich, 2003; Prensky, 2001). According to Léger (2006), results from these studies show that simulation games have the potential “to replicate in a simplified manner, the complexity of a real-life environment, giving the participants experience with a particular phenomenon.” Further research show that simulation games have been widely used in different areas, and Léger stated that simulations have also been used in the field of information technology. Léger cites an example from Nulden and Scheepers (2002) suggesting a “learning methodology to guide students through the experience of software development failure and escalation so that they can learn firsthand from this experience’ as well as “Bodoff & Forster (2005) who proposed an innovative “learning-by-doing” approach to teaching Enterprise Resource Planning (ERP) concepts....and Draijer and Schenk (2004)...(that) “presents a simulation game in which students have to run a business with a real-life ERP (SAP R/3).”

In the above example a “simulation software program and computer-automated script were developed to automate the sales process, so that every firm receives a large number of orders in each quarter of the simulation”. Léger (2006). These examples, (offering a pedagogical approach for teaching through simulation), suggest the potential for using software simulation to teach real world environments and refer to simulation configuration of the software, but do not go far enough to identify a specific universal and simple approach to configuring the software and hardware of a FTD simulator to suit many different situations. It is, however, useful to assist in guiding the exploration of simulator configuration by identifying the pedagogical purpose of the FTD simulator.

As discussed earlier, Williams identified a framework for simulation training suitable for the purposes of this study. This uses the “Conveyor Model”. The model places the interface in a central position, with the person and the simulation software at opposing poles as indicated in Figure 2.

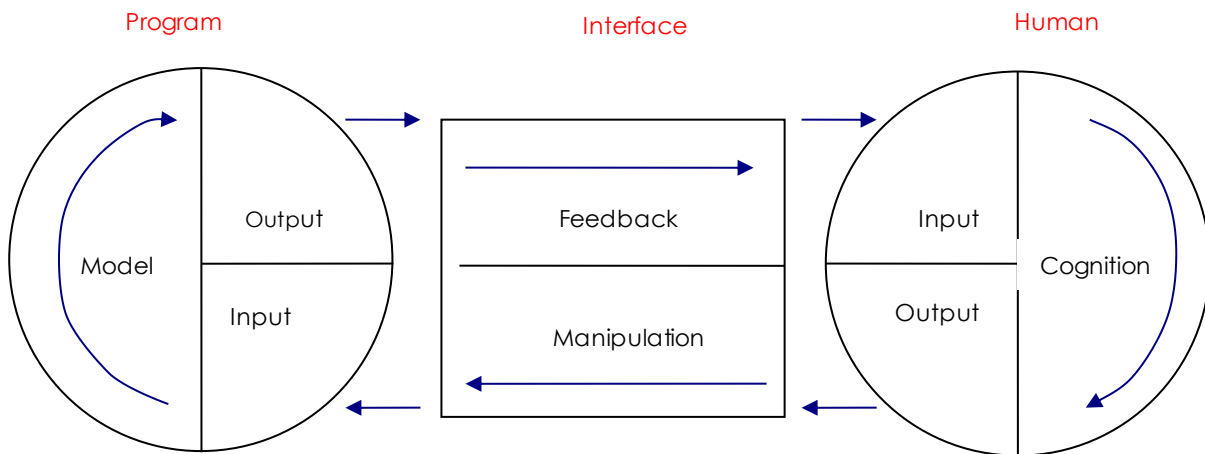


Figure 2 The Conveyor Simulation Model

The above framework as identified by (Williams, 2003) would be useful in flight simulator technologies, and since commercial and military pilot skills have been successfully taught through the use of flight simulators, these simulators have formed an integral part in the training of commercial pilots for decades. Williams defined the framework based on a model containing the human end, the interface and the program end. In this study, the framework from William was adopted in this thesis, and therefore an academic set of parameters as specified applied to measure how effective the simulation software would be for Private Pilot training and proficiency for VFR navigation using a suitable FDT simulator.

2.4 The Human End

In this phase, sensory input occurs through sight, hearing, touch, taste, smell and vestibular mechanisms. Usually only sight and hearing are included through a computer interface, but the use of touch sensory input through force feedback hardware is increasing (p5). Williams placed this phase within the *elicitation of specific learning processes* and the *presence of learner activity* of De Jong & Njoo's structure of the instructional use of simulations. (Alessi, S. M., 2000).

Since the primary purpose of the simulation software is to interact with a human being, the focus of this element of the framework is to measure how successful this interaction is and how effectively the simulation can represent a realistic experience to the user.

2.5 The Interface

Following Williams' framework, the keyboard, monitor(s), mouse devices and voice activation form the interface between human and computer (p9). He stated that most simulations rely on visual representations to provide the setting and to display feedback, manipulating the environments. The emphasis is placed on realism or fidelity, where increasingly rich graphical environments aim to reproduce the look and behaviour of the real-world environment. In simulations where skilled operation is the desired resultant, high levels of fidelity would result in the user being able to transfer learned procedures to the real working environment.

(Williams, 2003) further identified manipulation of the interface as contributing to the realism of the simulation. (Shneiderman, 2016) stated that direct manipulation of the interface involves three criteria:

- Continuous representation of interest
- Labelled button presses used instead of command line syntax; and
- Operations whose impact on the object of interest is immediately visible.

While these criteria presume a two-dimensional (2D) desktop environment, the principles broadly apply to three dimensional (3D) virtual environments and simulators. These guidelines are fundamental parameters in developing a graphical user interface. The simulation software uses the computer interface through a range of hardware. This ranges from the basic keyboard and mouse to force feedback joystick controllers, flight yokes and rudder pedals, and virtual reality 3D glasses. Therefore, these features of the software can be measured against this element of the framework.

2.6 The Program End

The Conveyor Model identified that any single learning simulation may involve multiple tasks or combinations of task outcomes, and Williams specifically uses the example of a flight simulator used for operational training (sequences for take-off and landing), which may also be used for teaching theory (p17).

Williams consequently specified the following parameters to identify and specify the role of the 'program end' for a simulation:

- Defining the models to be simulated by identifying variables and relations
- Balancing variable and relation complexity with task intention and the user's developmental stage
- Considering situational contexts by providing sufficient support material prior to and during the interaction
- Creating a set of guided goals to facilitate progressive discernment of model properties
- Matching task intention to the desired outcomes (p18).

(Chiniara et al, 2013) adopted this framework for instructional design and media selection in healthcare to assist educators in creating appropriate simulation experiences and provided a taxonomy to streamline future research in simulation. Following this research, and Williams' framework, the keyboard, monitor(s), mouse devices and voice activation supported within the FTD simulator used for this study formed the interface between human and computer. Consequently, these devices were used to interface with the simulation software used in this research. The data collection exercise as discussed in Chapter 6 used hardware with software through an interface where the user was given input of the simulation visually and aurally, and therefore it was appropriate to use Williams' framework in this study.

The user was required to respond to this input and interact through the keyboard, mouse, flight controller and rudder pedals. As a result, a clear cognitive process was created, and therefore fitted well within the overall definition of Williams' model. However, this research did not make use of force feedback hardware, and only included sight and sound sensory input.

2.7 Evaluation Framework

2.7.1 What Skills do Pilots Need for VFR Navigation?

To identify an evaluation framework for this study, it is important to identify what skills private pilots need to successfully navigate in a VFR environment during the training process to measure how effectively the simulation can contribute to developing these skills. For the purposes of this study, the main identified skill is the ability to be able to fly a VFR flight between two destinations to meet the Private Pilot licence standard. Along with this requirement, the ability to control an aircraft to successfully complete the flight is required as specified by the CASA (2010) and CAA (2018) PPL Syllabus.

Hunt (1997), as cited in (De Montalk, 2005) stated that "...pilot performance has traditionally derived from observations of flying skills (stick and rudder) and the individual's knowledge of flight rules and procedures.) There are many ways to measure pilot performance. Some examples are :

- Surveys (McCracken, 2011)
- Deviations such as altitude, heading, etc. (Degani et al., 1991)
- Eye movement (Mumaw et al., 2000, Huettig et al., 1999; Colvin et al., 2005, Diez et al., 2001, Pingali & Newman, 2017)

(Robertson, 2005) described these skills as Enhancing Pilot Decision-Making, which include higher order thinking skills (HOTS), such as analysis, synthesis, and evaluation. He further stated that these skills describe both the cognitive process and cognitive skills that are essential to judgment,

decision-making, and critical thinking. He also stated that these are taught like any other cognitive skill from simple to complex, and from concrete to abstract and that HOTS are learned in a similar way and are supported by the same learning theories that facilitate their development and transference (pp24-25).

Therefore, it was important to identify what higher order thinking skills could be learnt using the simulation software used in this study. However, to be able to identify these skills, it was also required to obtain an understanding of how these skills are learnt.

2.7.2 How are the Skills Learnt?

(Cotton, 1991; Robertson, 2005) noted that the teaching methods and strategies to teach these skills can be used via teaching methods used in disciplines outside of aviation. However, (Cotton, 1991) as cited in (Robertson, 2005) stated that there is no single way to teach thinking skills. Cotton added

“To foster the development of thinking skills, the instruction should include redirection/probing/reinforcement, asking higher-order questions, and lengthening wait-time”. (Robertson, 2005) further stated after looking at various reports and documents that “any strategy or technique employed to facilitate learning thinking skills can be effective, if properly administered. These strategies include engaging the learner in some form of mental activity, having the learner examine that mental activity, selecting the best solution, and challenging the learner to explore other ways to accomplish the task or the problem” (p25).

According to Robertson this implies that the cognitive skills needed are learned through experience, that is, they are not taught or learned through the instruction normally provided in the aviation education or flight training programs. He concludes that teaching higher-order thinking skills

effectively involves customizing the examination and exploration of the mental activity to meet the individual learning needs (p25). Robertson further noted that “Pilot training is multi-faceted; it consists of aeronautical knowledge, skills performance, and aeronautical decision-making (ADM) components (FAR Part 61 and Part 141)” (p67).

Robertson further stated that each of the components has its own instructional requirements. These include procedural knowledge, psychomotor skills, and cognitive skills respectively. The FAA identified four methods of instruction to facilitate learning of these components: lecture, demonstration-performance, cooperative or group learning, and guided discussion components” (Robertson, 2005, p67).

The above therefore is relevant to this thesis insofar as it is important to recognise that there are many facets of pilot training that require different requirements in skill. As such, to teach a specific skill, a FTD used for training will need to be configured differently for each skill.

(De Montalk, 2005) identified four categories of skills that pilots need to have. These are Leadership and Managerial Skills, Situational Awareness Skills, Decision Making Skills and Cooperation Skills. However, these skills referred to commercial pilots working within a multi-crew cockpit environment. This study focussed on a single-crew cockpit environment. Consequently, the categories relating to Managerial and Cooperation skills do not apply to the pilot skills needed for a private pilot and therefore this study excluded those skills. (CASA, 2010; CAA, 2018)

The question therefore arises what simulator configuration would increase the skills that can be learnt through a simulated environment. Since (CASA, 2010) specified the number of flying hours to acquire enough piloting skills before doing a flight test, many of which are based on motor skills, a great deal of repetition is required to effectively learn tasks. This is where a simulated environment

may be useful to expose the student pilot to cockpit procedures and aircraft handling skills similar to the actual flying environment. (Wiggins & O'Hare, 2003) stated that pilots' (decision making) responses to deteriorating weather conditions for example, can be improved by using a computer-based training system. Additionally, (O'Hare, 2001) envisaged "a training product based on current simulator software that will allow pilots to practice flying their intended routes in real time, using actual weather."

2.8 Conclusion

This chapter focused on the available literature within the field and scope as identified in chapter 1 by identifying work from various authors within the areas of pedagogical strategies for adult learners in simulation training. The chapter also identified an appropriate evaluative framework and model for flight simulation training and identified work from various authors on the use of flight simulation software within the identified field and scope of this study.

The following chapter focus on various possible research methodologies, identifying and discussing the research methodology used for this research.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

This chapter discusses possible research methodologies, and identifies the research methodology used for this research, and establishes a suitable procedural method for configuring a Flight Training Device suitable for acquiring VFR navigation skills, followed by a systematic process of data gathering, evaluation and reconfiguring until a suitable configuration is found using a small number of designs, making best use of available test participants, Other experimental research methods usually depend on large numbers of test participants, with large volumes of data and statistical analysis to determine results. This can be a very long, time consuming and expensive process, which is what this research is attempting to avoid.

(Estock et al. 2006) identified a scientific, quantitative approach using the RELATE model and identified a research method model combining several decades of work relating to simulator fidelity effects on performance, and to establish quantitative, predictive relationships between simulator fidelity and training effectiveness consisting of 6 steps:

- Identify relevant dimensions of fidelity
- Identify relevant knowledge and skills
- Map knowledge and skills to fidelity dimensions
- Develop mathematical functions
- Develop predictive algorithms
- Empirically validate functions and algorithms

This approach works well with known simulators that are approved for training where for example formal flight simulators are used by airlines to train pilots on specific aircraft. Those flight

simulators are exact replicas of the actual aircraft cockpit, and therefore the issue of fidelity is more readily quantifiable. For this study, this approach has limitations since the purpose of the study is to establish a method for configuring a FTD that is yet to be certified as offering fidelity to the level required for formal pilot training.

(Reimann, 1989) identified an inductive model of learning for computer simulations. This model comprises four phases:

- Testing and modifying the hypothesis;
- Designing an experiment;
- Making a prediction; and
- Evaluating and/or modifying the hypothesis

However, since this model looks at Experimental Design, and this study was not based on an experiment, the model from Reimann was deemed not appropriate.

(Rose et al, 1998) identified a Simulated Processing in a Learning Environment (SimPLE) model. This environment consists of a graphical user interface and an application model. The software used for this study also uses an application model with a graphical user interface. The use of a graphical user interface is applicable to the configuration of this FTD simulator, but on its' own the SimPLE model was deemed not enough to offer a viable research method model for this study.

(Lillie et al, 2011) introduced clinical trials based the N-of-1 or single subject clinical trial method in which the entire case study is done on a single patient and considers the unit of observation in the study investigates the efficacy or side-effect profiles of different interventions. According to Lillie et al. the “ultimate goal of an n-of-1 trial is to determine the optimal or best intervention for an individual patient using objective data-driven criteria.” (p.1) The research approach could serve as

aspiration for this research but cannot be directly appropriate because the FTD simulator process required different participants as is discussed in Chapters 6 and 7.

A research approach that is worth considering is Design Optimisation, which is an engineering design methodology that utilises a mathematical formulation of a design problem to support selection of the optimal design among many alternatives. This approach involves the following:

- Identifying variables to describe the design alternatives
- Determining the objective to elect the functional combination of variables
- Defining constraints as a combination of variables for any acceptable design alternative
- Establishing feasibility of the values for the set of variables that satisfies all constraints and minimizes/maximizes Objective (Papalambros et al, 2017)

Papalambros et al. (2017) further identified an optimisation checklist for their design as follows:

- Problem Identification
- Initial Problem Statement
- Analysis Models
- Optimal Design Model
- Model Transformation
- Local Iterative Techniques
- Global Verification
- Final Review

In practise optimisation problems are solved mathematically through optimisation software (Messac, 2015). This therefore indicates that Design Optimisation define an objective that can be solved mathematically as an equation. The study undertaken for this research could potentially be done with this approach, but that would require a great deal of time to be spent on finding an

optimised equation for each task requiring configuration, which is counterproductive to the approach of this study as the goal is to determine an efficient, quick and easy process. Furthermore, the process of determining the minimum configuration suitable for VFR navigation utilising hardware configuration as used in this study would not be suitable for a mathematical equation approach.

3.2 The Design Science Research Approach

Since this research method forces a rigorous process of design, the FTD simulator was refined through a Step approach for each iteration to the point where an optimal configuration is established.

(Carstensen & Bernhard, 2019) explained that design research was established as a field of study in 1966 when the Design Research Society was founded. The society's founders explained the need for this new field of study by noting that design seemed to have its own theoretical base (Roworth-Stokes 2011, 419), 'Designerly ways of knowing' (Cross, 1982) and 'a designerly way of thinking and communicating' (Archer, 1979) which merited investigation and analysis.

According to (Simon, 1996) the science of Design Science is a body of knowledge about the design of artificial objects and phenomenon (artefacts) designed to meet specific goals. Literature in this field specifies that the research must produce an artefact (in this case a FTD) designed to tackle a specific problem. (Vaishnavi & Kuechler, 2008) further added that the main purpose of design research in its original form was to develop a theory for the process or phenomenon of designing man-made objects and artefacts.

Design science research is described as a paradigm of three closely related cycles of activities; relevance, design and rigour where the relevance cycle instigates design science research within context of application with inputs describing the necessity for the research and the problem to be solved are identified alongside the acceptance criteria or equivalent for the ultimate evaluation of

the research results. The research project also needs to be informed by the foundations of scientific theories, methods, experience and expertise (Hevner, 2007).

Design Science is further described as the validity of design, where the validity and value of the research outcomes depend on specific criteria to demonstrate validity and design knowledge. The knowledge rests on good reasoning and arguments, instead of experimental data alone. (Khambete, 2019) suggests a template based on the philosopher Stephan Toulmin's' model of argumentation to guide the research with three stages of argumentation, reflecting the commonalities in the design research processes, namely Exploratory, Targeted and Confirmatory. These are described as follows:

- “Exploratory—Aimed at clarifying the research objectives, methodology to be followed, working hypotheses/propositions
- Targeted—Aimed at elaborating and specifying the research objectives in terms of the operationalising the chosen methodology
- Validating hypotheses/knowledge outcomes.” (Khambete, p10)

This approach is useful for Design Science research, but the potential issue with this method is that analysis and evaluation is open to interpretation and opinion. This research does not require the same level of structured initial research design, but it is important that proper guidelines are set to establish clear parameters for the research outcome.

(Hevner et al, 2004) provided practice rules for conducting DS research in the IS discipline in the form of seven guidelines that describe characteristics of well carried out research. They further specify that this artefact needs to be relevant to solving an unsolved problem, and that the artefact must be evaluated through a rigorous process, with a demonstrable contribution presented to the problem drawn from existing theories and knowledge. The research outcome must then be communicated in an effective manner to appropriate audiences.

Therefore, due to the limitations of the previously identified research methods to establish simulator fidelity and configuration, this study utilised a Design Science research model as presented by (Simon, 1996, Hefner et al, 2004, Helfert et al, 2012, Khambete, 2019) to follow a rigorous process to create a process configuring a FTD for suitable for successful VFR navigation as is discussed next.

3.3 Applying Design Science to the Research

According to (Carstensen & Bernard, 2019), the most commonly used methodology in Design Science research is as described by (Hideaki et al., 1990) and as illustrated in Figure 3:

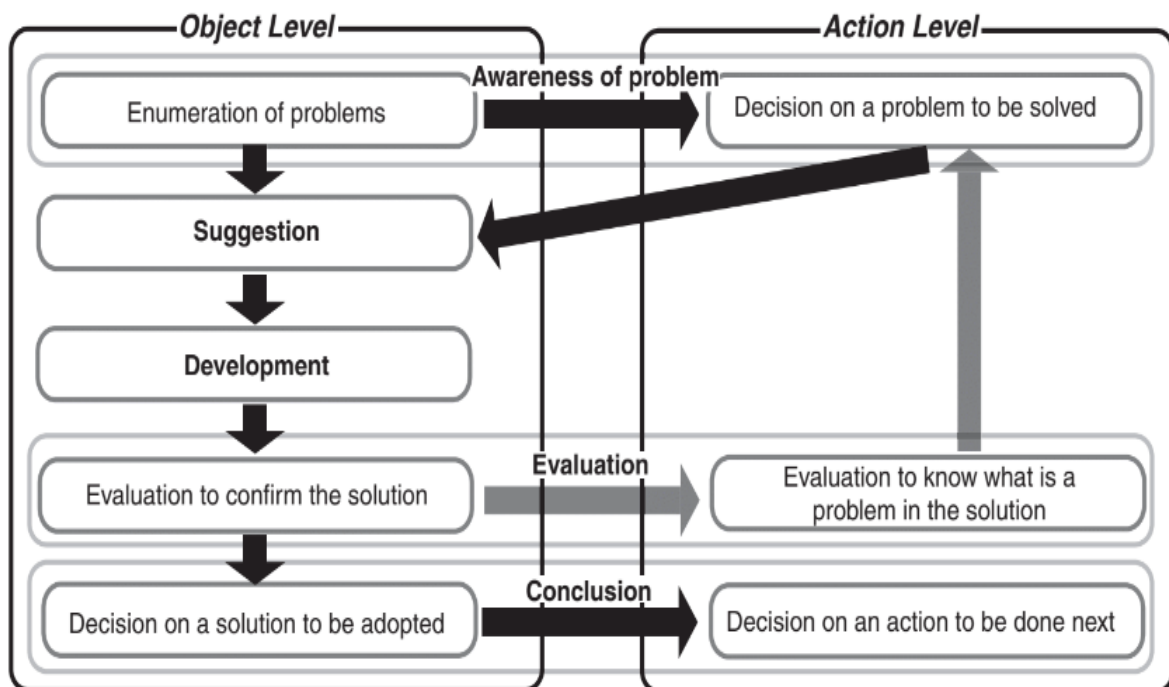


Figure 3 The Design Science Cycle

This study is based on the theoretical conceptualisation of the above arguments from Hevner, but as the contribution by Khambete was published after completion of this study, the findings of that

research would serve well to strengthen and offer a more rigorous outcome for Design Science as data collection method.

For this study, the above Design Science Cycle was interpreted in Figure 4:

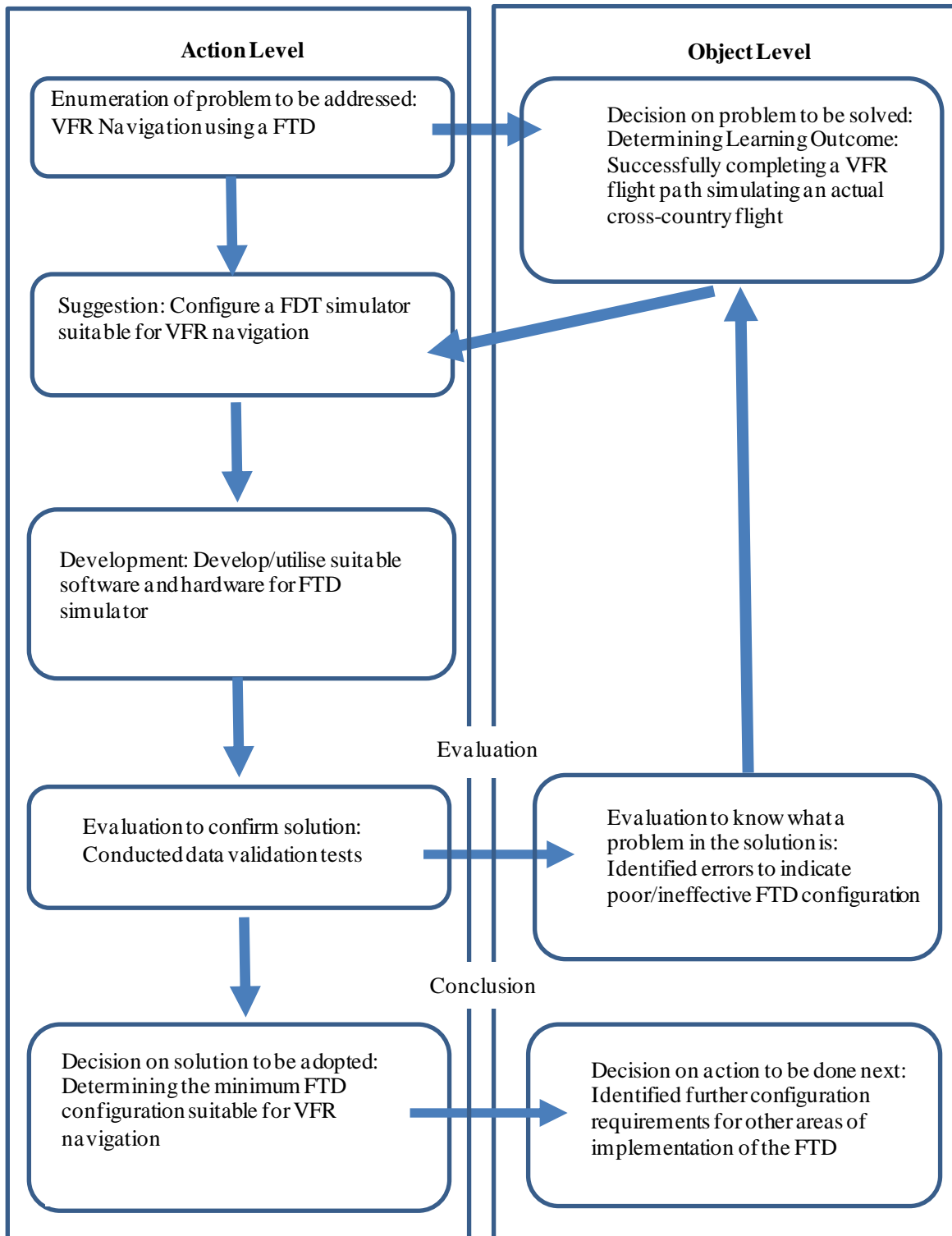


Figure 4 The Adopted Design Science Cycle

3.4 Design Science Step 1

3.4.1 Pilot Study

The previous chapters discussed the need for a configuration suitable for a FTD suitable for VFR navigation. Therefore, the purpose of this Design Science process is:

- To find a suitable configuration for a Cessna 172 FTD simulator, and
- To present an appropriate process that can be used to generate a suitable FTD configuration.

The configurations of previous research from (Harvey, 2006) and (Hayes et al, 2009) were used as guidelines to determine a baseline configuration for this research, but to identify the first configuration of a suitable Navigation FTD simulator (Build A), the basic design elements of the Design Science artefact need to be determined.

Therefore, a pilot study of 3 participants using a simulated VFR navigation flight as described in Appendix 5 was followed as follows:

Configuration 1

A PC-based flight simulator with display configuration using one 22" monitor divided into 2/3 to display the scenery, and 1/3 to display the cockpit with a flight yoke, rudder pedals, throttle lever, mouse, keyboard, and stereo speakers. A glass cockpit with traditional analogue instrumentation was used, and the flight simulation software used is Microsoft Flight Simulator X with scenery settings set at medium (3D contoured terrain with 3D objects added.)

Configuration 2

A PC-based flight simulator with display configuration using three 22" monitors divided into 2/3 to display the scenery, and 1/3 to display the cockpit with a flight yoke, rudder pedals, throttle lever, mouse, keyboard, and stereo speakers. A glass cockpit with traditional analogue

instrumentation was used, and the flight simulation software used is Microsoft Flight Simulator X with scenery settings set at medium (3D contoured terrain with 3D objects added.)

Configuration 3

A PC-based flight simulator with configuration using three 22” monitors used for scenery and an additional 20” to display the cockpit, with a flight yoke, rudder pedals, throttle lever, mouse, keyboard, stereo speakers was used. A glass cockpit with traditional analogue instrumentation was used, and the flight simulation software used is Microsoft Flight Simulator X with scenery settings set at maximum (3D contoured terrain with 3D objects added and aerial satellite images overlaid over the terrain with customised and accurate scenery with buildings and roads landmarks added.)

The results of this first step was used to determine the starting configuration required for the configuration of the FTD for the first participant.

3.5 Design Science Step 2

In the second step, the FTD (Build A) from the Design Step 1 was refined as per the findings of the results of the first 3 participants to determine the baseline configuration to be used, and the simulator reconfigured accordingly for each of followings – also using the simulated VFR navigation as described in Appendix 5. The next Build was then be presented to another participant to perform the navigation exercise, and this was repeated until an acceptable configuration is determined resulting in zero gross errors. The criteria used for evaluating the configuration success and the validity of the data was based on the following:

- The number of gross errors recorded on the simulation flight, with the goal to have no gross errors recorded.
- The ability of the participants to successfully navigate to each of the identified waypoints

- The ability of the FTD simulator to accurately represent the actual world within the virtual world
- The ability of the FTD simulator to allow the participants to effectively control the virtual aircraft for successful navigation
- Thematic analysis was used to analyse data obtained from the questionnaires, interviews and observations made by the participants. This data focussed on the participant experience and if it was positive or negative.

3.6 Design Science Step 3

In the third step, the results of each participant were evaluated according to the artefact evaluation framework from Helfert et al. (2012) for Design Science Research. Their research framework incorporates design evaluation along with the ongoing design process by using simple design criteria, interviews during artefact development, and a brief evaluation of the created design artefacts.

The research shows that not only utility of the final design artefact is important, but also quality evaluation during the build (design) phase. (Lee et al, 2002) offered an AIMQ methodology which provided general questions for evaluating Information Quality as determined by the researcher for this study. These questions follow the example criteria of consistent and adequate syntax, syntactical correctness, consistent representation, accessibility, precise definitions and terminology, easy to understand, interpretability, accuracy (free-of error), consistent content Relevance, usability, completeness, timeliness, actuality, efficiency.

3.7 Design Science Step 4

The research adopted a combination of quantitative and qualitative research methodology to evaluate the responses gathered from the questionnaires, backed up by interviewing and observations of the participants. After completion a questionnaire (Appendix 6) with value and open-ended questions was provided to all the participants at the end of the exercise, followed by an

interview. The purpose of the questionnaire was to establish the participants' perceptions and opinion on the simulator experience and configuration. Each participant was required to complete the questionnaire.

The questions and the observations focused on feedback on the artefact (FTD) configuration. This feedback was incorporated in the subsequent Builds and refined to a final Build is determined.

3.8 Using the Design Science Research Method

For this research, an artefact (FTD simulator) was configured, evaluated and improved using a Step-based approach based on preliminary results from an initial pilot study.

A methodology involving a practical simulation flight and a thematic analysis was performed. A procedure was adapted from (Dennis & Harris, 1998) using ten to fifteen participants as approved by Federation University Ethics Committee (HREC B17-023), aged between 20 and 60 years as this age range was chosen to maximise the representation of the typical broad age group of general aviation pilots with no previous flying experience to remove flying experience influencing simulator performance results. The participants were asked to fill in a consent form (Appendix 4) and were then assigned a simulator configuration that increases incrementally from low fidelity to high fidelity until an optimum range of configuration settings is found.

Each participant was required to fly a simulation flight along a pre-determined planned route. To obtain the required data for determining successful navigation, the flight data was captured as follows:

- FTD Simulator recorded data * (Refer to p69 in Chapter 5 for data collection detail)
- Written questionnaire
- Verbal interview with follow-up questions
- Observation notes.

** Flight data variables:*

- Heading: Aircraft heading recorded at each 2-minute aircraft position along the flight path in degrees
- Deviation: Deviation to desired flight path recorded every 2 minutes along the flight path as a number.
- Gross Error: All numbers outside the accepted deviation of 1.5 recorded as a Gross Error (GE)

Participants were given basic background and instruction on how to use a flight simulator installed at the Federation University Mt Helen campus. The background instruction included the following concepts:

- Broad theory of navigation and aircraft headings. This included an explanation of aircraft navigation is, and how the aircraft instrumentation needs to be used to set, maintain and alter a heading
- Broad theory of aircraft handling to set heading, maintain heading and change heading. This included an understanding of how to use the aircraft controls to fly the aircraft towards different headings, waypoints and to maintain height and airspeed.
- Broad understanding of reading an aviation chart and reading waypoint headings. This included an understanding of how to understand an aviation navigational chart and how to determine and identify waypoints and landmarks.
- Broad skills in reading and understanding aircraft instrumentation relating to navigation and heading. This included an understanding of the various aircraft instrumentation used for determining compass headings.
- Broad knowledge of the simulator and how to operate within the simulation environment. This include an understanding of how to use the simulator software.
- Background and instruction on how to use a flight simulator (described below) with a brief on handling and controlling the virtual aircraft, including instruction to understand the process of navigating and finding waypoints using a flight map.

This training was adopted for all the participants and not changed for each subsequent Build configuration change. It is to be noted here that it is important to formulate the learning objective accurately during Step 2 (Refinement of Build A) of configuration process so that the correct amount of training to achieve the learning outcome can be achieved.

A navigation exercise in the simulator was performed to measure the impact of the simulator configuration on the participants' ability to successfully navigate during the flight. The simulator recorded flight data while the researcher observed the participants.

After completion of the simulation flight, participants were asked to complete a post-flight survey (Appendix 6) to solicit their views on the flight and simulator configuration and invited to be interviewed by the researcher to solicit additional feedback. Notes were taken from any verbal responses and transcribed into written question responses and analysed thematically. The simulator was set up with an initial configuration setting (scenery, cockpit and hardware) to assess the effectiveness of each configuration, and the fidelity setting incrementally increased for each participant to identify an optimum configuration to maximise navigation.

The simulated flight required the participants to fly an individual flight of about 30-50 minutes to a predetermined destination as given below. A scoring system described in Chapter 4 was used to measure the accuracy of the interface and visual settings.

The specific factors that were measured are:

- Current heading (Using recorded timestamps from observer)
- The maximum deviation (Using flight path gross error recordings)

Successful navigation was measured against the amount of gross errors recorded against a predetermined optimum flight path. The focus was on the following configuration variables as it relates to successful navigation:

- The realism of VFR scenery to facilitate cross-country navigation using actual Visual Navigation Charts.
- The Field of View (FOV) enabling successful VFR navigation.

In each of the pilot configuration settings the amount of scenery detail and the scenery and field of view was set from low, medium and high scenery detail and each participant was given the same basic navigation exercise to fly between a set of set visual reference point located on an aeronautical chart corresponding with the scenery in the simulator. The participants were required to find waypoints in the simulator as they fly the specified route as specified below.

A mixed-method approach was adopted for the study, using a combination of four methods of data collection was utilised for this study:

- FTD Simulator Exercise (Described in Chapter 5)
- Written questionnaire
- Verbal interview with follow-up questions
- Observation notes

The participants performed a navigational exercise in the simulator to measure the impact of the simulator configuration on ability to successfully navigate during the flight to the desired destination as specified through several waypoints. (In Figure 5 below, each image illustrates the heading indicated via a yellow line pointing towards the next destination/waypoint)

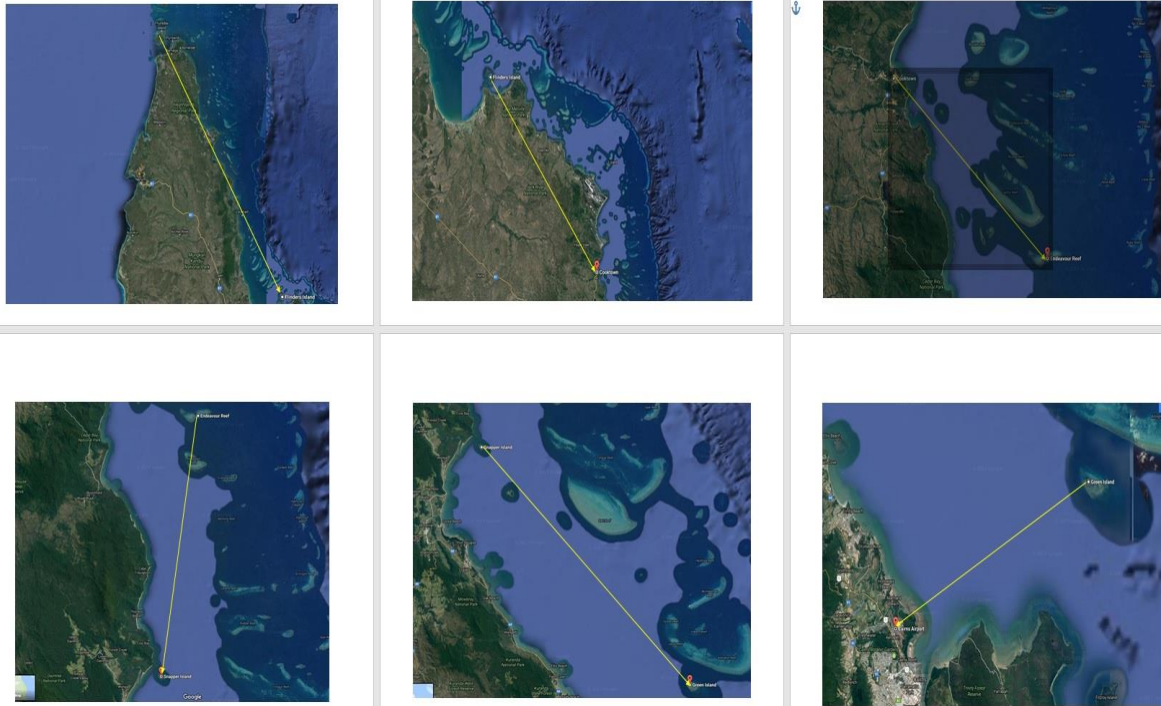


Figure 5 Navigation Exercise

The participants were required to fly a simulated flight from a mid-air starting position at Hom Island airport to Cairns airport far north Queensland, Australia. They were not be required to land the aircraft at the final waypoint, as the flight was terminated upon reaching the overfly point specified on the navigation map. There are 6 waypoints marked along the flight route on the navigation map, and the participants were required to make any necessary alterations to the aircraft heading as required to find the landmarks identified on the navigation map, including the final destination. They could refer to the supplied navigation chart to assist in identifying and finding the visual landmarks, but the intent is to navigate using visual identification of the landmarks and utilising information given as per the cockpit and simulator configuration. They were informed that if they were unable to find a waypoint, or that they felt here were off course, any flight path adjustments deemed necessary to get back on course are to be made.

The intent of the exercise is to determine their ability to successfully navigate with the particular simulator configuration setup given. The same exercise flight path was used for the pilot study and all subsequent participants to ensure results could be compared across participants.

At the completion of the flight, the participants were asked to complete a post-flight survey to solicit their specific views on the flight and simulator configuration and interviewed by the researcher to solicit additional feedback. Further notes were taken from any verbal responses recorded along with written question responses and analysed thematically afterwards.

The participation's contribution ceased at the end of the interview and no further input or involvement was required after that point. The data collected and the results were anonymised.

3.9 Conclusion

This chapter discussed possible research methodologies and identified the research methodology used for this research. This was followed by describing a suitable procedural method for configuring a Flight Training Device suitable for acquiring VFR navigation skills, and identified the use of a Design Science research model as presented by (Simon, 1996; Hefner et al, 2004; Helfert et al, 2012; and Khambete, 2019) to follow a rigorous process to create a process configuring a FTD for suitable for successful VFR navigation. The next chapter discusses the method adopted for measuring FTD Navigation Error.

CHAPTER 4

NAVIGATION ERROR MEASUREMENT

4.1 Introduction

This chapter identifies factors and validity threats affecting successful navigation and identifies an error measurement model is to determine the fidelity of a navigation FTD simulator and presents a suitable method for measuring errors in the flight simulator.

4.2 FTD Configuration for Navigation

To understand what is meant by successful navigation in aviation terms, it is important to know when navigation errors occur. Navigation error is the inability to stay in track, within a deviation threshold along a pre-specified flight path. Navigation errors can be made at numerous points along a flight path, where a flight path is defined as the precise route taken or due to be taken through the air by an aircraft or spacecraft (American Heritage Dictionary, 2016). It is important to identify and analyse VFR navigation error to assess navigation performance. However, cumulatively summing errors is not an ideal metric for VFR navigation because of the cumulative effect of an initial navigation error compounding and influencing subsequent errors.

Historically, research in measuring accuracy in navigation systems focussed on the analysis of error distributions in navigation. Extensive research by Burgerhout, (1973), Hsu (1983), and Lord and Overton, (1971), Fraser (2018), Braff & Shively (2005), Anderson et al (2018) have all attempted to address the problem. However, none of these studies offered a simple solution appropriate to configure a FTD simulator - specifically suitable for VFR navigation, and each presented different arguments for defining error measurement. Caretta & Dunlap (1998) researched the training effectiveness of flight simulation and concluded that there was “insufficient detail regarding research methods, training characteristics, and simulator fidelity.” In addition to these methodological concerns, there appears to be a lack of true simulator-to-aircraft transfer studies

involving complex pilot skills utilising FTD devices. This may be due to problems such as inadequate simulator design, cost, and availability, and access to simulators in operational flying units.

As mentioned earlier, Allen et al (2003) conducted a preliminary study to configure a driving simulator using configurations that included a desktop system with a single narrow field-of-view display and a desktop system with wide field of view display, and a cab with wide field of view display. They concluded that a PC-based platform “has proven to be easy to administer in school classrooms as well as in laboratories, and computer technology will continue to improve for the foreseeable future in terms of computing power and visual and auditory display. They further stated that the potential capability of PC-based training and evaluation platforms will also advance, limited primarily by software development. This is still relevant today as the effectiveness of such technologies are still being researched. Hays et al (2009) found that many questions about the use of specific training strategies and simulator configurations remain to be answered, and in their research into the training effectiveness of flight simulators they determined that the gathering of information for analysis on fidelity of simulation was hampered by two factors:

- The deficiency of detailed reporting of simulator configuration parameters, and
- the lack of a validated taxonomy of flight tasks.

To this end, the taxonomy of flight task focussed on for this study refers to one task - that of successful navigation. Mertikas (1985) suggested that investigating navigation errors is important for the following reasons:

- To better understand limitations of the error metrics;
- To plan navigation accuracy standards; and
- To standardise navigation accuracy measures and assurance of uniform publication of statistics (i.e., communication of information).

In this study the measurement of navigation errors was important for the configuration of the FTD simulator. Flight simulators can be operated in many configurations, with various software and hardware combinations. Therefore, the challenge was to identify a configuration conducive to the acquisition of navigation skills. A low-grade simulator was required to be configured, but there are various levels of possible realism settings. For example, there are many options in the scenery settings, flight control options, eye tracking, sound and haptic feedback interaction with the simulator. Configuring a FTD simulator is also different to a 100% realistic full motion simulator where the variables are known and matched to an actual aircraft cockpit configuration. Therefore, selecting appropriate FTD simulator settings that enhance Private Pilot license navigation skills is an exercise in the design of the configuration. In this case the measurement and analysis of navigation error was central for rigorously testing each iteration of the configuration design process.

As mentioned earlier, research has been done in simulator configuration, but each was specific and with varying focus, and without a simplified procedural method for a FTD configuration that can be experientially validated. Farmer et al. (2017) stated that “experiences with the procurement and use of training simulators has not always been as successful, often owing to a lack of knowledge of didactics and of training programme development, and also to inadequate simulator specifications”

Therefore, this thesis attempted to find a suitable method for the measurement and analysis of navigation errors for the purpose of evaluating a FTD simulator configuration suitable for VFR navigation, inspired by an adaptation of the Kolmogorov-Smirnoff non-parametric model of error distribution. The premise was that the FTD simulator could be valuable and useful for private pilot training, specifically successfully completing VFR navigation. However, the Mathematical formula of Kolmogorof-Smirnoff (KS) has no relevance in this study, as there would be little benefit in including the mathematical formula, because the KS-Test mathematical formula will not fit the Design Science approach used described on p67.

4.2.1 Other Factors affecting navigation

In addition to the identified factors affecting Flight Training Devices to facilitate successful navigation (the ability to fly towards specific waypoints), there are other human factors that need to be considered that affect accurate navigation:

Route Directions

The impact of effective route directions (the instructions given to find specific waypoints to reach a given destination) appears to also impact the ability to successfully navigate, thereby highlighting the importance for proper navigational assistance. The research performed by Daniel et al. (2003) analysed the structure and content of the descriptions in navigating in an unfamiliar environment, and found that the ability to successfully navigate depended on the effectiveness of route directions and their ability “to connect actions to landmarks, that is, to closely link the prescriptive and the descriptive parts of this specific type of spatial discourse.”

Age and Gender

In Daniel et al. (2003), spatial navigational skills were also found to be affected by the impact it has with advancing age. The research has also shown that there is evidence of age-associated limitations associated with decrements in spatial navigational skills. The impact of age differences was observed in both wayfinding (the cognitive element of navigation that does not involve movement of any kind but only the tactical and strategic parts that guide movement) and route learning (Jansen-Osman et al, 2007). For wayfinding, there were negative age effects in recalling landmarks, and recognizing environmental scenes. In the route learning condition, older adults evidenced difficulty with the location, temporal order and directional information of landmarks. In both conditions, there was evidence of age-related differences in the acquisition of knowledge (Head & Isom, 2010). To make this possible, to minimise the impact on the validity of the data in this thesis, a tolerance range of navigation error was allowed and discounted in the navigation error calculation.

Driscoll et al. (2004) researched the impact of age, sex and hormones on virtual navigational abilities. The study found that certain cognitive processes, including spatial ability, decline with normal aging. Furthermore, they found that spatial ability has robust sex differences typically favouring males. Their findings show that men have a spatial advantage over women which may be related to circulating testosterone and independent of generalized age-related cognitive decline.

Validity Threats

It is to be noted that the following possible factors may impact negatively on the accuracy of the simulator flight data collection during this process. Participant:

- Prior knowledge in the area of flight simulation and/or aviation
- Natural ability to acquire the skills
- Level of computing literacy
- Not being able to pilot a real aircraft of the type used in the simulator
- Any medical condition such as epilepsy preventing the use of the simulator or piloting a real aircraft
- Possible impact of age, gender or other cultural influences yet to be discovered
- Any other issue yet to be discovered

For this thesis a low-grade simulator is required to be configured, but there are various levels of possible realism configurable, for example the level of details of the scenery. Participants with no previous flight experience were tested in a controlled VFR navigation simulation exercise to identify features of an optimal personal computer simulator configuration for navigational training. Selecting simulator settings that enhance Private Pilot license navigation skills is an exercise in the design of a configuration. Therefore, in this case the measurement and analysis of navigation error

is central for the rigor cycle of each iteration of the configuration design process, and Hevner's Design Science method is of relevance.

However, an analysis of the effectiveness of simulation-based training requires navigational error to be measured. Therefore, in this chapter, a model for the determination of error is presented. Following that, the use of the metric in measuring errors by trainees in a low-grade simulation are presented before concluding remarks.

4.3 Measuring Navigation Error

This study did not follow navigation concepts as found on seafaring vessels as it has been validated with shipping navigation data, whereas this study focussed on a smaller dataset with aerial navigation. This is because navigating on land water, in the air, or in space is different. All three types of navigating required different types of information. For example, a topographical map does not help navigation on sea. Furthermore, aircraft can change direction much quicker than ships, which can more quickly correct error or lose set locations or waypoints. Waypoints are visual and not coordinates, which is used extensively in seafaring navigation. Therefore, shipping navigation error distribution measurement is not appropriate for aircraft navigation in this instance.

Navigation error is the inability to track within a deviation threshold along a pre-specified flight path, and it is possible that navigation errors can be made at numerous points along a flight path. It is therefore important to measure and analyse navigational errors for VFR navigation to assess navigation performance. It is to be noted that there is an accepted difference between navigating with waypoints and wayfinding. Barker (2018) stated even though the two terms are often used interchangeably, wayfinding differs from navigation in three critical aspects:

1. It occurs where the individual is traversing an environment or aiming for an objective with which they are unfamiliar, whereas navigation does not necessarily focus on this issue.

2. Processes of self-monitoring such as monitoring the environment, orientation, location and the effectiveness of a course of action are not addressed.
3. Wayfinding is examined here within the setting of everyday life whereas navigation is often considered within the context of professional activity or particular profession.

Barker further identified 12 types of navigation behaviours that influence navigation, but only the behaviour of following fixed-location instructions was deemed to be useful for this thesis, indicating an accurate error correction method of a systematic error as defined by Mazzei et al. (2014). In this context a systematic error is defined by them as “Shortcomings of the instruments, such as defective or worn parts, and effects of the environment on the equipment or the user.” A simple approach therefore would be to calculate current deviation at regular intervals and keep a sum of total error calculation.

However, cumulatively summing errors is not an ideal metric for VFR navigation because of the cumulative effect of an initial navigation error compounding and influencing subsequent errors. This is because when a pilot goes off track, then the initial course variation gets larger over distance and time if not corrected. Therefore, any further flight path progress is impacted, and all subsequent errors made affected as a result. Extensive research in measuring accuracy in navigation systems has focussed on the analysis of error distributions in navigation, and (Burgerhout, 1973; Hsu, 1981; 1983; Lord & Overton, 1971) have all attempted to solve the problem with various foci on navigation in general but have not actually looked at the context of configuring a FTD for VFR navigation. Burgerhout had the view that to express the accuracy of observations some assumptions about the pattern of the distribution of errors needed to be made in the form of a single compact mathematical model as there is a direct relationship between the order of magnitude of the error and the frequency (distribution) with which an error of this order occurs in a large collection of results. Further to this, Lord & Overton explained that aircraft across-track errors are synthesised by means

of a mathematical model using statistical parameters, Hsu (1981) provided further insights into several theoretical models and formal procedures for the estimation of parameters crucial to the evaluation and design of navigational systems and investigates the potentials of a broader system of distribution models. However, this is aimed at navigators and air traffic control authorities are provided within a real-world application.

For the purpose of determining if a FTD simulator is effectively configured for VFR navigation, the hypothesis can be made that it is required to identify individual errors to determine large variances in errors that can be linked to poor simulator configuration. Mertikas (1985) suggested that of investigating navigation errors is important for the following reasons:

- “To better understand limitations of the error metrics.
- To plan navigation accuracy standards. To standardize navigation accuracy measures and assurance of uniform publication of statistics (i.e., communication of information).
- To monitor existing and future navigation systems for their compliance with established specifications (e.g., those proposed by Air Traffic Control (ATC), International Maritime Organization (IMO), International Civil Aviation Organization (ICAO), etc.)”

In this thesis, to support the hypothesis, and in addition to the reasons advanced by Mertikas (1985), the measurement of navigation errors is important for the configuration of the low-grade simulation.

To find a suitable error measurement model, a suitable model can be traced in the origins of the Kolmogorov-Smirnov test, which tries to compare 2 probability distributions whilst making no assumptions about the distributions, but measures the distance between the cumulative distributions.

However, the KS-Test is based on a mathematical equation to determine the difference in error distribution. The method required for this thesis could not use a mathematical equation due to the Design Science data collection method, and the fact that the error determination required for this

study was not based on cumulative errors, but cumulatively adding up gross errors. To adopt this test for the purpose of a navigation FTD, an understanding of navigational errors needs to be found.

In the Exponential distribution theory (Anderson, 1965) and research from (Abbott, 1965; Crossley, 1966; Lloyd, 1966; Parker, 1972; Anderson, 1976), emphasis is given to the occurrence of large errors instead of small errors since this is important to establishing collision risk and the general tendency of navigational errors to form an exponential function. Hsu (1979a, b), and Mertikas (1985) stated that in navigation emphasis should be given to the occurrence of large errors (far-tail region).

Traditionally gross errors result from human mistakes, equipment failure, carelessness or computational errors. (Einax & Reichenbacher, 2011). These values are so far above or below the true value that they are usually discarded when assessing navigation performance. For instance, errors in the data that has no significance to the data set as a result from equipment failure. However, for the purposes of this study the interpretation of gross errors refers to large error variations within the acceptable range of navigation flight path errors made during the simulation flight.

The Anderson-Darling test from Stephens (1974) tests if a sample of data came from a population with a specific distribution and gives more weight to the tails than does the K-S test. The Goodness Test is relevant to this thesis as it uses a sample data set representing an error total for the duration of the flight of 1 research participant flying a navigational route with a flight simulator. The errors are scored as a number of deviations outside of the acceptable range, in this case the cumulative distribution between the expected navigation route and the actual route flown by the participant (Figure 26). The main motivation for focussing on large errors instead of small errors is mainly to facilitate the accepted range of navigation deviation from the desired flight path to keep with practicality and accepted deviations on industry requirements. Therefore, this study adopted the

approach by focussing on the gross navigation errors of each participant flight in order to identify gross errors. The gross errors in turn was then used to indicate effective FTD configuration.

4.4 Flight Simulator Navigation Data Collection

In this thesis data was collected from a select group of participants (as discussed in Chapter 5) using a FTD simulator flying a predetermined route with navigation waypoints. One situation (the control data set from the expected flight path), was compared to data collected in a different situation (actual flight path of participant) with the aim of seeing if the first situation produces different results from the second situation. If the outcomes for the treatment situation were "the same" as the outcomes in the control situation, the assumption could be made that the simulator configuration caused no effect. However, if the data was different, then the effect of the simulator configuration could be determined.

In this thesis a dataset from each participant, where the maximum distance between the ideal flight path and participant flight path (in red) was collected, is illustrated in Figure 6:

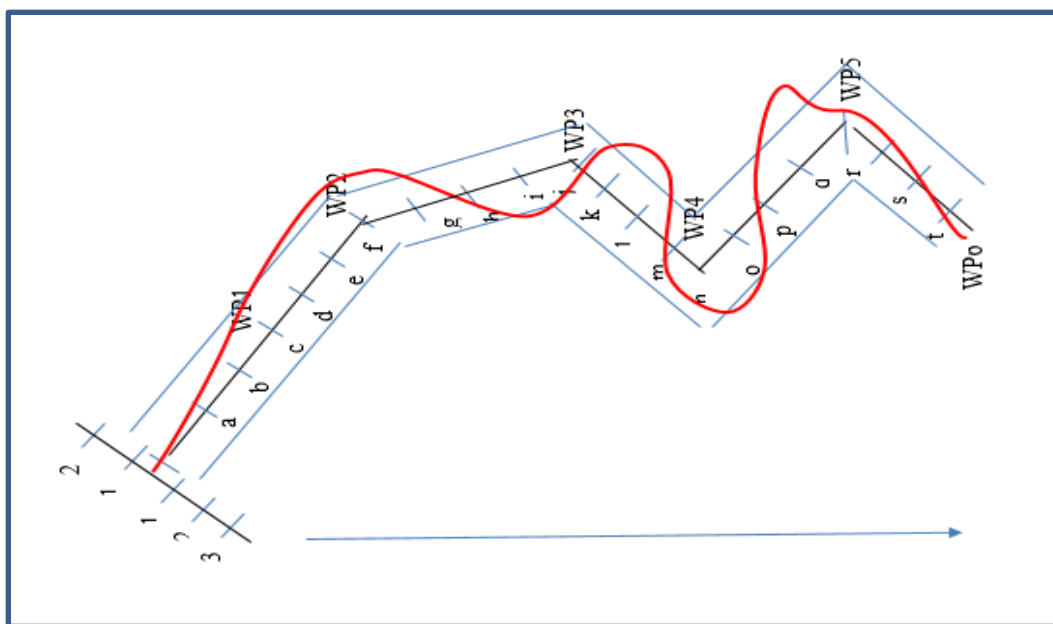


Figure 6 Distance Vs Time for pre-specified target flight path vs Actual flight path

The data was collected from participants flying a predetermined route with navigation waypoints. The ideal data set (the control data set from the expected flight path), was compared to the data collected in an actual flight path with the aim of determining if the first situation produces different results compared with the second situation. If the outcome for the treatment situation were the same as the outcome in the control situation, the assumption was made that the simulator configuration causes no effect. However, if the data was different, then the effect of the simulator configuration was determined as shown in Figure 7, where the ideal flight path and actual flight path is plotted and the variance between the 2 data sets are shown as a number, indicating the size of the difference or error in navigation.

A data set representing an error total for the duration of the flight of each research participant flying a navigational route with a flight simulator was recorded. The errors were scored as a number of deviations outside of the acceptable range. In this case the errors were added as a distribution between the expected navigation route and the actual route flown by the participant - the cumulative distribution between the expected navigation route and the actual route flown by the participant as illustrated in Figure 7.

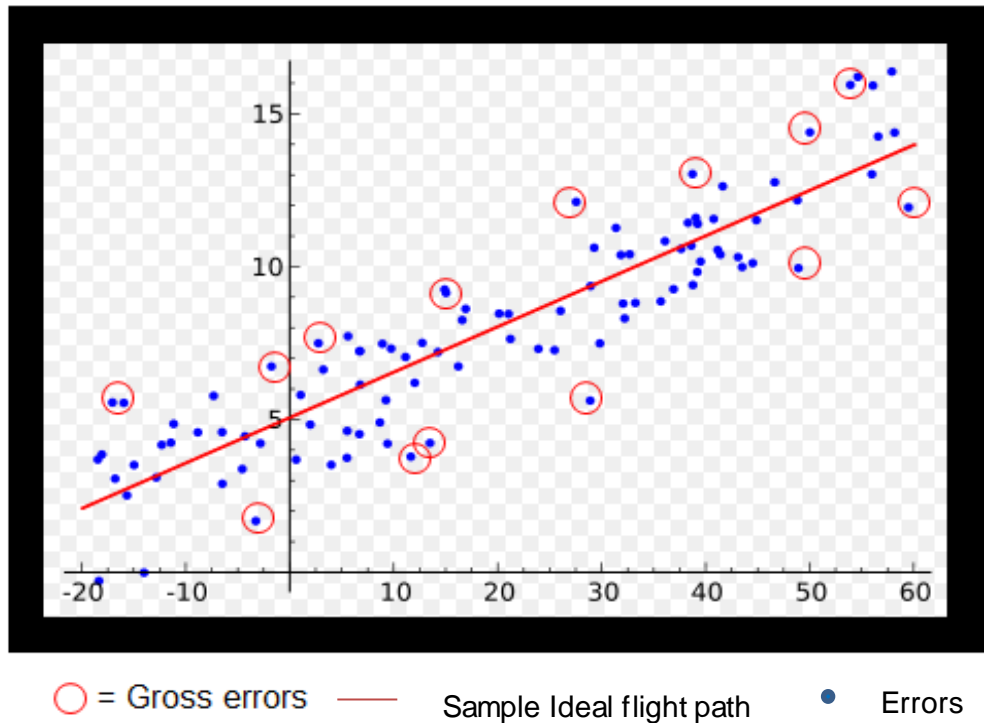


Figure 7 Sample flight path gross error chart

Gross errors in navigation track were sought as indicators as opposed to average errors. The premise was that this could be an indication that the configuration is more effective. Conversely, a low navigational accuracy with higher fluctuations in navigation accuracy should indicate a less effective simulator configuration.

4.5 Conclusion

This chapter identified and discussed a suitable method for an error measurement model to determine the fidelity of a navigation FTD simulator by presenting a method to determine navigation errors and linking to FTD configuration. The main purpose of this method is to focus on gross errors instead of many minor errors to determine if a particular simulator configuration is optimal, as applied in Chapter 5.

CHAPTER 5

DATA COLLECTION, ANALYSIS, EVALUATION AND FTD NAVIGATION SIMULATOR CONFIGURATION

5.1 Introduction

This chapter discusses the process for determining the FTD configuration for successful VFR navigation using Design Science and applying the error measurement method as described in the previous chapter.

5.2 Phase 1 Pilot Study

To establish the baseline configuration for the FTD, a process was followed using the base FTD configuration from the referenced literature in the Introduction chapter was used, followed by a Pilot Study using 3 participants as shown in Figure 8.

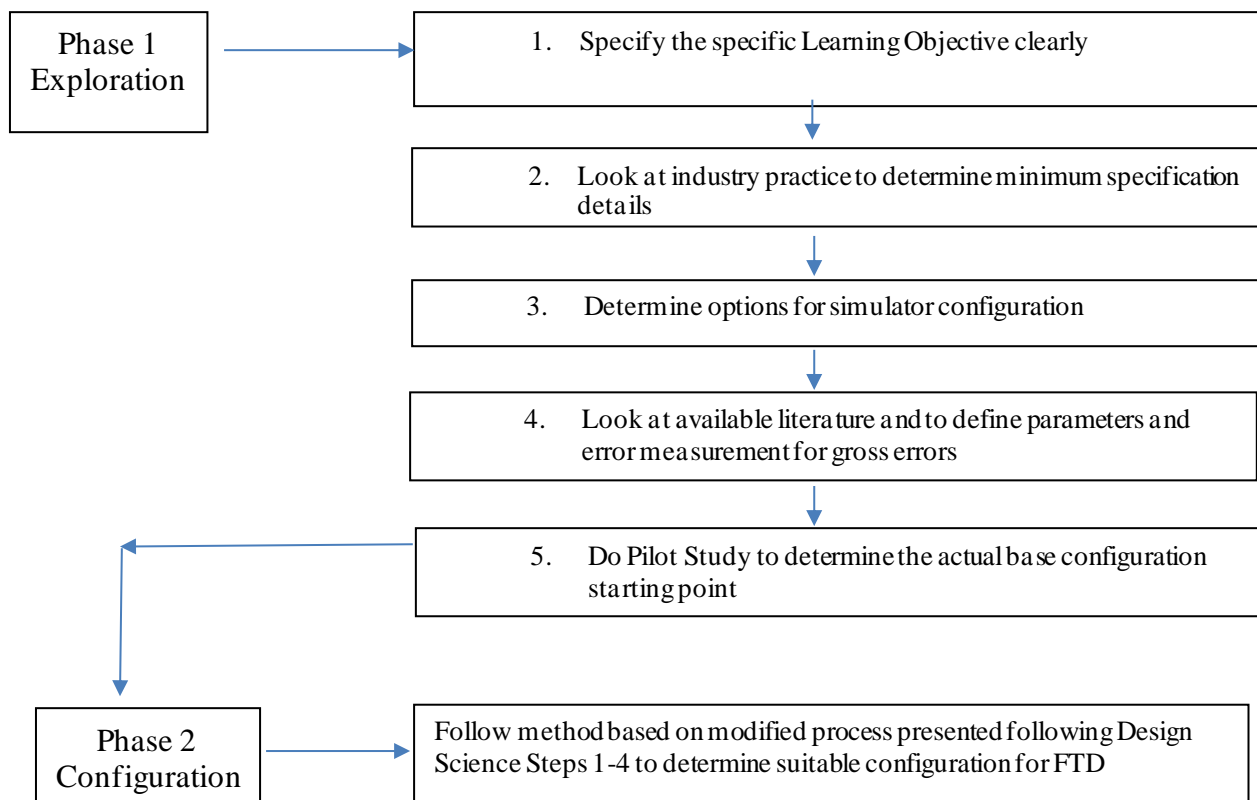


Figure 8 Pilot Study

During Step 1, the Learning Objective was specified as the ability to successfully navigate an actual VFR cross country flight similar in complexity to that per requirements of a typical PPL licence. During Step 2, the initial configuration for the FTD simulator was determined based on a combination of the configurations research:

- a. A cockpit display configuration as presented by Pingali & Newman (2017) utilising a glass cockpit display with analogue instrumentation.
- b. The configuration setup from Allen et al (2003) for a driving simulator training system utilising 3 different simulator configurations including a desktop system with a single monitor with a narrow field of view display, a desktop system with wide field of view display and a cab with wide field of view display.
- c. The configuration setup from Hayes et al (2009) for a flight training simulator a using only the two variables used to evaluate visual imaging systems were total field of view (FOV) of the system and use of CGI technology
- d. The simulation software platform as described by (CarpAir, 2003) using Microsoft Flight Simulator and Harvey (2006) using a basic FTD utilising a computer with 1 monitor, a flight yoke, pedals and Microsoft Flight Simulator 2004 create a graphical representing the real world.

The results from this data was then used to configure the first build of the FTD with subsequent builds utilising the data from each participant to make changes to the next superseding builds until there were no further errors recorded. The final FTD build was then authenticated with a further 3 participants to validate the data gained from the previous builds.

5.2.1 FTD Simulator Configuration 1 (Pilot Study)

A configuration was adopted using a PC-based FTD simulator with display configuration using one 22” monitor divided into a 2/3rd to display the scenery and 1/3 to display the instrumentation, with a flight yoke, rudder pedals, throttle lever, mouse, keyboard, and stereo speakers. A computer configuration utilising a glass cockpit with traditional analogue instrumentation configuration was used, and the flight simulation software used is Microsoft Flight Simulator X with scenery settings set at minimum (flat terrain with no 3D objects) with no 3D scenery and objects such as buildings visible, as illustrated in Figure 9 and Table 1 below:



Figure 9 Pilot Study Configuration 1

Component	Minimum system requirement
Operating system	Windows XP Service Pack 2 (SP2)
Computer processor	Intel Pentium 3.0 gigahertz (GHz)
Memory	1 gigabyte (GB) RAM
Hard disk space	4 gigabytes (GB) available hard disk space
Video card	DirectX 9 (or later version)-compatible video card
	128 MB or more video RAM, Shader Model 1.1 or later version
DVD drive	32x speed
Sound	Soundblaster X Sound Card speakers/ headset
Pointing device	Keyboard and mouse
Internet connection for online play	Broadband Internet access for Windows Live multiplayer gameplay Network adapter for software updates
Monitor	1 x 22" Monitor
Additional Hardware Components	
Flight Yoke USB	
Flight Pedals USB	
Throttle Controls USB	
Engine start-up controls USB	
Analogue Glass cockpit instrument layout	
Microsoft Windows X	
Microsoft Flight Simulator X	

Table 1 Initial FTD Configuration

5.2.1.1 Flight Preparation

As discussed in Chapter 5, the participant, male aged between 25-27, was given basic background and instruction on how to use the FTD flight simulator installed in the T Building of the Mt Helen campus. This was done on a 1:1 basis individually. The background instruction included the following concepts:

- Basic theory of navigation and aircraft headings, including a basic explanation of aircraft navigation and how the aircraft instrumentation were utilised to set, maintain and alter a heading
- Basic theory of aircraft handling to set heading, maintain heading and change heading, including a basic understanding of how the aircraft controls are utilised to fly the aircraft towards different headings, waypoints and to maintain height and airspeed.

- Basic understanding of reading an aviation chart and reading waypoint headings, including a basic understanding of aviation navigational charts and determining and identifying waypoints and landmarks.
- Basic skills in reading and understanding aircraft instrumentation relating to navigation and heading, including a basic understanding of the various aircraft instrumentation used for determining compass headings.
- Basic theory and understanding of what a flight plan with waypoints is, and what is involved in creating a VFR flight plan. (In this instance the participants were not required to create the flight plan since the exercise flight plan was given)
- Basic knowledge of the simulator operating within the simulation environment, including an understanding of the simulator software.

The initial theoretical training session took about 1.5 hours in total. This was overall positively received by the participant, and the decision was made to keep the brief in the format and content for subsequent participants, with the only expected variable the time needed taken to explain and practice using the simulator before the actual flight dependent on the individual.

5.2.1.2 The Simulation Flight

The participant flight data is depicted as indicated in Figure 10 which illustrates the following:

- The flight path from start in the top left corner through waypoints WP1 to WP6.
- A Corridor of 3 units to indicate the gross error size.
- The red line representing the actual flight path as flown by the participant.
- The alphabetical sequence indicates the 2-minute intervals used.
- The blue line represents the flight direction;

and in Figure 11 the error and average deviation of the participant flight path is illustrated.

During the flight the participant went off track without realising it at position E. A decision was made not to intervene, but to continue monitoring progress. After the participant failed to find the first waypoint, he finally suspected that something was off, but could not self-correct the heading. The simulation was paused, and the participant asked to visually check the aircraft position on the screen using the overhead view with the printed map given. This showed his aircraft position and confirmed he was off course. The participant mentioned that he could not visually identify the aircraft location in relation to the waypoint direction. He suggested that the scenery detail needed to be in more detail. At this point the aircraft position was set back to the correct heading and position. The participant then proceeded to correct his course by using the proper navigation technique and flew to the waypoint. After that he managed to find the waypoints, but it was evident he never fully established his location during the simulation. Of note was that the participant completely lost the flight track at points L, M and N. For this reason, the deviation was recorded at the maximum of size of 3 on the deviation scale. This indicated that a need for the simulator configuration settings to be adjusted to a higher level of detail as mentioned by the participant so that it would be easier to find visual confirmation of aircraft position. In a real flight, pilots cannot pause the flight to check location even though the pilot is able to look at an overhead satellite GPS view to establish position.

During the interview after the completion of the flight, the participant stated that the distance was too long to the first waypoint and that there wasn't enough of the outside world visible through the visual display. However, the intent for the long distance to the first waypoint was that the participant could utilise the time to get comfortable with the simulator and make corrections whilst flying to the waypoint. Later during the flight, the distances and time between the legs of the flight reduce dramatically to facilitate heading corrections. The flight duration was 51 minutes in total, including the pausing of the simulator (6 times in total). (It is to be noted that the simulator does not record

the pauses). The actual flight time was 43 minutes, but the flight can be flown in around 30 - 35 minutes if there are no errors in navigation, depending on airspeed.

Flight data was recorded at 2-minute intervals relative to the desired/expected position. The accepted flight path deviation was set at 1.5 off the course. The flight time was recorded but not considered for data analysis.

There were other anticipated variables with the flight that were not considered in determining the success as they were deemed not relevant to the learning objective of navigating to the various waypoints. These were:

- d. Aircraft height. The participant had issues remaining at a constant height and attempted to fly at a lower altitude to attempt to have greater visual reference of the ground. This did not result in seeing more because the detail level setting was minimum as height difference will only assist when flying higher – not lower.
- e. Aircraft speed: The participant did not keep a constant speed. This was because of varying height and not focussing on the instruments enough.
- f. Simulator experience: This caused the participant to make several height, speed and course adjustments. This is simply due to a combination of simulator sensitivity and experience in handling the simulator controls. By adjusting the sensitivity of the controls, it would compensate for this issue. (Note: This results in less accurate setting of the flight controls in relation to actual real-life flight controls. However, if required this can also be adjusted to improve flight control integrity, but in this instance the only focus was on the ability to successfully navigate.

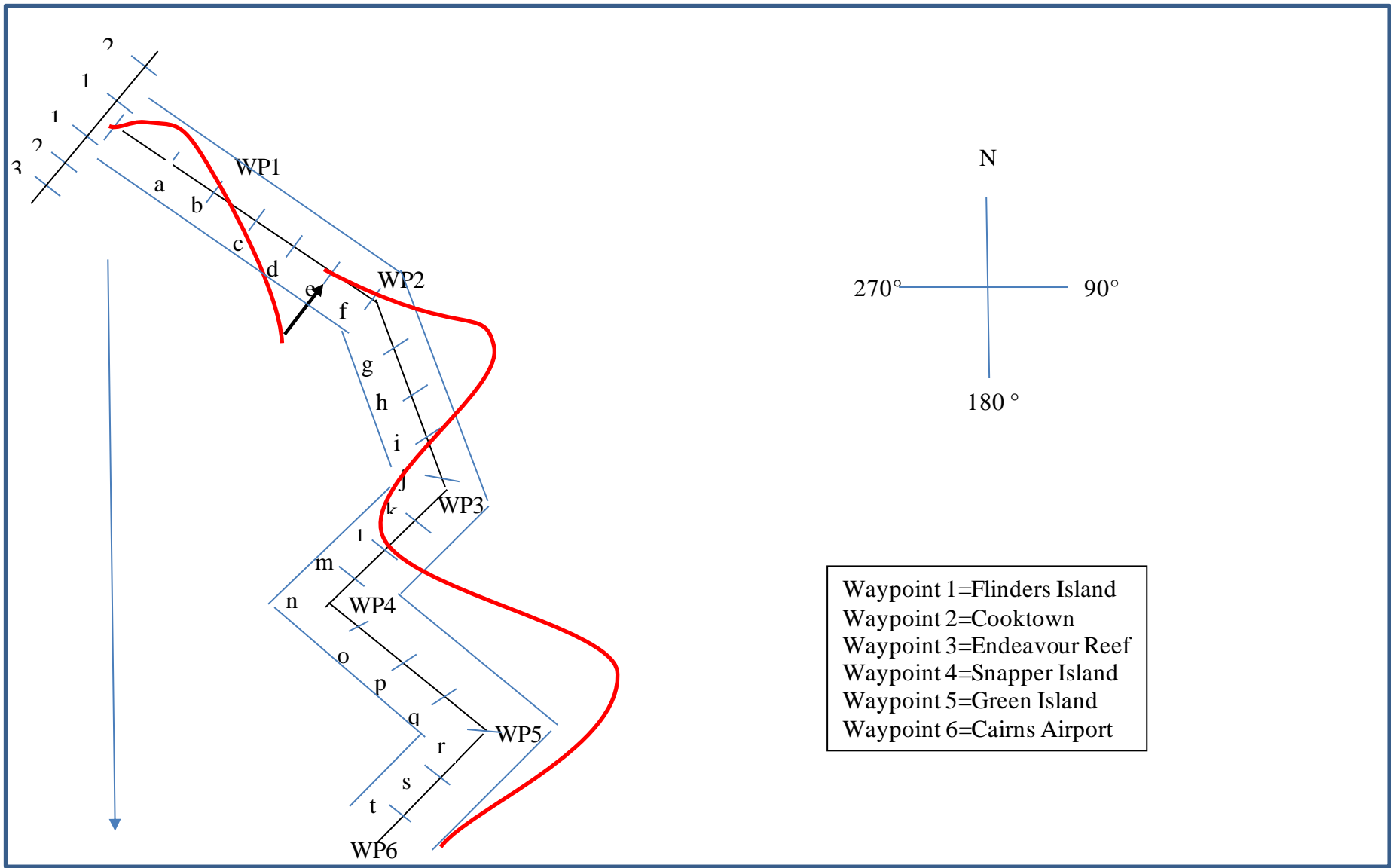


Figure 10 Participant 1 Flight Path

Error Measurement

Heading/Position	Deviation Size	Gross Error = 1
A=150 ⁰	0.7	0
B=154 ⁰	0.2	0
C=160 ⁰	1	0
D=165 ⁰	1.6	1
E=140 ⁰	2.2	1
F=110 ⁰	0.1	0
G=100 ⁰	2.1	1
H=200 ⁰	2.2	1
I=220 ⁰	1.6	1
J=212 ⁰	3	1
K=202 ⁰	0.9	0
L=186 ⁰	3	1
M= 133 ⁰	3	1
N=115 ⁰	3	1
O=113 ⁰	2.1	1
P=111 ⁰	2.8	1
Q=119 ⁰	2.9	1
R=223 ⁰	2	1
S=232 ⁰	1.8	1
T=231 ⁰	1.6	1

Table 2 Participant 1 Error Measurement Data

Accepted Deviation = 1.5

Deviation Accumulation Size = 35.6

Gross Error Count = 15

Figure 11 below shows the participant error size and average deviation from the ideal flight path.

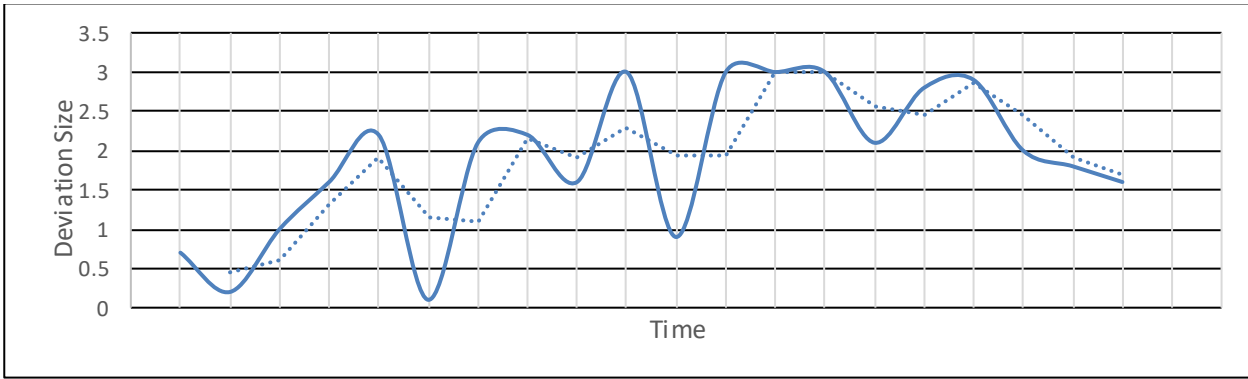


Figure 11 Participant 1 Error and Average Deviation Chart

Participant Questionnaire Data

The importance of scenery realism aspects on the ability to navigate to the various waypoints and the final destination:

- Scale: **0** = Not able to navigate successfully
1 = Some degree of navigation possible with difficulty
2 = Reasonable degree of navigation feasible
3 = Navigation possible with some errors
4 = Navigation possible with little or negligible errors
5 = Navigation with high degree of accuracy

	0	1	2	3	4	5
Landmarks						X
Buildings					X	
Roads and rivers					X	
Terrain and topography						X

The ability to navigate to the various waypoints and the final destination:

- Scale: **0** = Not able to navigate
1 = Some degree of navigation possible with difficulty
2 = Reasonable degree of navigation feasible
3 = Navigation possible with some errors
4 = Successful navigation with little or negligible errors
5 = Successful navigation with high degree of accuracy

0	1	2	3	4	5
	X				

The importance of the following visual realism aspects on the ability to navigate to the various waypoints and the final destination:

Scale: **0** = Not relevant

1 = Successful navigate impossible

2 = Some degree of navigation possible with difficulty

3 = Reasonable degree of navigation feasible

4 = Successful navigation possible with little or negligible errors

5 = Successful navigation with high degree of accuracy

	0	1	2	3	4	5
Screen size						X
Displaying selected instrumentation on screen instead of actual physical instrumentation				X		
Utilising multiple displays to represent internal and/or external visuals (scenery)						X
Terrain and topography						X

Effectiveness experienced during the simulator exercise:

Scale: **0** = Not Relevant/Applicable

1 = Not effective

2 = Some degree of effectiveness

3 = Reasonable degree of effectiveness

4 = Effective

5 = Extremely effective

	0	1	2	3	4	5
Visual elements						
Scenery		X				
Screen Size		X				
Screen Brightness					X	
Simulator Controls						
Switches					X	
Flight Yoke and Pedals		X				

5.2.1.3 Overall Conclusions from Data

The screen setup on the low configuration proved to be too challenging to see enough scenery to navigate successfully. The configuration was not at the optimal setting to allow successful navigation using the particular setup/configuration. The flight clearly showed some areas where the limitations are with respect to how effective the configuration of the simulator is to aid successful navigation. To address this the decision was made to use 2 screens for the next participant to increase the field of view as the baseline configuration and increasing the visual scenery details through the software settings. The monitors were placed in a vertical placement with the top screen used for the display of the scenery, and the bottom screen to display the cockpit instruments.

From this data adjustments to the simulator setup and configuration was made to address the issues highlighted by the first participant and the flight data as shown in Table 2. The question remained how much adjustment is required. Therefore, the following configuration changes were made for the next configuration:

- a. An incremental adjustment to the visual settings, and
- b. An additional screen added dedicated to display the flight instruments.

5.2.2 FTD Simulator Configuration 2 (Pilot Study)

The previous configuration was utilised, but with display configuration using one 22" monitor with the monitors divided into a 70/30 division to display the simulator scenery as is illustrated in Figure 12. The scenery settings set at medium (flat terrain with no 3D objects). The flight controls sensitivity was also changed to make it easier to control the aircraft as per the feedback from participant 1.



Figure 12 Pilot Study Configuration 2

5.2.2.1 Flight Preparation

The participant, female aged between 24-29, was given basic background and instruction on how to use the FTD flight simulator installed in the T Building of the Mt Helen campus. The background instruction was the same as for participant 1. The initial theoretical training session took about 1 hour and 20 minutes in total. The configuration of the FTD simulator for participant 1 was used, with the added screen using 2 monitors. The flight controls configuration from participant 1 was

used. The scenery was adjusted to a medium setting, using more detailed visuals with basic 3D scenery and objects such as buildings and trees visible. A glass cockpit with traditional analogue instrumentation configuration was used, and the flight simulation software used was identical to the configuration for participant 1, but with scenery settings changed to medium, showing more detail.

5.2.2.2 The Simulation Flight

As with the previous participant, the initial briefing and theory included a basic understanding of navigation, and how to operate the simulator, including familiarity of the flight simulator and flight controls. This took about 1.4 hours in total. This was well received by the participant, with the time needed taken to explain and practice using the simulator before the actual flight the only notable variable. The participant flight data is depicted as indicated in Figure 13 which illustrates the following:

- The flight path from start in the top left corner through waypoints WP1 to WP6.
- A Corridor of 3 units to indicate the gross error size.
- The red line representing the actual flight path as flown by the participant.
- The alphabetical sequence indicates the 2-minute intervals used.
- The blue line represents the flight direction; and

in Figure 14 the error and average deviation of the participant flight path is illustrated.

The participant initially went off track without realising, and the researcher did not intervene. The participant did not correct the heading and could not visually identify the aircraft location in relation to the waypoint direction. As with participant 1, the simulation was paused, and the participant instructed to visually check the aircraft position on the screen using the overhead view with the printed map given. This showed her aircraft position and confirmed she was off course. The participant then attempted to correct her course by using the proper navigation technique and flew towards the waypoint. However, she did not manage to keep on track and continues to deviate off

track as indicated by positions C, D, E., G, H, I, J, K and L and M. It is clear from the data that she managed to find her way, but never managed to find the correct flight track. This indicated, along with feedback from the participant, that the simulator configuration settings needed further adjustment to a higher level of detail so that it would be easier to find visual confirmation of aircraft position.

After the completion of the flight, the participant expressed that the simulation scenery was not detailed enough to allow for sufficient visual referencing. The screen setup on the medium configuration (1 screen for scenery) was too challenging to see enough scenery to navigate successfully, and she suggested that a wider field of view would make it easier to see the outside scenery. The flight duration was 49 minutes in total, including the pausing of the simulator (6 times in total). The simulator does not record the pauses. The actual flight time was 43 minutes, but the flight can be flown in around 30 - 35 minutes if there are no errors in navigation, depending on airspeed.

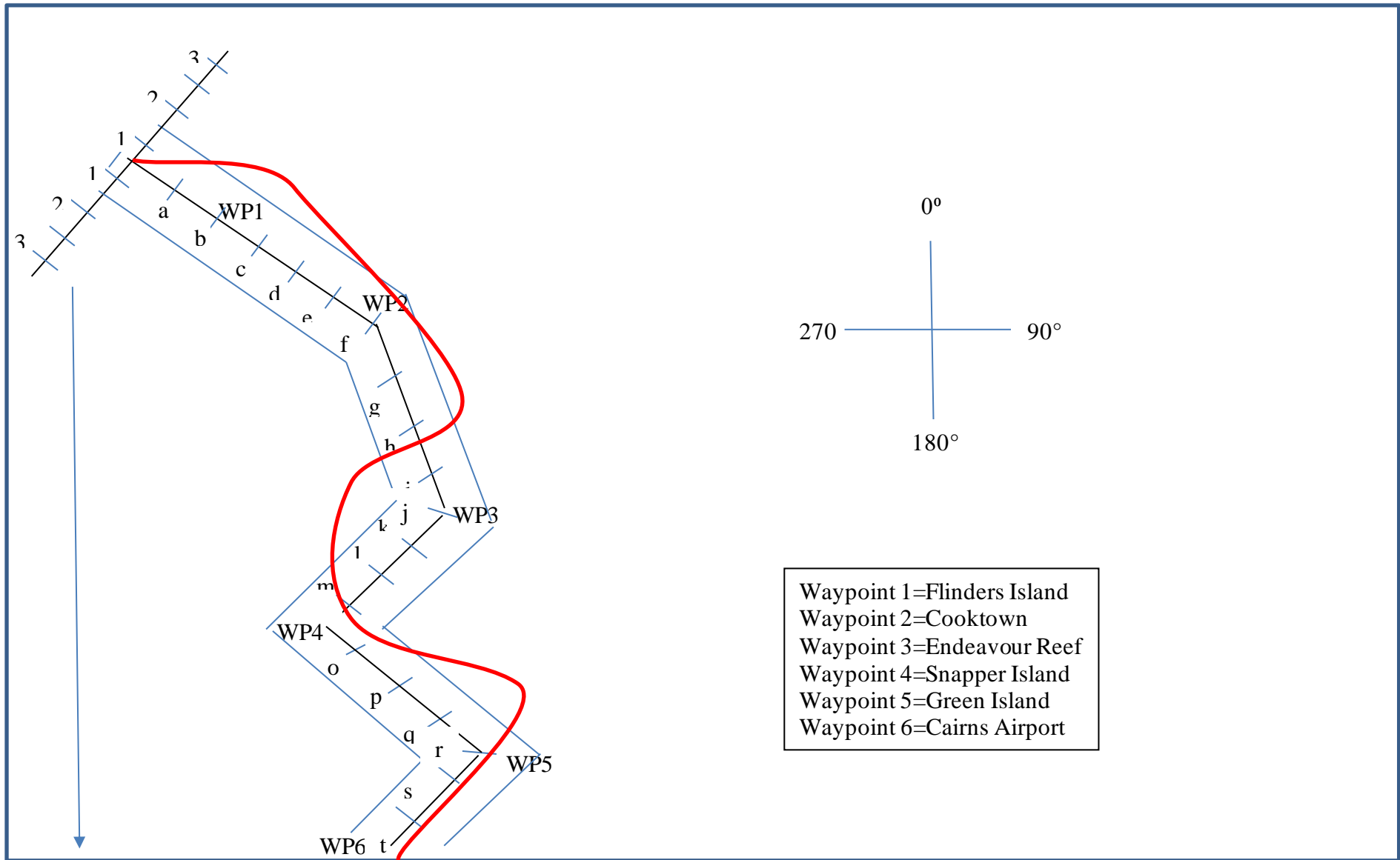


Figure 13 Participant 2 Flight Path

5.2.2.3 Error Measurement

Flight data was recorded at 2-minute intervals relative to the desired/expected position. The accepted flight path deviation was set at 1.5 off the course. Aircraft height was not recorded. The flight time was recorded but not considered for data analysis. The below table shows the participants' flight data as recorded by the simulator indicating the relationship between the aircraft heading/position and size of deviation off the flight path. Any points where the aircraft position is outside of the acceptable corridor deviation of 1.5 is identified a Gross Error (GE). The GE accumulative size is then derived from the sum of the GE numbers.

Heading/Position	Deviation Size	Gross Error = 1
A=090 ⁰	1.3	0
B=104 ⁰	2	1
C=138 ⁰	1.9	1
D=138 ⁰	1.7	1
E=141 ⁰	1.6	1
F=140 ⁰	1.4	0
G=146 ⁰	1.7	1
H=180 ⁰	2	1
I=199 ⁰	2.5	1
J=200 ⁰	2.5	1
K=94 ⁰	2	1
L=180 ⁰	2	1
M=148 ⁰	0.2	0
N=137 ⁰	0.5	0
O=111 ⁰	0.5	0
P=102 ⁰	1.8	1
Q=119 ⁰	2	1
R=223 ⁰	0.1	0
S=222 ⁰	0.2	0
T=222 ⁰	0.3	0

Table 3 Participant 2 Error Measurement Data

Accepted Deviation = 1.5

Deviation Accumulation Size = 28.3

Gross Error Count = 12

Figure 14 below shows the participant error size and average deviation from the ideal flight path.

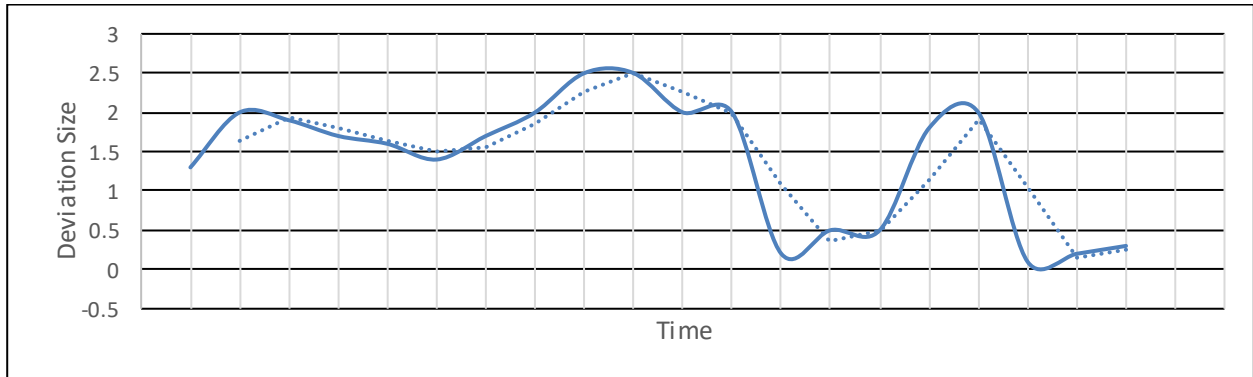


Figure 14 Participant 2 Error and Average Deviation Chart

Participant Questionnaire Data

The importance of scenery realism aspects on the ability to navigate to the various waypoints and the final destination:

- Scale: **0** = Not able to navigate successfully
1 = Some degree of navigation possible with difficulty
2 = Reasonable degree of navigation feasible
3 = Navigation possible with some errors
4 = Navigation possible with little or negligible errors
5 = Navigation with high degree of accuracy

	0	1	2	3	4	5
Landmarks						X
Buildings					X	
Roads and rivers				X		
Terrain and topography						X

The ability to navigate to the various waypoints and the final destination:

Scale: **0** = Not able to navigate

1 = Some degree of navigation possible with difficulty

2 = Reasonable degree of navigation feasible

3 = Navigation possible with some errors

4 = Successful navigation with little or negligible errors

5 = Successful navigation with high degree of accuracy

0	1	2	3	4	5
	X				

The importance of the following visual realism aspects on the ability to navigate to the various waypoints and the final destination:

Scale: **0** = Not relevant

1 = Successful navigate impossible

2 = Some degree of navigation possible with difficulty

3 = Reasonable degree of navigation feasible

4 = Successful navigation possible with little or negligible errors

5 = Successful navigation with high degree of accuracy

	0	1	2	3	4	5
Screen size						X
Displaying selected instrumentation on screen instead of actual physical instrumentation					X	
Utilising multiple displays to represent internal and/or external visuals (scenery)						X
Terrain and topography						X

Effectiveness experienced during the simulator exercise:

Scale: **0** = Not Relevant/Applicable

1 = Not effective

2 = Some degree of effectiveness

3 = Reasonable degree of effectiveness

4 = Effective

5 = Extremely effective

	0	1	2	3	4	5
Visual elements						
Scenery		X				
Screen Size		X				
Screen Brightness					X	
Simulator Controls						
Switches					X	
Flight Yoke and Pedals				X		

5.2.2.4 Overall Conclusions from Data

The screen setup for this configuration showed an improvement in the ability to find the waypoints as there was more of the outside world visible using a dedicated screen for the world scenery but proved to be still too challenging to see enough scenery to navigate successfully as indicated by the gross error count being too far off the desired number of 0.

The gross error count for this participant was 12 and deviation accumulation size 28.3. This showed an improvement on the previous participant gross error count of 15 and deviation accumulation size of 35.6. Therefore, the assumption was made that this configuration was better, not yet at the optimal setting to allow successful navigation using the particular setup/configuration. The flight clearly showed some areas where the limitations are with respect to how effective the configuration of the simulator is to aid successful navigation. From this result the decision was made to make a further incremental adjustment to the visual settings and add maximum scenery visuals for the next participant. As with participant 1, the issues of aircraft height, speed and simulator experience were not taken into consideration.

5.2.3 FTD Simulator Configuration 3 (Pilot Study)

The flight control configuration based on participant 2 was used, but with a second 22" monitor added to display the scenery and using more detailed visuals with detailed 3D scenery, with a higher level of objects such as buildings and trees visible, and using a more traditional configuration to align with an aircraft design with the cockpit instrumentation below the window view of the outside scenery, as illustrated by Figure 15. The flight simulation software used was identical to the configuration for participant 2.



Figure 15 Pilot Study Configuration 3

5.2.3.1 Flight Preparation

As with the previous participants, a briefing was conducted covering the theory to a basic understanding of navigation, and how to operate the simulator, including familiarity of the flight simulator and flight controls. The format and content were retained from the previous participant, and this took about 45 minutes in total. This was also well received by the participant. The only variable that changed was the time needed taken to explain and practice using the simulator before the actual flight. This individual used a similar time to learn the theory and adopt to the simulator than the previous participants.

5.2.3.2 The Simulation Flight

This participant, male aged between 35-40, achieved a more accurate flight path than participants 1 and 2. The flight took another 46.31 minutes in total, including pausing of the simulator once. The simulator does not record the pauses, a manual note of this as an observation was made. The actual flight time was 42.54 minutes.

The participant flight data is depicted as indicated in Figure 16 which illustrates the following:

- The flight path from start in the top left corner through waypoints WP1 to WP6.
- A Corridor of 3 units to indicate the gross error size.
- The red line representing the actual flight path as flown by the participant.
- The alphabetical sequence indicates the 2-minute intervals used.
- The blue line represents the flight direction;

and in Figure 17 the error and average deviation of the participant flight path is illustrated.

The participant managed to stay on track until point B, and continued to go off course at point C, D, E. He managed to find the waypoint at point F, but again went off course at point G, H, I, J, K, and M. The researcher intervened at point J, paused the simulator and showed the aircraft position through the overhead map display. The participant calculated the correct heading and attempted to self-correct the heading. When the researcher pointed this out the participant self-corrected and managed to turn the aircraft back on a heading to place the aircraft to the correct heading to intercept the waypoint. However, the participant continued to lose track of the waypoint heading and this cycle repeated until the end of the flight. This indicated that even though there was 1 monitor offering a larger display of the outside environment, and the simulator configuration settings at the maximum, the configuration settings needed to be adjusted to a wider field of view and a higher level of scenery detail so that it would be easier to find visual confirmation of aircraft position.

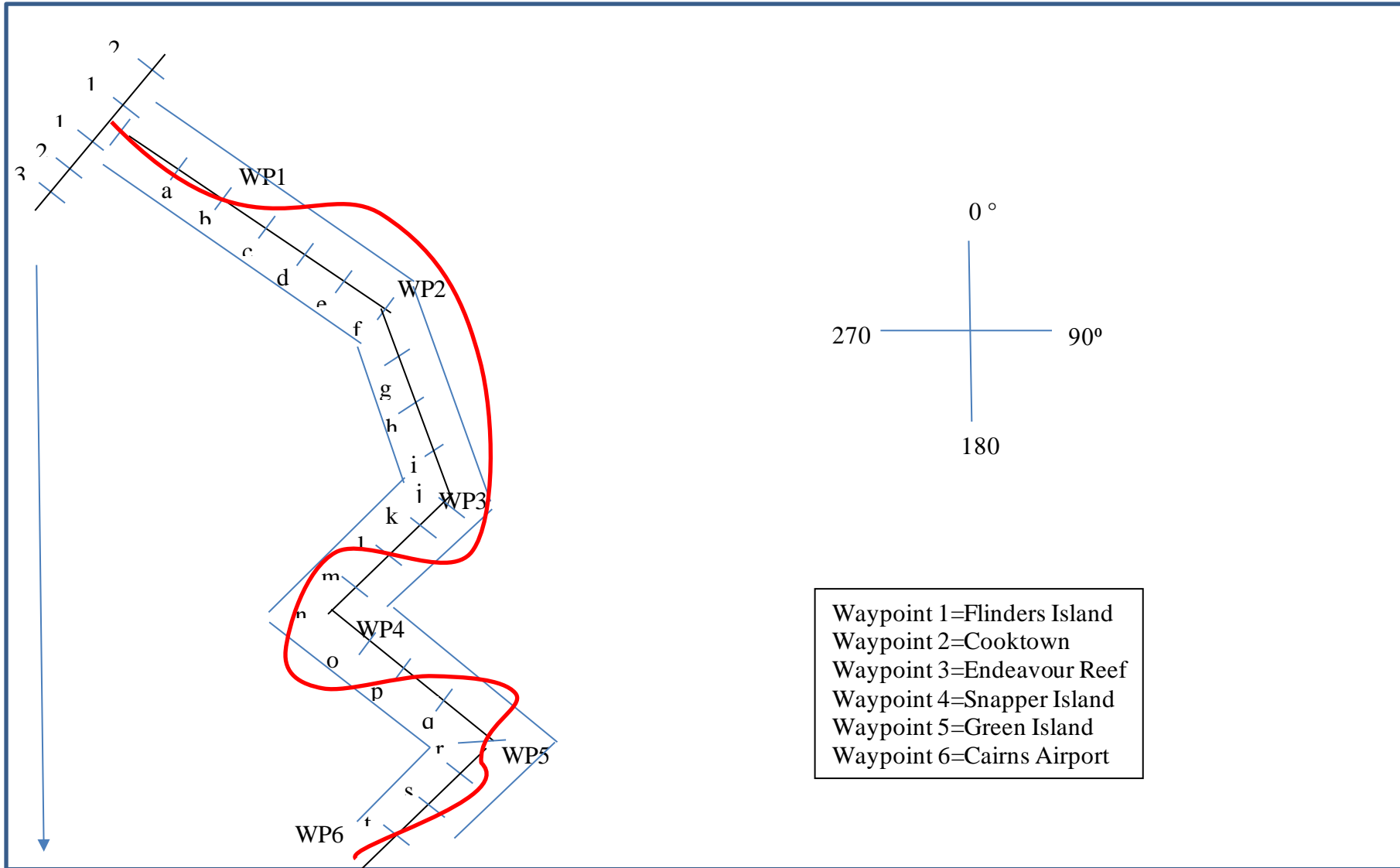


Figure 16 Participant 3 Flight Path

5.2.3.3 Error Measurement

Heading/Position	Deviation Size	Gross Error = 1
A=131°	0.1	0
B=105°	0	0
C=083°	1	0
D=087°	2.2	1
E=130°	2.1	1
F=146°	2	1
G=162°	2.1	1
H=170°	2	1
I=180°	1.5	1
J=206°	1.6	1
K=260°	1.7	1
L=278°	0	0
M=215°	1.5	0
N=190°	1.2	0
O=089°	1.8	1
P=080°	0.2	0
Q=096°	1.1	0
R=233°	0	0
S=245°	0.4	0
T=244°	0	0

Table 4 Participant 3 Error Measurement Data

Accepted Deviation = 1.5

Deviation Accumulation Size = 22

Gross Error Count = 9

Figure 17 below shows the participant error size and average deviation from the ideal flight path.

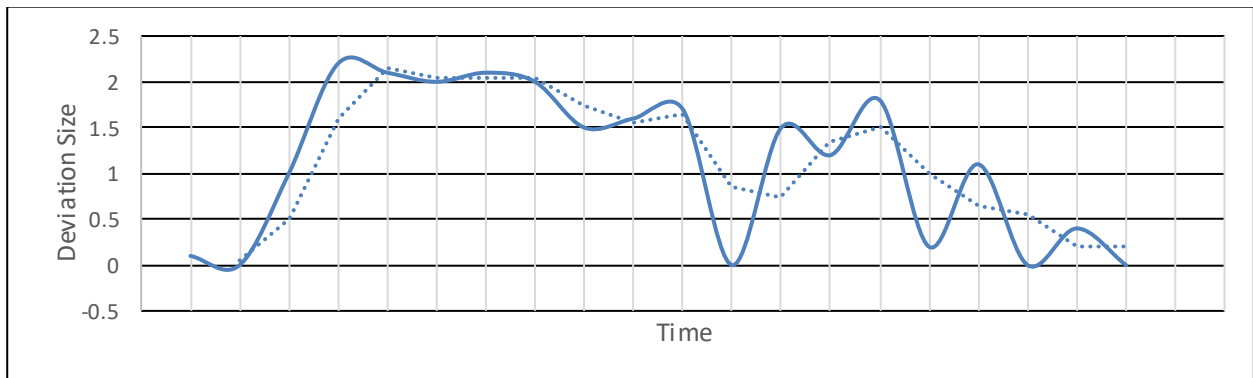


Figure 17 Participant 3 Error and Average Deviation Chart

5.2.3.4 Participant Questionnaire Data

The importance of scenery realism aspects on the ability to navigate to the various waypoints and the final destination:

- Scale: **0** = Not able to navigate successfully
1 = Some degree of navigation possible with difficulty
2 = Reasonable degree of navigation feasible
3 = Navigation possible with some errors
4 = Navigation possible with little or negligible errors
5 = Navigation with high degree of accuracy

	0	1	2	3	4	5
Landmarks						X
Buildings						X
Roads and rivers					X	
Terrain and topography						X

The ability to navigate to the various waypoints and the final destination:

- Scale: **0** = Not able to navigate
1 = Some degree of navigation possible with difficulty
2 = Reasonable degree of navigation feasible
3 = Navigation possible with some errors
4 = Successful navigation with little or negligible errors
5 = Successful navigation with high degree of accuracy

0	1	2	3	4	5
		X			

The importance of the following visual realism aspects on the ability to navigate to the various waypoints and the final destination:

Scale: **0** = Not relevant

1 = Successful navigate impossible

2 = Some degree of navigation possible with difficulty

3 = Reasonable degree of navigation feasible

4 = Successful navigation possible with little or negligible errors

5 = Successful navigation with high degree of accuracy

	0	1	2	3	4	5
Screen size						X
Displaying selected instrumentation on screen instead of actual physical instrumentation				X		
Utilising multiple displays to represent internal and/or external visuals (scenery)						X
Terrain and topography						X

Effectiveness experienced during the simulator exercise:

Scale: **0** = Not Relevant/Applicable

1 = Not effective

2 = Some degree of effectiveness

3 = Reasonable degree of effectiveness

4 = Effective

5 = Extremely effective

	0	1	2	3	4	5
Visual elements						
Scenery			X			
Screen Size		X				
Screen Brightness					X	
Simulator Controls						
Switches					X	
Flight Yoke and Pedals		X				

5.2.3.4 Overall Conclusions from Data

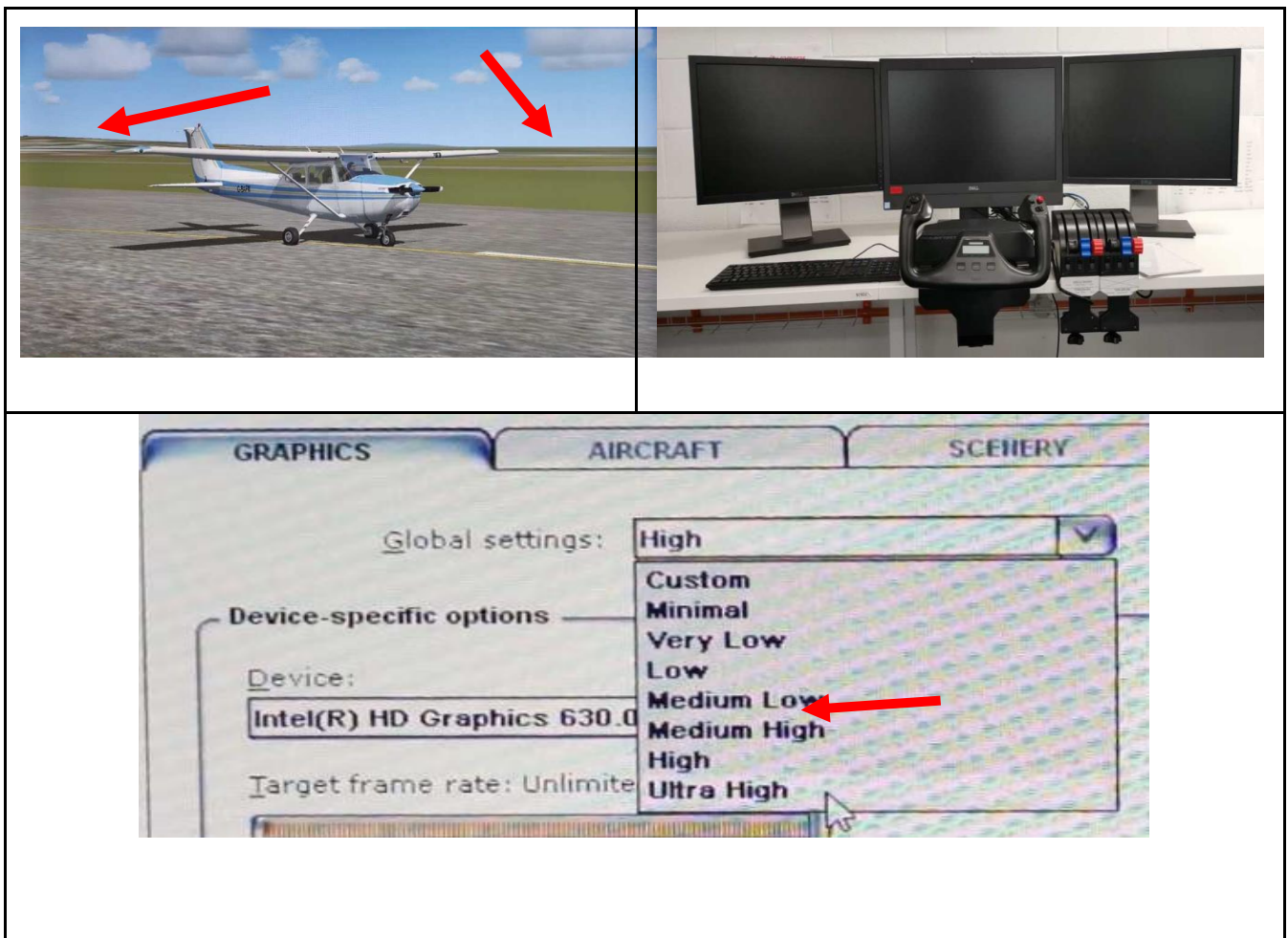
This configuration showed a further improvement in navigation ability but was not yet at the optimal setting to allow successful navigation using the setup/configuration. The gross error count for this participant was 9 and deviation accumulation size 22. This showed an improvement on the previous participant gross error count of 12 and deviation accumulation size of 28.3. Therefore, the assumption was made that this configuration was better than the previous configuration, but not yet at the optimal setting to allow successful navigation using the particular setup/configuration as the flight clearly showed some areas where the limitations are with respect to how effective the configuration of the simulator is to aid successful navigation. To address this, it was decided to expand the outside scenery visuals by adding a further 2 x 22" screens in a 3-monitor configuration setup as base configuration for the Design Science process Build A configuration using participant 4. As with the first participant, there were other issues with the flight that were not considered in determining the success of the navigational exercise. As with all the previous participants, the anticipated issues of aircraft height, speed and simulator experience were not considered in determining the success of the navigational exercise.

This ended the pilot study to establish to establish the first baseline configuration and Phase 1, followed by Phase 2 as discussed next to determine the actual minimum acceptable configuration for the VFR Navigation FTD.

5.3 Phase 2 Configuration

5.3.1 FTD Configuration Build A

The baseline configuration of the FTD simulator for participant 3 was used, but 2 additional monitors were added to display the outside field of view and scenery. The flight controls configuration from participant 3 was used. The maximum scenery settings from the participant 3 was maintained. A glass cockpit with traditional analog instrumentation configuration was used, and the flight simulation software used was identical to the configuration for participant 3, but with medium scenery complexity settings. (3D scenery, with a higher level of objects such as buildings and trees visible) A glass cockpit with traditional analogue instrumentation configuration was used, and the flight simulation software used was identical to the configuration for participant 2 as illustrated in Figure 18 below:



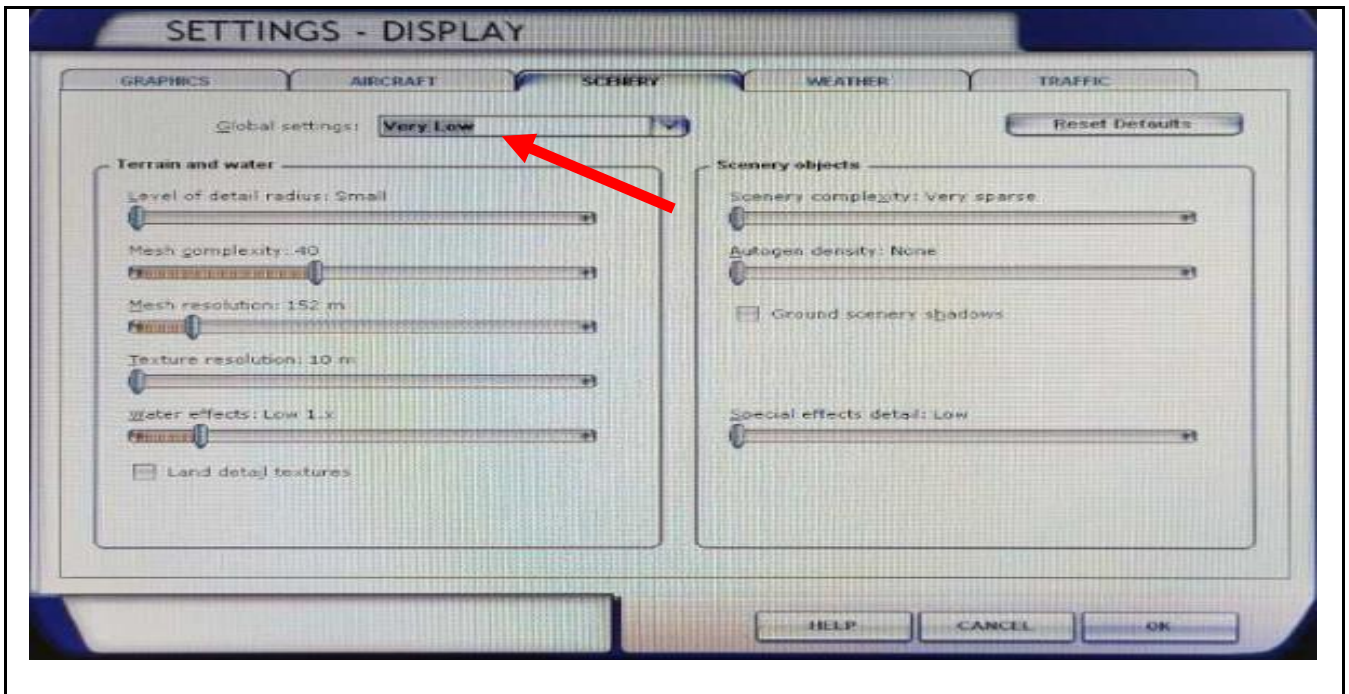


Figure 18 FTD Configuration 1 Build A

5.3.1.1 Flight Preparation

As with the previous participants, a briefing was conducted covering the theory to a basic understanding of navigation, and how to operate the simulator, including familiarity of the flight simulator and flight controls. The format and content were retained from the previous participant, and this took about 48 minutes in total. This was also well received by the participant. The only variable that changed was the time needed to explain and practice using the simulator before the actual flight. This individual used a similar time to learn the theory and adopt to the simulator than the previous participants.

5.3.1.2 The Simulation Flight

The participant, a female aged between 20-25, flight data is depicted as indicated in Figure 19 which illustrates the following:

- The flight path from start in the top left corner through waypoints WP1 to WP6.
- A Corridor of 3 units to indicate the gross error size.

- The red line representing the actual flight path as flown by the participant.
- The alphabetical sequence indicates the 2-minute intervals used.
- The blue line represents the flight direction; and

in Figure 20 the error and average deviation of the participant flight path is illustrated.

The participant initially followed the flight path well but went off track without realising it at positions B, C, D, E and F before the researcher paused the simulation so that the participant could visually check the aircraft position on the screen using the overhead view with the printed map given. This showed her aircraft position and confirmed he was off course. The participant proceeded to correct his course by using the proper navigation technique and flew to the waypoint, but on a parallel track to positions G, H and I. She did reach the position at J but failed to correctly alter the heading as directed and kept flying in the wrong direction and realised between position K and L that she was off the flight path. He corrected and attempted to correct the heading towards waypoint 4. At position M she realised that she was again off the flight path and altered the heading to attempt to find waypoint 5 but could not identify the landmark given. This resulted in the aircraft being off the flight path at position O. She attempted to correct the heading but did not manage to identify the landmark. This resulted in again flying off track at position P and Q. The research paused the simulator and prompted the participant to correct the heading at this point as per the previous participants' method of using the overhead view. At this point she could identify her location and successfully navigated towards the final waypoint 6.

The data from this participant, along with her feedback, indicated that the simulator configuration settings needed to be adjusted to a higher level of detail so that it would be easier to find visual confirmation of aircraft position. As before - in a real situation pilots cannot pause the flight to check location even though the pilot is able to look at an overhead satellite GPS view.

After the completion of the flight, the participant expressed that it was difficult to identify landmarks and find the waypoints. The flight duration was 58 minutes in total, including the pausing of the simulator (2 times in total). The simulator does not record the pauses. The actual flight time was 51 minutes, but the flight can be flown in around 30 - 35 minutes if there are no errors in navigation, depending on airspeed.

Flight data was recorded at 2-minute intervals relative to the desired/expected position. The accepted flight path deviation was set at 1.5 off the course. Aircraft height was not recorded. The flight time was recorded but not considered for data analysis.

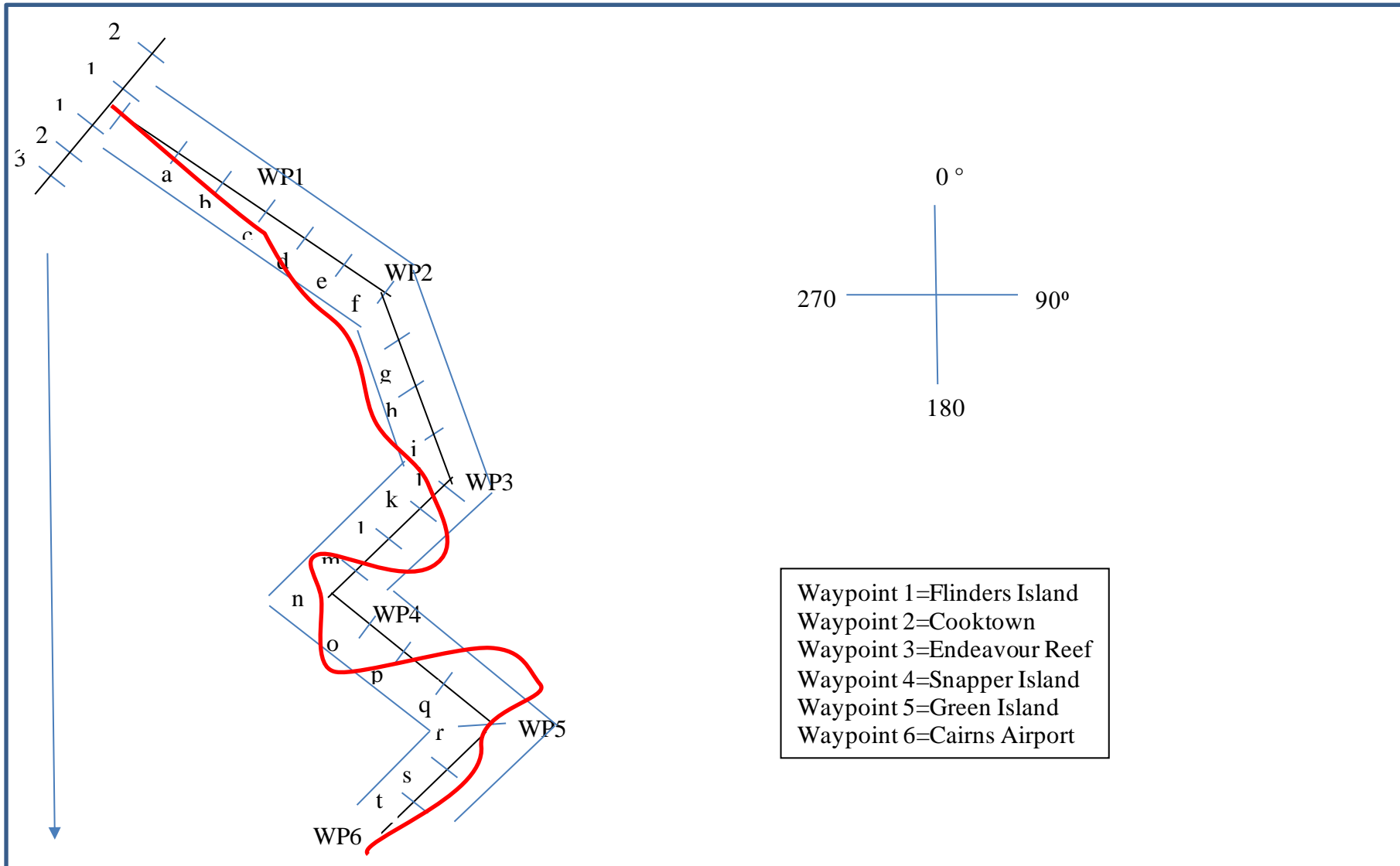


Figure 19 Participant 4 Flight Path

5.3.1.3 Error Measurement

Heading/Position	Deviation Size	Gross Error = 1
A=129 ⁰	0.2	0
B=129 ⁰	0.3	0
C=128 ⁰	0.4	0
D=140 ⁰	1.3	0
E=121 ⁰	1.7	1
F=151 ⁰	1.8	1
G=167 ⁰	1.8	1
H=143 ⁰	1.7	1
I=134 ⁰	0.8	0
J=158 ⁰	1.3	0
K=178 ⁰	1	0
L=265 ⁰	1.7	1
M=275 ⁰	0.7	0
N=180 ⁰	0.2	0
O=180 ⁰	1.7	1
P=080 ⁰	0.2	0
Q=083 ⁰	1.6	1
R=210 ⁰	0	0
S=230 ⁰	0.3	0
T=229 ⁰	0.2	0

Table 5 Participant 4 Error Measurement Data

Accepted Deviation = 1.5

Deviation Accumulation Size = 17.9

Gross Error Count = 6

Figure 20 below shows the participant error size and average deviation from the ideal flight path.

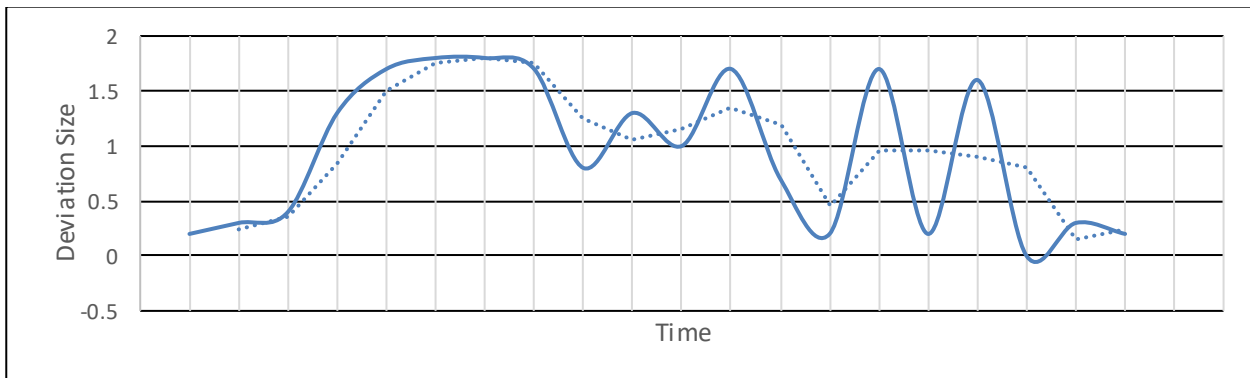


Figure 20 Participant 4 Error and Average Deviation Chart

5.3.1.4 Participant Questionnaire Data

The importance of scenery realism aspects on the ability to navigate to the various waypoints and the final destination:

- Scale: 0 = Not able to navigate successfully
 1 = Some degree of navigation possible with difficulty
 2 = Reasonable degree of navigation feasible
 3 = Navigation possible with some errors
 4 = Navigation possible with little or negligible errors
 5 = Navigation with high degree of accuracy

	0	1	2	3	4	5
Landmarks						X
Buildings						X
Roads and rivers					X	
Terrain and topography						X

The ability to navigate to the various waypoints and the final destination:

- Scale: 0 = Not able to navigate
 1 = Some degree of navigation possible with difficulty
 2 = Reasonable degree of navigation feasible
 3 = Navigation possible with some errors
 4 = Successful navigation with little or negligible errors
 5 = Successful navigation with high degree of accuracy

0	1	2	3	4	5
		X			

The importance of the following visual realism aspects on the ability to navigate to the various waypoints and the final destination:

Scale: **0** = Not relevant

- 1 = Successful navigate impossible
- 2 = Some degree of navigation possible with difficulty
- 3 = Reasonable degree of navigation feasible
- 4 = Successful navigation possible with little or negligible errors
- 5 = Successful navigation with high degree of accuracy

	0	1	2	3	4	5
Screen size						X
Displaying selected instrumentation on screen instead of actual physical instrumentation					X	
Utilising multiple displays to represent internal and/or external visuals (scenery)						X
Terrain and topography						X

Effectiveness experienced during the simulator exercise:

Scale: **0** = Not Relevant/Applicable

- 1 = Not effective
- 2 = Some degree of effectiveness
- 3 = Reasonable degree of effectiveness
- 4 = Effective
- 5 = Extremely effective

	0	1	2	3	4	5
Visual elements						
Scenery			X			
Screen Size				X		
Screen Brightness					X	
Simulator Controls						
Switches					X	
Flight Yoke and Pedals					X	

5.3.1.5 Overall Conclusions from Data

The screen setup on the medium configuration proved to be too challenging to see enough scenery to navigate successfully the configuration was not at the optimal setting to allow successful navigation using the particular setup/configuration.

The gross error count for this participant was 6 and deviation accumulation size 17.9. This showed an improvement on the previous participant gross error count of 9 and deviation accumulation size of 22. The flight clearly showed some areas where the limitations are with respect to how effective the configuration of the simulator is to aid successful navigation. To address this, and after feedback from the participant, the decision was made to utilise a combination of 3 x 22" screens, and the scenery level/realism was adjusted to display more object detail and scenery complexity.

From this result further adjustments to the simulator setup and configuration was made by adding more detailed landmark detail and textures. The issue remained at this stage how much adjustment would be required, so the decision was made to make an incremental adjustment to the visual settings.

As with all the previous participants, the anticipated issues of aircraft height, speed and simulator experience were not considered in determining the success of the navigational exercise.

5.3.2 FTD Configuration Build B

5.3.2.1 Flight Preparation

The configuration of the FTD simulator for participant 4 was used with further scenery enhancements installed on top of the default scenery. This consisted of more detailed utilising satellite imagery with added 3D objects depicting actual scenery as illustrated in Figure 21 below:

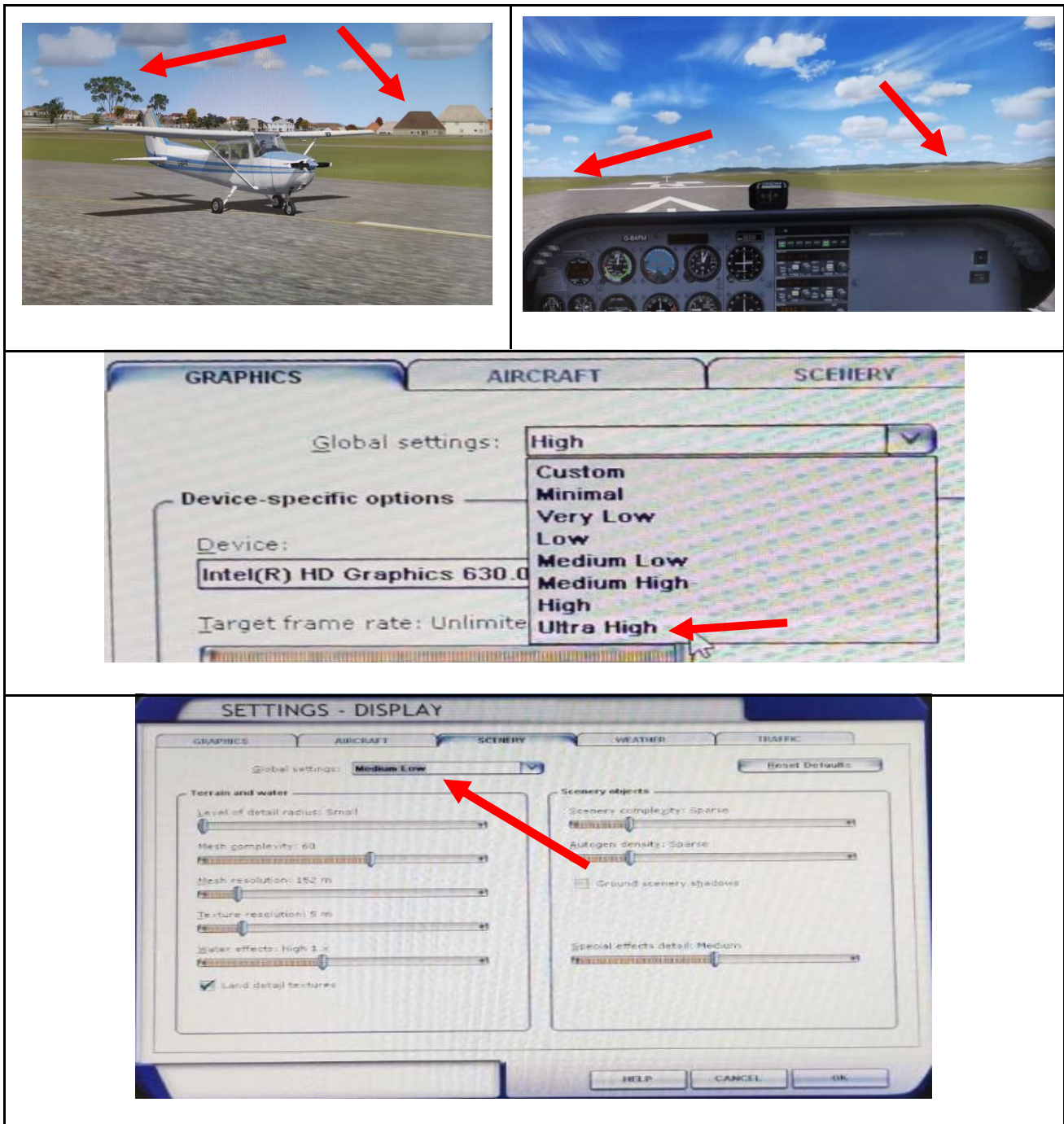


Figure 61 FTD Configuration 2 Build B

5.3.2.2 The Simulation Flight

The background instruction was the same as for participant 1, but the participant, male aged between 31-34, appeared to grasp the theory more quickly than the previous participants. The participant flight data is depicted as indicated in Figure 22 which illustrates the following:

- The flight path from start in the top left corner through waypoints WP1 to WP6.
- A Corridor of 3 units to indicate the gross error size.
- The red line representing the actual flight path as flown by the participant.
- The alphabetical sequence indicates the 2-minute intervals used.
- The blue line represents the flight direction; and

in Figure 23 the error and average deviation of the participant flight path is illustrated.

The participant started the flight on track, but gradually drifted of the flight path at positions A, B, C, D, E and F. The observation was made that he did not notice the small error in the initial heading, and this was compounded over time so as to drift off track without realising. When the participant arrived at the expected position F the waypoint was not found. This was due to the fact that he had drifted off the track. The simulation was paused so that the participant visually could check the aircraft position on the screen using the overhead view with the printed map given. This showed his aircraft position and confirmed he was off course. The participant proceeded to correct his course by using the proper navigation technique and flew to the waypoint. At position G he changed heading without instruction and flew off track at H. During the post flight interview, he stated that he could not identify his location and attempted to self-correct his heading. It was explained to him that he was flying parallel to the actual flight path even though his heading was correct, but he would not find the waypoint without further correction. He attempted to correct the heading at I towards waypoint 3 but missed it and decided to continue to waypoint 4 instead of trying to find waypoint 3. At this point he followed the heading towards waypoint 4, and only managed to find the flight path at position M, but he had to continually repeat this to establish his location, still flying parallel

to the flight path position R. For the remainder of the flight he managed to find the flight path. This indicated that the simulator configuration settings needed to be adjusted to an even higher level of detail so that it would be easier to find visual confirmation of aircraft position.

The flight duration was 58 minutes in total, including the pausing of the simulator (1 time in total). The simulator does not record the pauses. The actual flight time was 45 minutes, but the flight can be flown in around 30 - 35 minutes if there are no errors in navigation, depending on airspeed.

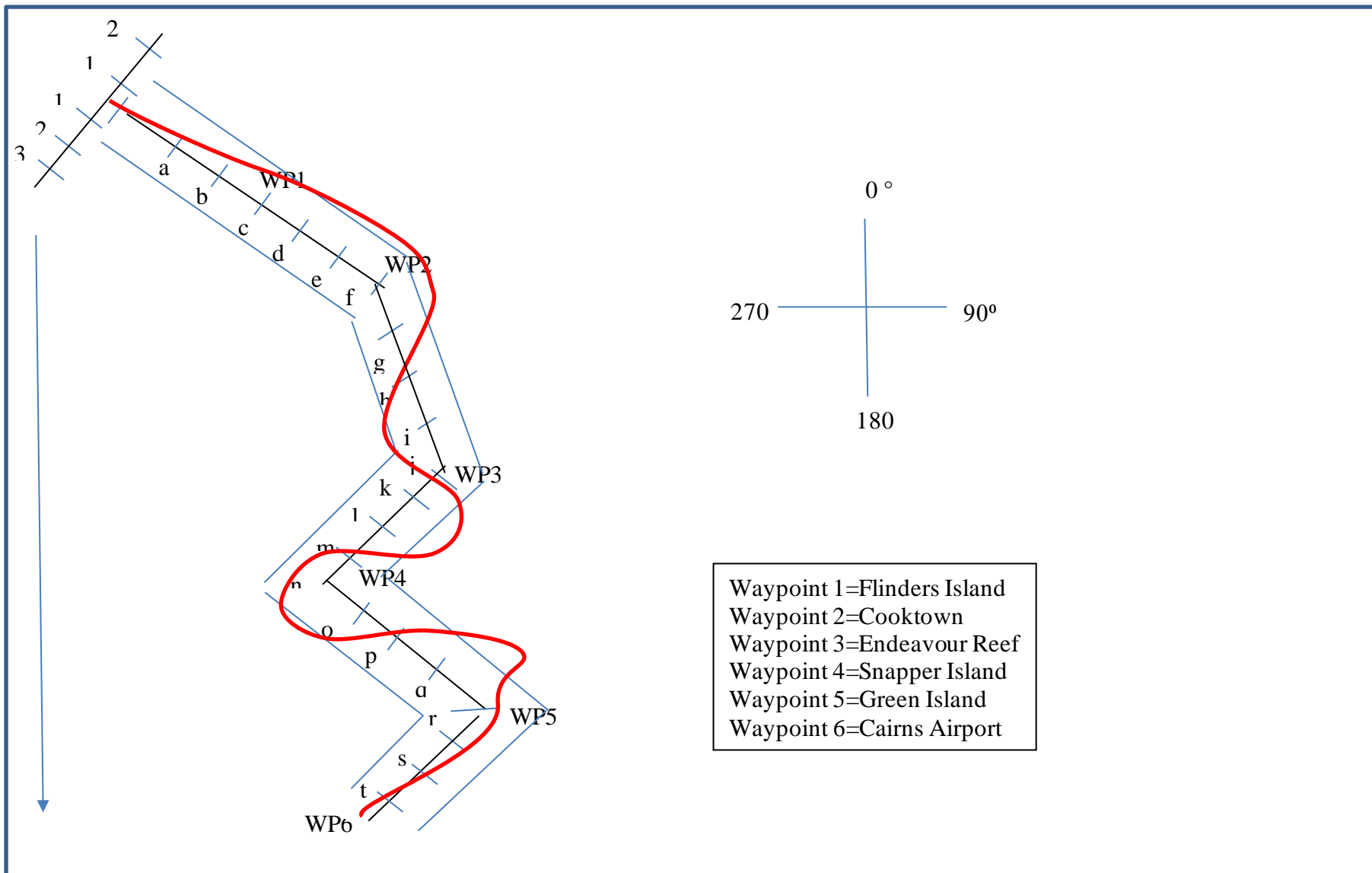


Figure 22 Participant 5 Flight Path

5.3.2.3 Error Measurement

Flight data was recorded at 2-minute intervals relative to the desired/expected position. The accepted flight path deviation was set at 1.5 off the course. Aircraft height was not recorded. The flight time was recorded but not considered for data analysis.

The below table shows the participants' flight data as recorded by the simulator indicating the relationship between the aircraft heading/position and size of deviation off the flight path. Any points where the aircraft position is outside of the acceptable corridor deviation of 1.5 is identified a Gross Error (GE). The deviation accumulative size is then derived from the sum of the deviation numbers.

Heading/Position	Deviation Size	Gross Error = 1
A=112°	0.3	0
B=119°	1	0
C=116°	0.8	0
D=119°	1.5	0
E=122°	1.6	1
F=135°	1.6	1
G=205°	1.8	1
H=205°	0	0
I=159°	1.7	1
J=121°	1.8	1
K=200°	1.8	1
L=271°	1.7	1
M=270°	0.1	0
N=215°	0.7	0
O=114°	1.7	1
P=085°	0.2	0
Q=096°	0.6	0
R=195°	0.2	0
S=233°	0.4	0
T=232°	0.2	0

Table 6 Participant 5 Error Measurement Data

Accepted Deviation = 1.5

Deviation Accumulation Size = 18.8

Gross Error Count = 8

Figure 23 below shows the participant error size and average deviation from the ideal flight path.

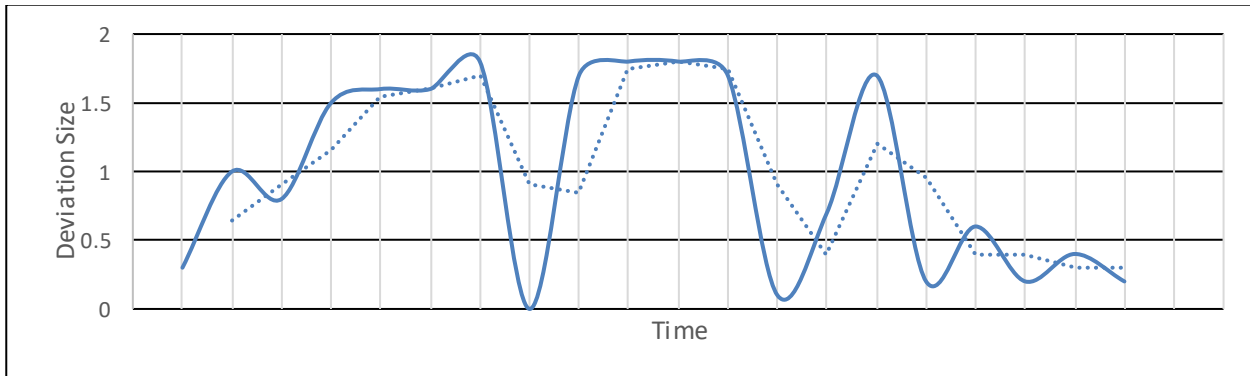


Figure 23 Participant 5 Error and Average Deviation Chart

5.3.2.4 Participant Questionnaire Data

The importance of scenery realism aspects on the ability to navigate to the various waypoints and the final destination:

- Scale: 0 = Not able to navigate successfully
1 = Some degree of navigation possible with difficulty
2 = Reasonable degree of navigation feasible
3 = Navigation possible with some errors
4 = Navigation possible with little or negligible errors
5 = Navigation with high degree of accuracy

	0	1	2	3	4	5
Landmarks						X
Buildings					X	
Roads and rivers				X		
Terrain and topography						X

The ability to navigate to the various waypoints and the final destination:

- Scale: 0 = Not able to navigate
1 = Some degree of navigation possible with difficulty
2 = Reasonable degree of navigation feasible
3 = Navigation possible with some errors
4 = Successful navigation with little or negligible errors
5 = Successful navigation with high degree of accuracy

0	1	2	3	4	5
			X		

The importance of the following visual realism aspects on the ability to navigate to the various waypoints and the final destination:

- Scale: **0** = Not relevant
1 = Successful navigate impossible
2 = Some degree of navigation possible with difficulty
3 = Reasonable degree of navigation feasible
4 = Successful navigation possible with little or negligible errors
5 = Successful navigation with high degree of accuracy

	0	1	2	3	4	5
Screen size						X
Displaying selected instrumentation on screen instead of actual physical instrumentation					X	
Utilising multiple displays to represent internal and/or external visuals (scenery)						X
Terrain and topography						X

Effectiveness experienced during the simulator exercise:

- Scale: **0** = Not Relevant/Applicable
1 = Not effective
2 = Some degree of effectiveness
3 = Reasonable degree of effectiveness
4 = Effective
5 = Extremely effective

	0	1	2	3	4	5
Visual elements						
Scenery				X		
Screen Size					X	
Screen Brightness					X	
Simulator Controls						
Switches					X	
Flight Yoke and Pedals					X	

5.3.2.5 Overall Conclusions from Data

The participant data, along with the participant feedback and observation of the researcher during the flight indicated that the simulator configuration settings needed to be adjusted to a higher level of detail so that it would be easier to find visual confirmation of aircraft position. The emphasis on accurate scenery detail and complexity was clearly stated by the participant to facilitate successful VFR navigation.

Of important note is that this participant had a higher gross error score (8) compared to the previous participant (6) and higher average deviation score (18.8) and the previous participant (17.9). This presented a challenge as to the reason since the simulator configuration scenery detail was adjusted and increased from the previous participant. During the post flight interview this was discussed with the participant, and he indicated that he was felt that his concentration was compromised due to personal matters on his mind and he did not take as much notice when he veered off track. This may have impacted on his results. Consequently, the decision was made to re-use the configuration setup for the next participant to validate the configuration, but to also make an incremental change to the scenery as suggested by this participant.

Flight data was recorded at 2-minute intervals relative to the desired/expected position. The accepted flight path deviation was set at 1.5 off the course. Aircraft height was not recorded. The flight time was recorded but not considered for data analysis.

As with all the previous participants, the anticipated issues of aircraft height, speed and simulator experience were not considered in determining the success of the navigational exercise.

5.3.3 FTD Configuration Build C

5.3.3.1 Flight Preparation

The configuration of the FTD simulator for participant 5 was used with added scenery settings to the default scenery at a medium setting. This consisted of more detailed scenery with added 3D objects depicting actual scenery in illustrated in Figure 24.

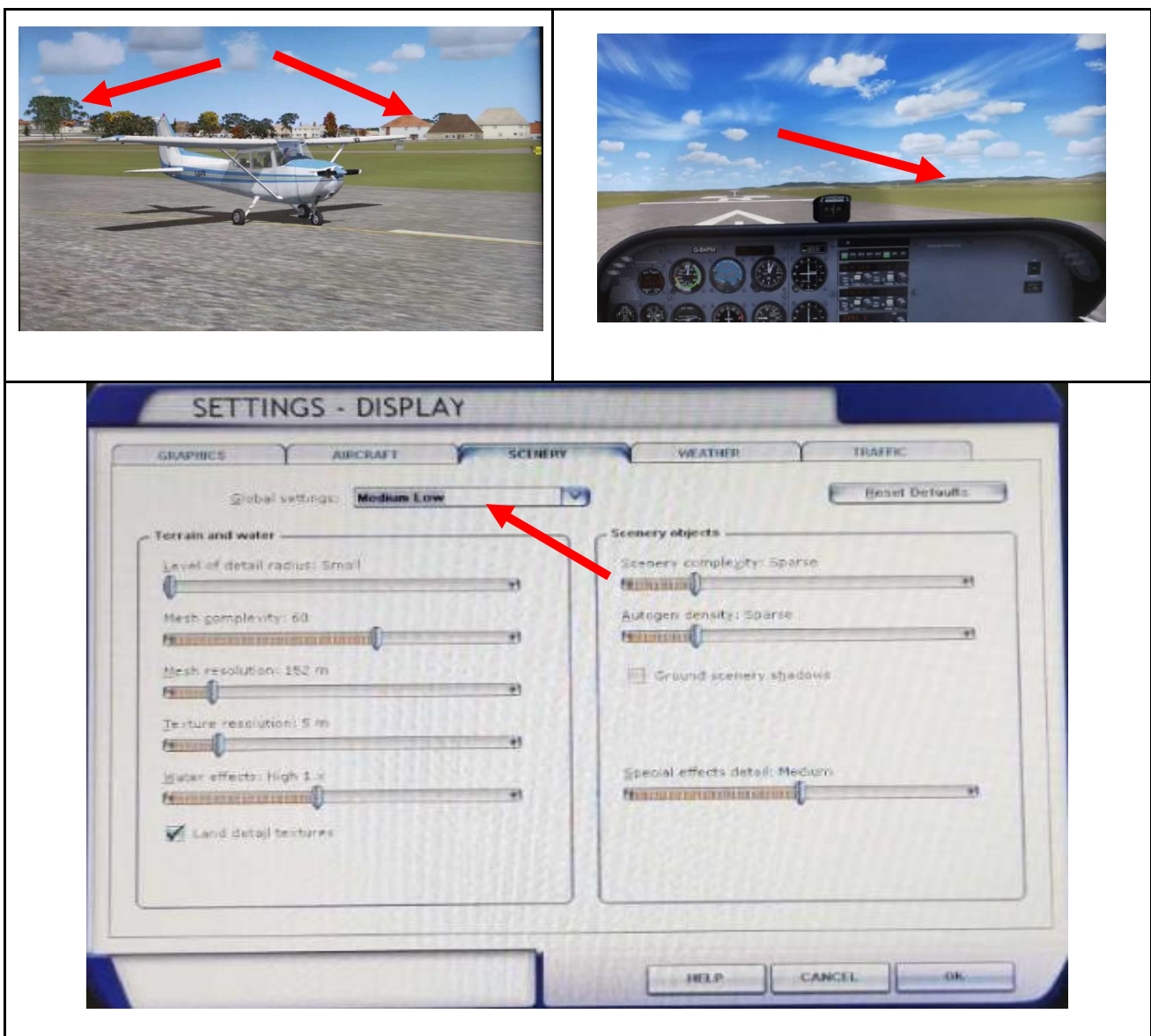


Figure 24 FTD Configuration 3 Build C

5.3.3.2 The Simulation Flight

The initial briefing and theory included a basic understanding of navigation, and how to operate the simulator, including familiarity of the flight simulator and flight controls. This took about 1.3 hours in total. The participant indicated that she was satisfied with format and content. The participant flight data is depicted as indicated in Figure 25 which illustrates the following:

- The flight path from start in the top left corner through waypoints WP1 to WP6.
- A Corridor of 3 units to indicate the gross error size.
- The red line representing the actual flight path as flown by the participant.
- The alphabetical sequence indicates the 2-minute intervals used
- The blue line represents the flight direction

and in Figure 26 the error and average deviation of the participant flight path is illustrated.

The participant, female aged between 45-50, set the correct waypoint heading, but drifted off track without realising it at position A, B, C and D. The researcher intervened and prompted the participant to correct using the same technique as for the previous participants. The simulation was paused so that the participant could visually check the aircraft position on the screen using the overhead view with the printed map given. This showed his aircraft position and confirmed she was off course. The participant proceeded to correct the course by using the proper navigation technique and flew correctly at position G. The participant again lost the flight path heading at H, I, and J, and corrected at K. The flight path was lost again at positions M and O. The remaining waypoints were found.

After the completion of the flight, the participant expressed that the simulation detail could be improved to properly identify the landmarks and scenery. The data showed clearly where the landmarks were more visible the flight path improved. The flight duration was 48 minutes in total, including the pausing of the simulator (1 time in total).

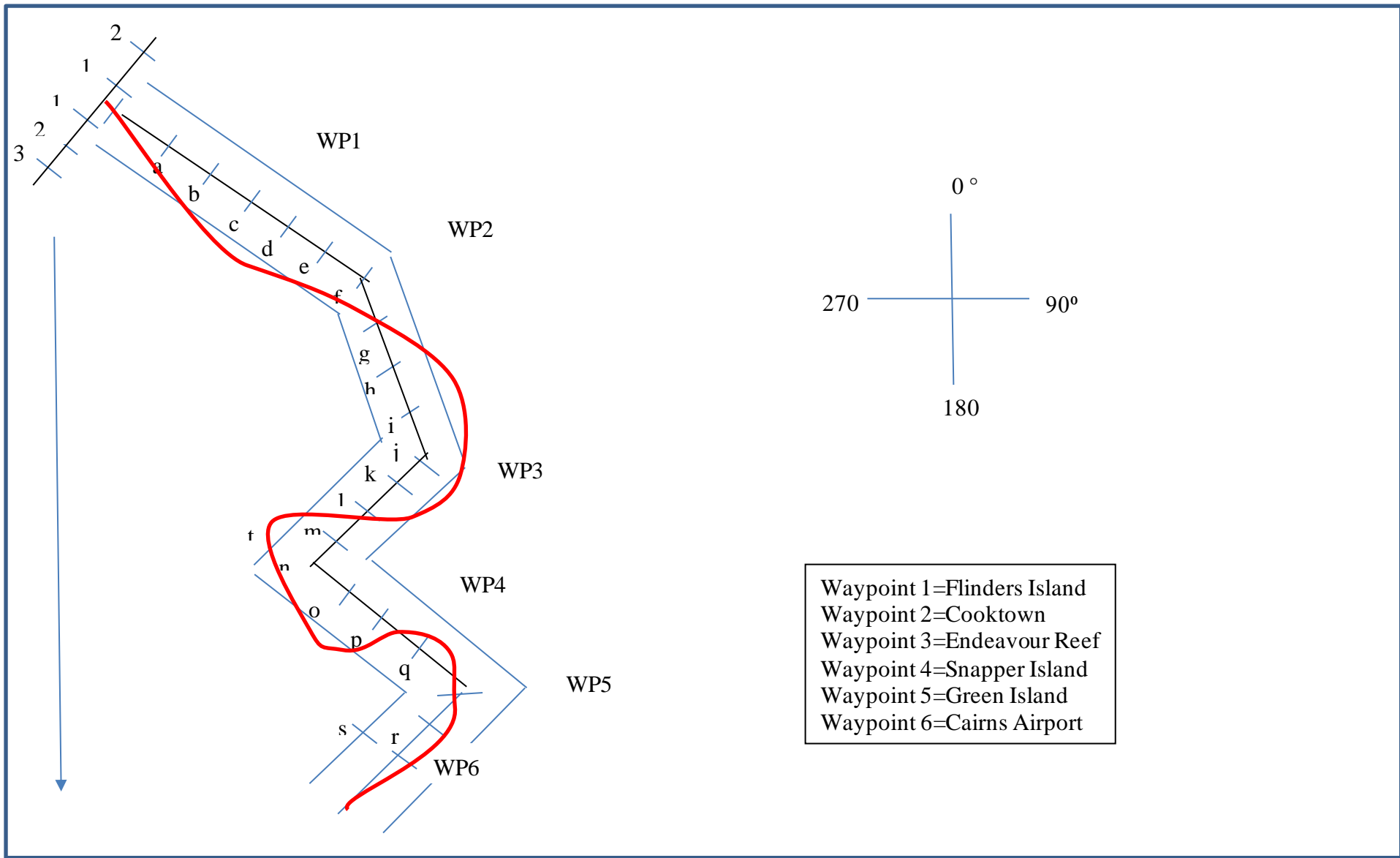


Figure 25 Participant 6 Flight Path

Error Measurement

Flight data was recorded at 2-minute intervals relative to the desired/expected position. The accepted flight path deviation was set at 1.5 deviation off the course. Aircraft height was not recorded. The flight time was recorded but not considered for data analysis.

The below table shows the participants' flight data as recorded by the simulator indicating the relationship between the aircraft heading/position and size of deviation off the flight path. Any points where the aircraft position is outside of the acceptable corridor deviation of 1.5 is identified a Gross Error (GE). The deviation accumulative size is then derived from the sum of the deviation numbers.

Heading/Position	Deviation Size	Gross Error = 1
A=144 ⁰	1	0
B=140 ⁰	1.5	0
C=139 ⁰	1.7	1
D=109 ⁰	1.7	1
E=102 ⁰	1.4	0
F=116 ⁰	1.3	0
G=119 ⁰	0	0
H=125 ⁰	1.4	0
I=157 ⁰	1.8	1
J=210 ⁰	1.6	1
K=245 ⁰	1.6	1
L=272 ⁰	0.3	0
M=269 ⁰	1.5	0
N=151 ⁰	0.6	0
O=151 ⁰	1.7	1
P=054 ⁰	1.4	0
Q=115 ⁰	1	0
R=180 ⁰	0.3	0
S=211 ⁰	0.2	0
T=230 ⁰	0.1	0

Table 7 Participant 6 Error Measurement Data

Accepted Deviation = 1.5

Deviation Accumulation Size = 22.1

Gross Error Count = 6

Figure 26 below shows the participant error size and average deviation from the ideal flight path.

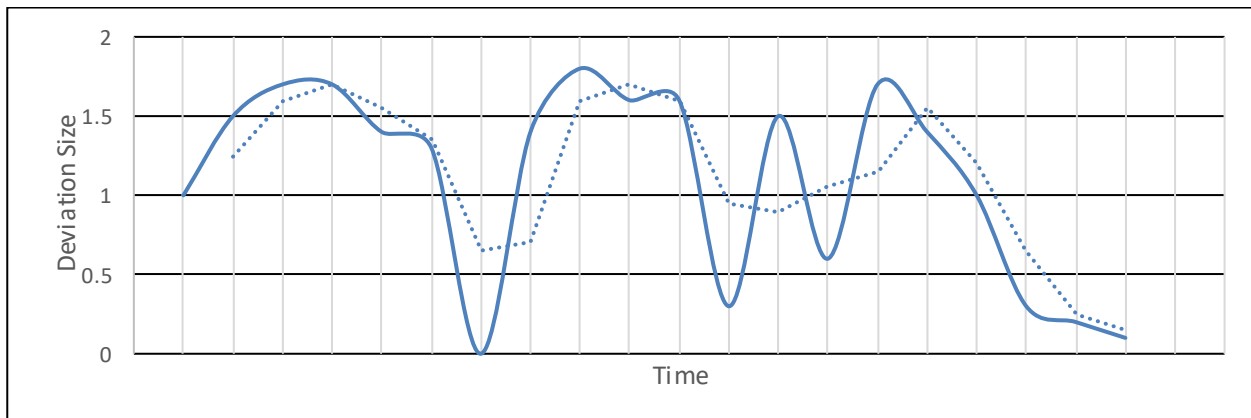


Figure 26 Participant 6 Error and Average Deviation Chart

Participant Questionnaire Data

The importance of scenery realism aspects on the ability to navigate to the various waypoints and the final destination:

- Scale: **0** = Not able to navigate successfully
1 = Some degree of navigation possible with difficulty
2 = Reasonable degree of navigation feasible
3 = Navigation possible with some errors
4 = Navigation possible with little or negligible errors
5 = Navigation with high degree of accuracy

	0	1	2	3	4	5
Landmarks						X
Buildings						X
Roads and rivers					X	
Terrain and topography						X

The ability to navigate to the various waypoints and the final destination:

Scale: 0 = Not able to navigate

1 = Some degree of navigation possible with difficulty

2 = Reasonable degree of navigation feasible

3 = Navigation possible with some errors

4 = Successful navigation with little or negligible errors

5 = Successful navigation with high degree of accuracy

0	1	2	3	4	5
			X		

The importance of the following visual realism aspects on the ability to navigate to the various waypoints and the final destination:

Scale: 0 = Not relevant

1 = Successful navigate impossible

2 = Some degree of navigation possible with difficulty

3 = Reasonable degree of navigation feasible

4 = Successful navigation possible with little or negligible errors

5 = Successful navigation with high degree of accuracy

	0	1	2	3	4	5
Screen size						X
Displaying selected instrumentation on screen instead of actual physical instrumentation						X
Utilising multiple displays to represent internal and/or external visuals (scenery)						X
Terrain and topography						X

Effectiveness experienced during the simulator exercise:

Scale: 0 = Not Relevant/Applicable

1 = Not effective

2 = Some degree of effectiveness

3 = Reasonable degree of effectiveness

4 = Effective

5 = Extremely effective

	0	1	2	3	4	5
Visual elements						
Scenery				X		
Screen Size					X	
Screen Brightness					X	
Simulator Controls						
Switches					X	
Flight Yoke and Pedals					X	

5.3.3.3 Overall Conclusions from Data

The screen setup on the medium configuration proved to be too challenging to see enough scenery to navigate successfully. The configuration was not at the optimal setting to allow successful navigation using the particular setup/configuration. The flight clearly showed some areas where the limitations are with respect to how effective the configuration of the simulator is to aid successful navigation. To address this further adjustment needed to be made to increase the scenery level/realism.

Of note was that this participant had a gross error count of 6, and a deviation accumulation size of 22.1. The gross error count was an improvement over the previous participant, but the deviation accumulation size was higher. This indicated an improvement with regards to the simulator configuration, but the higher deviation size could be accounted to the individual skill level or individual influences as discussed earlier and was not taken into consideration for the simulator configuration changes for the next participant.

As with all the previous participants, the anticipated issues of aircraft height, speed and simulator experience were not considered in determining the success of the navigational exercise.

5.3.4 FTD Configuration Build D

5.3.4.1 Flight Preparation

The configuration of the FTD simulator for participant 6 was used, and the default scenery realism settings changed to maximum. (Figure 27)

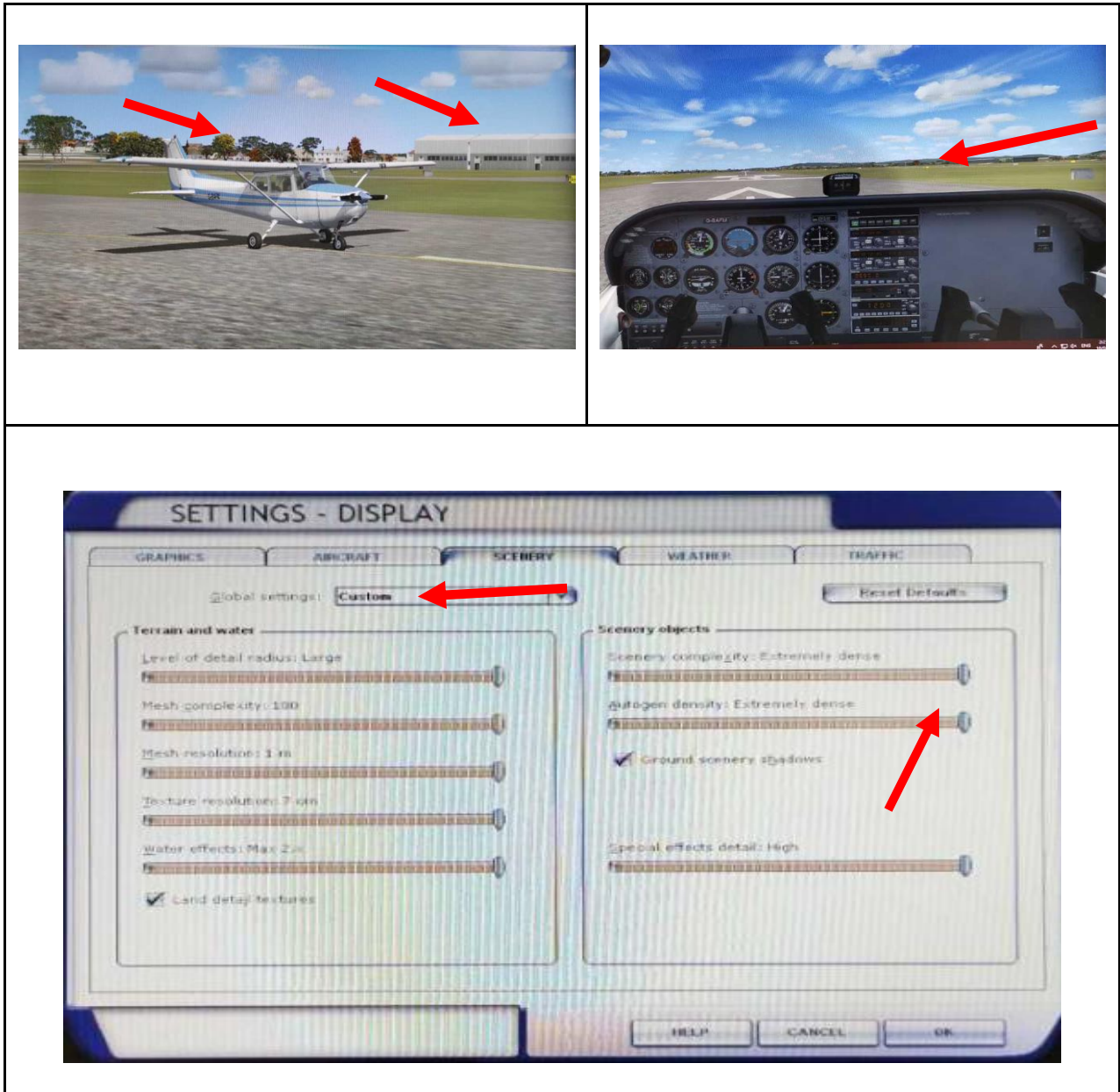


Figure 27 FTD Configuration 4 Build D

5.3.4.2 The Simulation Flight

The initial briefing and theory included a basic understanding of navigation, and how to operate the simulator, including familiarity of the flight simulator and flight controls. This took about 49 minutes in total. The participant flight data is depicted as indicated in Figure 28 which illustrates the following:

- The flight path from start in the top left corner through waypoints WP1 to WP6.
- A Corridor of 3 units to indicate the gross error size.
- The red line representing the actual flight path as flown by the participant.
- The alphabetical sequence indicates the 2-minute intervals used.
- The blue line represents the flight direction; and

in Figure 29 the error and average deviation of the participant flight path is illustrated.

The participant, female aged between 36-38, managed to stay well on the flight path and was the first participant to stay within the accepted corridor deviation of 1.5 for waypoints 1 and 2. He accurately found waypoint 2, but went off track without realising it at position G, H, and I. He self-corrected at position J and stayed within the flight path corridor and positions K. However, he drifted off track at position L so that he flew outside the deviation corridor at position M. He turned onto the correct heading at position N towards waypoint 5, but at position O he changed the heading without instruction until midway between positions Q and R. This could be an indication of taking too much time to turn onto the correct heading in between 2 waypoints fairly close together on the flight plan. The participant then proceeded to correct his course and flew correctly to waypoint 6. This indicated that the simulator configuration settings needed to be adjusted to a higher level of detail so that it would be easier to find visual confirmation of aircraft position. In a real situation pilots cannot pause the flight to check location even though the pilot is able to look at an overhead satellite GPS view.

After the completion of the flight, the participant expressed that the simulation did not show enough detail of the outside world through the visual display. The actual flight time was 41 minutes, but the flight can be flown in around 30 - 35 minutes if there are no errors in navigation, depending on airspeed.

Flight data was recorded at 2-minute intervals relative to the desired/expected position. The accepted flight path deviation was set at 1.5° off the course. Aircraft height was not recorded. The flight time was recorded but not considered for data analysis.

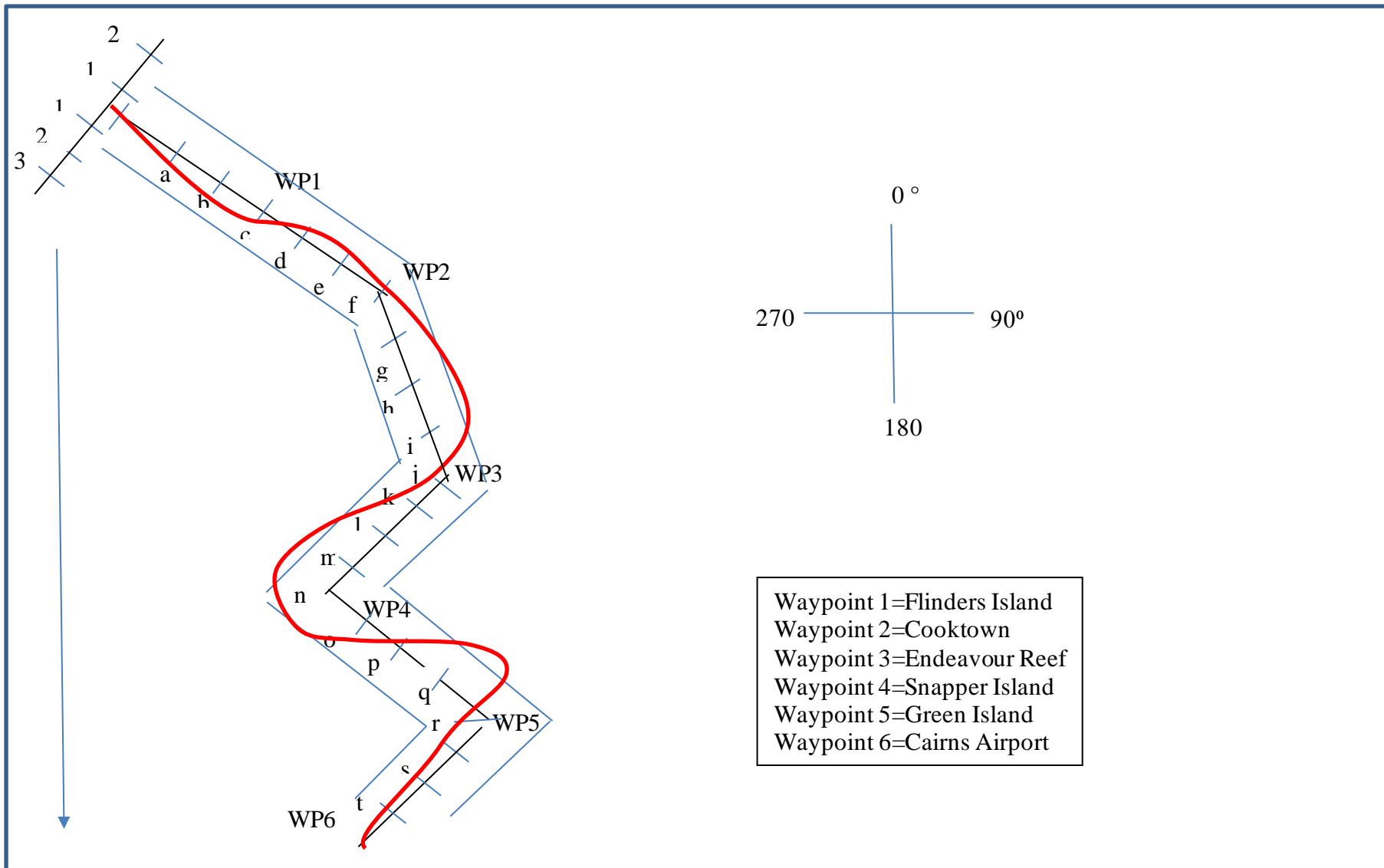


Figure 28 Participant 7 Flight Path

5.3.4.3 Error Measurement

Flight data was recorded at 2-minute intervals relative to the desired/expected position. The accepted flight path deviation was set at 1.5 off the course. Aircraft height was not recorded. The flight time was recorded but not considered for data analysis.

The below table shows the participants' flight data as recorded by the simulator indicating the relationship between the aircraft heading/position and size of deviation off the flight path. Any points where the aircraft position is outside of the acceptable corridor deviation of 1.5 is identified a Gross Error (GE). The GE accumulative size is then derived from the sum of the GE numbers.

Heading/Position	Deviation Size	Gross Error = 1
A=130°	0.2	0
B=126°	0.3	0
C=094°	0.2	0
D=100°	0.2	0
E=140°	0.3	0
F=137°	0.1	0
G=144°	0.9	1
H=154°	1.7	1
I=180°	1.6	1
J=244°	0.2	0
K=248°	0.7	0
L=250°	1.3	0
M=230°	1.7	1
N=152°	1.3	0
O=091°	1.5	0
P=091°	0.2	0
Q=110°	1.6	0
R=217°	0.3	0
S=229°	0.2	0
T=228°	0.1	0

Table 8 Participant 7 Error Measurement Data

Accepted Deviation = 1.5

Deviation Accumulation Size = 14.1

Gross Error Count = 4

Figure 32 below shows the participant error size and average deviation from the ideal flight path.

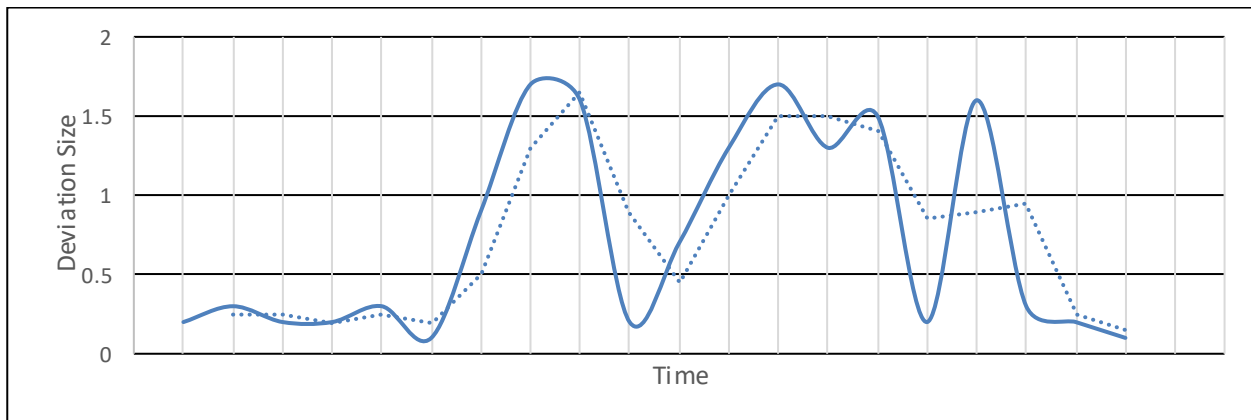


Figure 29 Participant 7 Error and Average Deviation Chart

Participant Questionnaire Data

The importance of scenery realism aspects on the ability to navigate to the various waypoints and the final destination:

- Scale: **0** = Not able to navigate successfully
1 = Some degree of navigation possible with difficulty
2 = Reasonable degree of navigation feasible
3 = Navigation possible with some errors
4 = Navigation possible with little or negligible errors
5 = Navigation with high degree of accuracy

	0	1	2	3	4	5
Landmarks						X
Buildings						X
Roads and rivers						X
Terrain and topography						X

The ability to navigate to the various waypoints and the final destination:

Scale: 0 = Not able to navigate

1 = Some degree of navigation possible with difficulty

2 = Reasonable degree of navigation feasible

3 = Navigation possible with some errors

4 = Successful navigation with little or negligible errors

5 = Successful navigation with high degree of accuracy

0	1	2	3	4	5
			X		

The importance of the following visual realism aspects on the ability to navigate to the various waypoints and the final destination:

Scale: 0 = Not relevant

1 = Successful navigate impossible

2 = Some degree of navigation possible with difficulty

3 = Reasonable degree of navigation feasible

4 = Successful navigation possible with little or negligible errors

5 = Successful navigation with high degree of accuracy

	0	1	2	3	4	5
Screen size						X
Displaying selected instrumentation on screen instead of actual physical instrumentation					X	
Utilising multiple displays to represent internal and/or external visuals (scenery)						X
Terrain and topography						X

Effectiveness experienced during the simulator exercise:

Scale: 0 = Not Relevant/Applicable

1 = Not effective

2 = Some degree of effectiveness

3 = Reasonable degree of effectiveness

4 = Effective

5 = Extremely effective

	0	1	2	3	4	5
Visual elements						
Scenery				X		
Screen Size					X	
Screen Brightness					X	
Simulator Controls						
Switches					X	
Flight Yoke and Pedals					X	

5.3.4.4 Overall Conclusions from Data

The FTD simulator configuration with the screen setup and controls from participant 6 and improved scenery levels at maximum default scenery settings indicated that VFR navigation is feasible, but gross errors were still evident.

This participant had a gross error score of 4 compared to the previous participant (6) and lower average deviation score (14.1) and the previous participant (22.1). This indicated an improved simulator configuration, but also that the configuration was not at the optimal setting to allow successful navigation using the particular setup/configuration, as was evident from the data and the participant feedback. The flight clearly showed some areas where the limitations are with respect to how effective the configuration of the simulator is to aid successful navigation. To address this the decision was made increase the scenery level/realism to the absolute maximum level possible with added scenery enhancements to further ad realism and detail.

As with all the previous participants, the anticipated issues of aircraft height, speed and simulator experience were not considered in determining the success of the navigational exercise.

5.3.5 FTD Configuration Build E

5.3.5.1 Flight Preparation

The configuration of the FTD simulator for participant 7 was used with added scenery enhancements installed on top of the default scenery at maximum settings. This consisted of more detailed utilising satellite imagery with added 3D objects depicting actual scenery as illustrated in Figure 30 below:

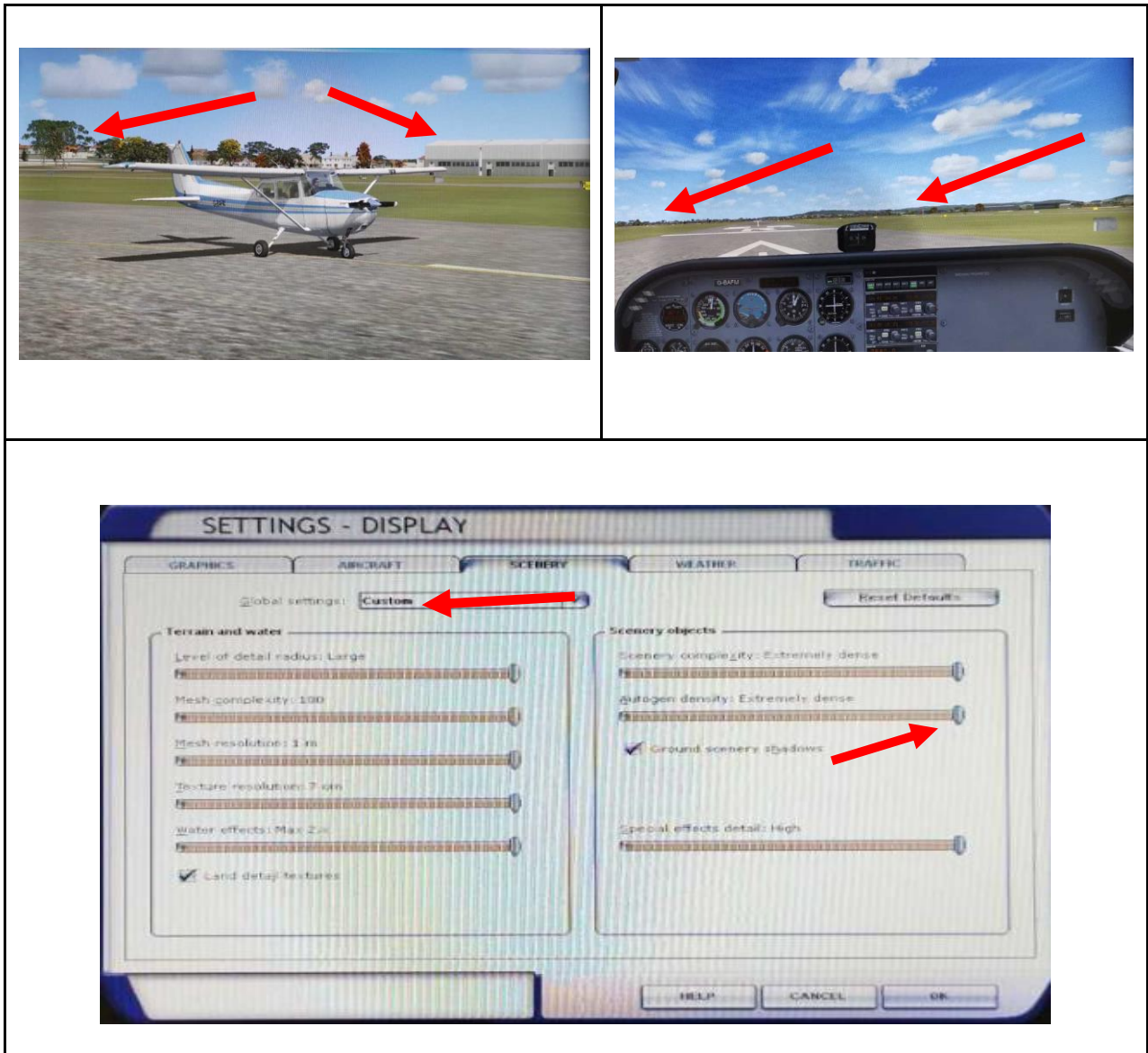


Figure 30 FTD Configuration 5 Build E

5.3.5.2 The Simulation Flight

The initial briefing and theory included a basic understanding of navigation, and how to operate the simulator, including familiarity of the flight simulator and flight controls. This took about 67 minutes in total. The participant flight data is depicted as indicated in Figure 31 which illustrates the following:

- The flight path from start in the top left corner through waypoints WP1 to WP6.
- A Corridor of 3 units to indicate the gross error size.

- The red line representing the actual flight path as flown by the participant.
- The alphabetical sequence indicates the 2-minute intervals used.
- The blue line represents the flight direction; and

in Figure 32 the error and average deviation of the participant flight path is illustrated.

The participant, female aged between 20-25, initially veered off track at positions A and B but corrected the heading at C and flew accurately to waypoint 2. This participant appeared to not be concentrating very well at the start of the flight but did get more confident after this point. He accurately identified the landmarks for the majority of the flight but deviated slightly from the flight path at waypoint 4. However, his flight data showed only 3 gross errors. This indicated that the simulator configuration settings may be very close to the desired configuration, and that the gross error count may be due to the individual level of simulator competence, or that further simulator adjustments were required.

After the completion of the flight, the participant expressed that the participant expressed the opinion that she was not confident to handle the simulator to be able to control the aircraft to find and maintain the desired heading, but this improved with time. The actual flight time was 39 minutes, but the flight can be flown in around 30 - 35 minutes if there are no errors in navigation, depending on airspeed.

The decision was made to make no further changes to the scenery settings, but to check the aircraft flight controls, and these were tweaked to a less sensitive setting. This would result in a slightly higher tolerance level to control input. Flight data was recorded at 2-minute intervals relative to the desired/expected position. The accepted flight path deviation was set at 1.5 off the course. Aircraft height was not recorded. The flight time was recorded but not considered for data analysis.

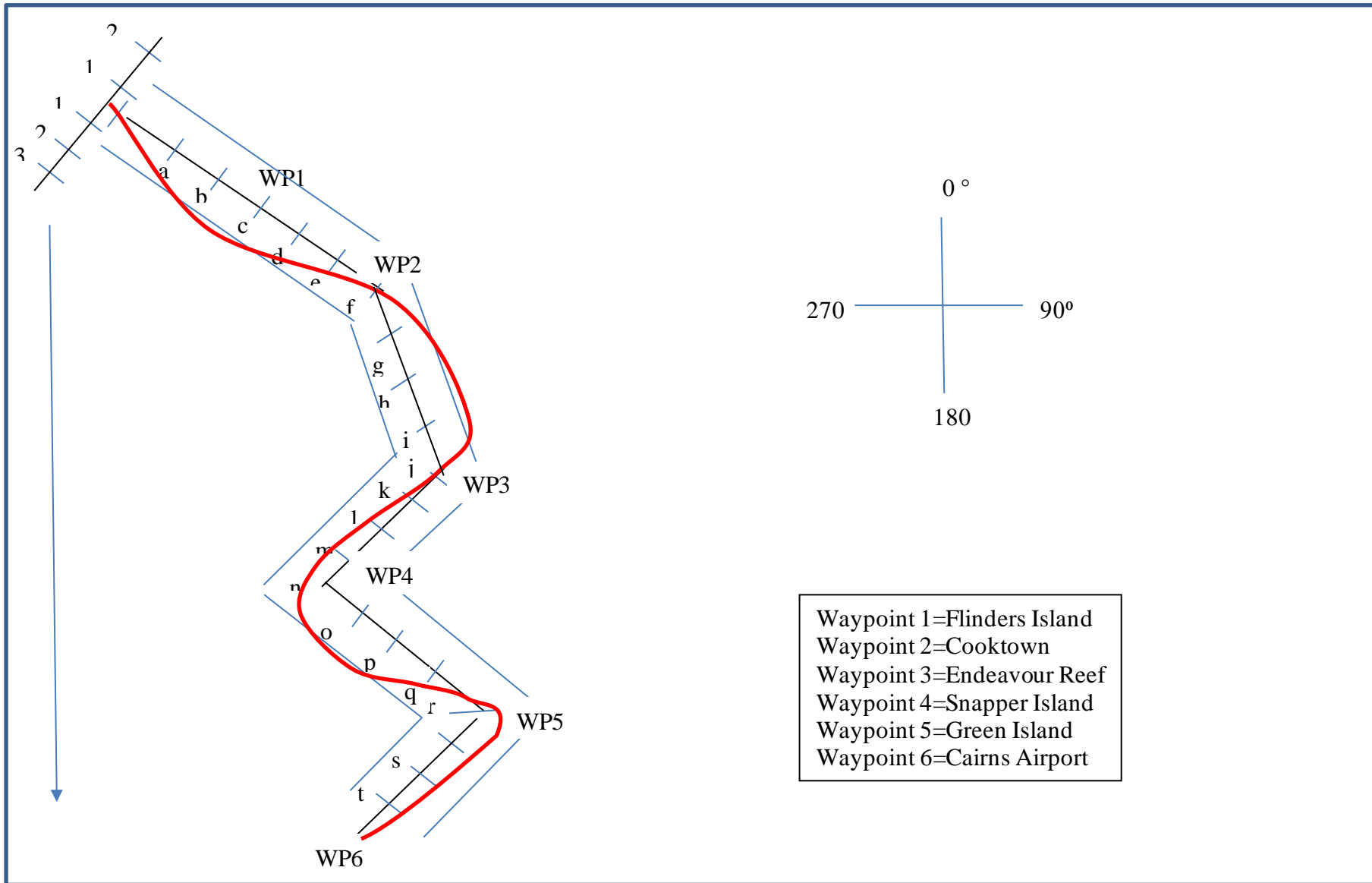


Figure 31 Participant 8 Flight Path

5.3.5.3 Error Measurement

Flight data was recorded at 2-minute intervals relative to the desired/expected position. The accepted flight path deviation was set at 1.5 off the course. Aircraft height was not recorded. The flight time was recorded but not considered for data analysis.

The below table shows the participants' flight data as recorded by the simulator indicating the relationship between the aircraft heading/position and size of deviation off the flight path. Any points where the aircraft position is outside of the acceptable corridor deviation of 1.5 is identified a Gross Error (GE). The GE accumulative size is then derived from the sum of the GE numbers.

Heading/Position	Deviation Size	Gross Error = 1
A=148°	0.8	0
B=150°	1.6	1
C=114°	1.6	1
D=106°	0.8	0
E=108°	0.4	0
F=127°	0	0
G=150°	0.6	0
H=155°	1.5	0
I=162°	1.6	1
J=225°	0	0
K=234°	0.2	0
L=232°	0.4	0
M=229°	0.5	0
N=180°	0.4	0
O=139°	1.5	0
P=101°	1.5	0
Q=103°	0.5	0
R=190°	0.4	0
S=230°	0.3	0
T=229°	0.2	0

Table 9 Participant 8 Error Measurement Data

Accepted Deviation = 1.5

Deviation Accumulation Size = 14

Gross Error Count = 3

Figure 32 below shows the participant error size and average deviation from the ideal flight path.

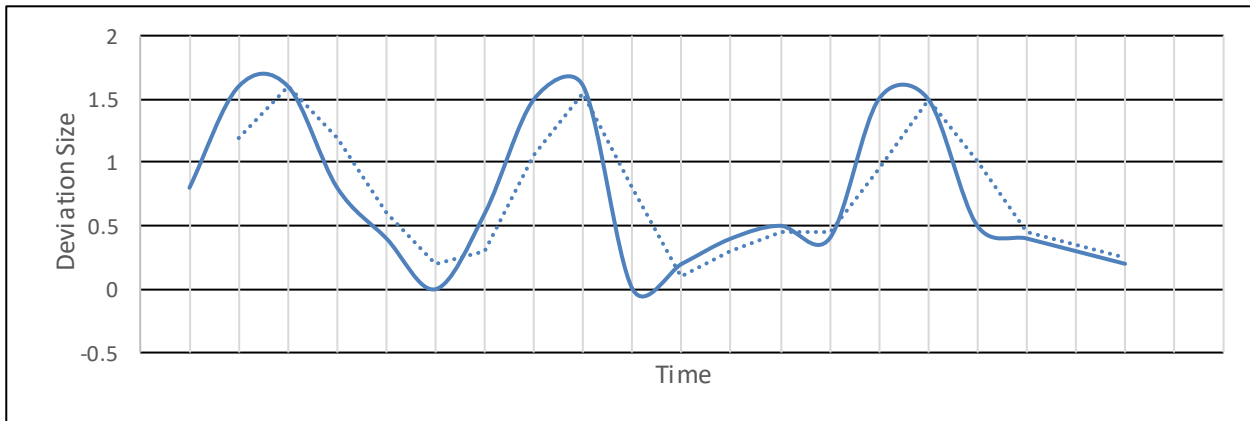


Figure 32 Participant 8 Error and Average Deviation Chart

Participant Questionnaire Data

The importance of scenery realism aspects on the ability to navigate to the various waypoints and the final destination:

- Scale: **0** = Not able to navigate successfully
 1 = Some degree of navigation possible with difficulty
 2 = Reasonable degree of navigation feasible
 3 = Navigation possible with some errors
 4 = Navigation possible with little or negligible errors
 5 = Navigation with high degree of accuracy

	0	1	2	3	4	5
Landmarks						X
Buildings						X
Roads and rivers					X	
Terrain and topography						X

The ability to navigate to the various waypoints and the final destination:

- Scale: **0** = Not able to navigate
 1 = Some degree of navigation possible with difficulty
 2 = Reasonable degree of navigation feasible
 3 = Navigation possible with some errors
 4 = Successful navigation with little or negligible errors
 5 = Successful navigation with high degree of accuracy

0	1	2	3	4	5
				X	

The importance of the following visual realism aspects on the ability to navigate to the various waypoints and the final destination:

Scale: **0** = Not relevant

1 = Successful navigate impossible

2 = Some degree of navigation possible with difficulty

3 = Reasonable degree of navigation feasible

4 = Successful navigation possible with little or negligible errors

5 = Successful navigation with high degree of accuracy

	0	1	2	3	4	5
Screen size						X
Displaying selected instrumentation on screen instead of actual physical instrumentation						X
Utilising multiple displays to represent internal and/or external visuals (scenery)						X
Terrain and topography						X

Effectiveness experienced during the simulator exercise:

Scale: **0** = Not Relevant/Applicable

1 = Not effective

2 = Some degree of effectiveness

3 = Reasonable degree of effectiveness

4 = Effective

5 = Extremely effective

	0	1	2	3	4	5
Visual elements						
Scenery				X		
Screen Size					X	
Screen Brightness					X	
Simulator Controls						
Switches					X	
Flight Yoke and Pedals					X	

5.3.5.4 Overall Conclusions from Data

The FTD simulator configuration with the screen setup and controls from participant 6 and improved scenery levels at maximum default scenery settings indicated that VFR navigation is feasible, but gross errors were still evident.

This participant had a gross error score of 3 compared to the previous participant (4) and lower average deviation score of 14, and the previous participant (14.1). This showed a further improvement in the simulator configuration, but the data and the participant feedback indicated that the configuration was still not at the optimal setting to allow successful navigation using the particular setup/configuration. The flight clearly showed some areas where the limitations are with respect to how effective the configuration of the simulator is to aid successful navigation. To address this the decision was made to increase the scenery level/realism to the absolute maximum level possible with added scenery enhancements to further add realism and detail. (Additional scenery was then installed for the subsequent participants to overlay the default scenery to further increase the realism of the terrain and scenery objects as described in Chapter 2 and illustrated in Figure 53). As with all the previous participants, the anticipated issues of aircraft height, speed and simulator experience were not considered in determining the success of the navigational exercise.

5.3.6 Final FTD Configuration Build F

5.3.6.1 Flight Preparation

The configuration of the FTD simulator for participant 8 was used with no further added scenery enhancements installed on top of the default scenery at maximum setting. This consisted of more detailed utilising satellite imagery with added 3D objects depicting actual scenery as illustrated in Figure 33 below:

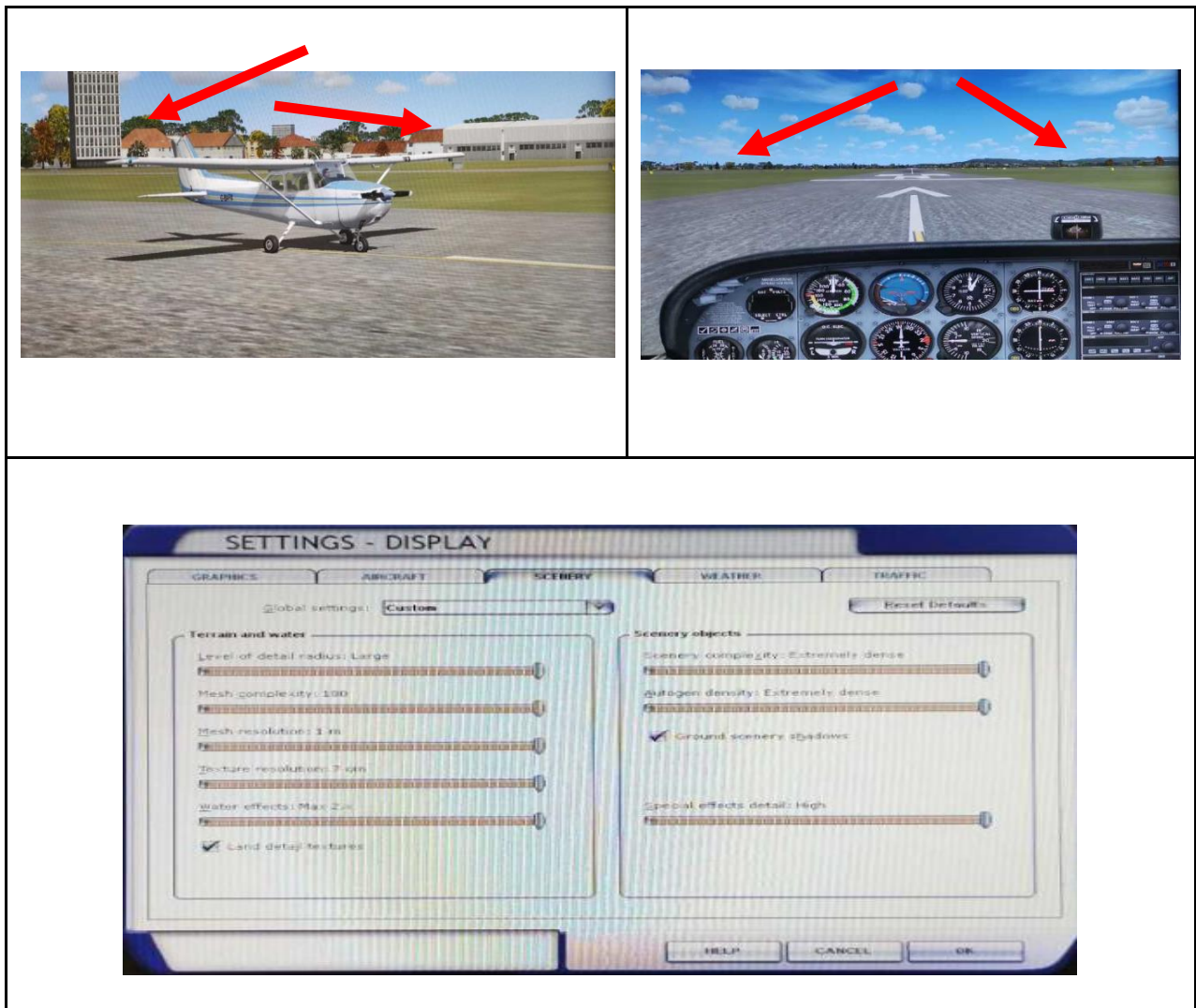


Figure 33 FTD Configuration 6 Build F

5.3.6.2 The Simulation Flight

The initial briefing and theory included a basic understanding of navigation, and how to operate the simulator, including familiarity of the flight simulator and flight controls. This took about 45 minutes in total. The participant flight data is depicted as indicated in Figure 34 which illustrates the following:

- The flight path from start in the top left corner through waypoints WP1 to WP6.
- A Corridor of 3 units to indicate the gross error size.
- The red line representing the actual flight path as flown by the participant.
- The alphabetical sequence indicates the 2-minute intervals used
- The blue line represents the flight direction; and

in Figure 35 the error and average deviation of the participant flight path is illustrated.

This participant, male aged between 30-34, was the first to fly within the desired flight path with zero gross errors. He did deviate but stayed within the corridor as specified throughout the flight. This indicated that the configuration of the FTD may be at the minimum acceptable configuration for successful VFR navigation.

After the completion of the flight, the participant expressed that the simulator felt easy to handle and he felt comfortable with the controls. The flight duration was 33.7 minutes in total, including the pausing of the simulator (6 times in total). The simulator does not record the pauses. The actual flight time was 43 minutes, but the flight can be flown in around 30 - 35 minutes if there are no errors in navigation, depending on airspeed.

Flight data was recorded at 2-minute intervals relative to the desired/expected position. The accepted flight path deviation was set at 1.5 off the course. Aircraft height was not recorded. The flight time was recorded but not considered for data analysis.

The decision was made to make no further adjustments to the FTD configuration, but to validate the data by using a further 3 participants to eliminate individual simulator experience and/or abilities influencing the data.

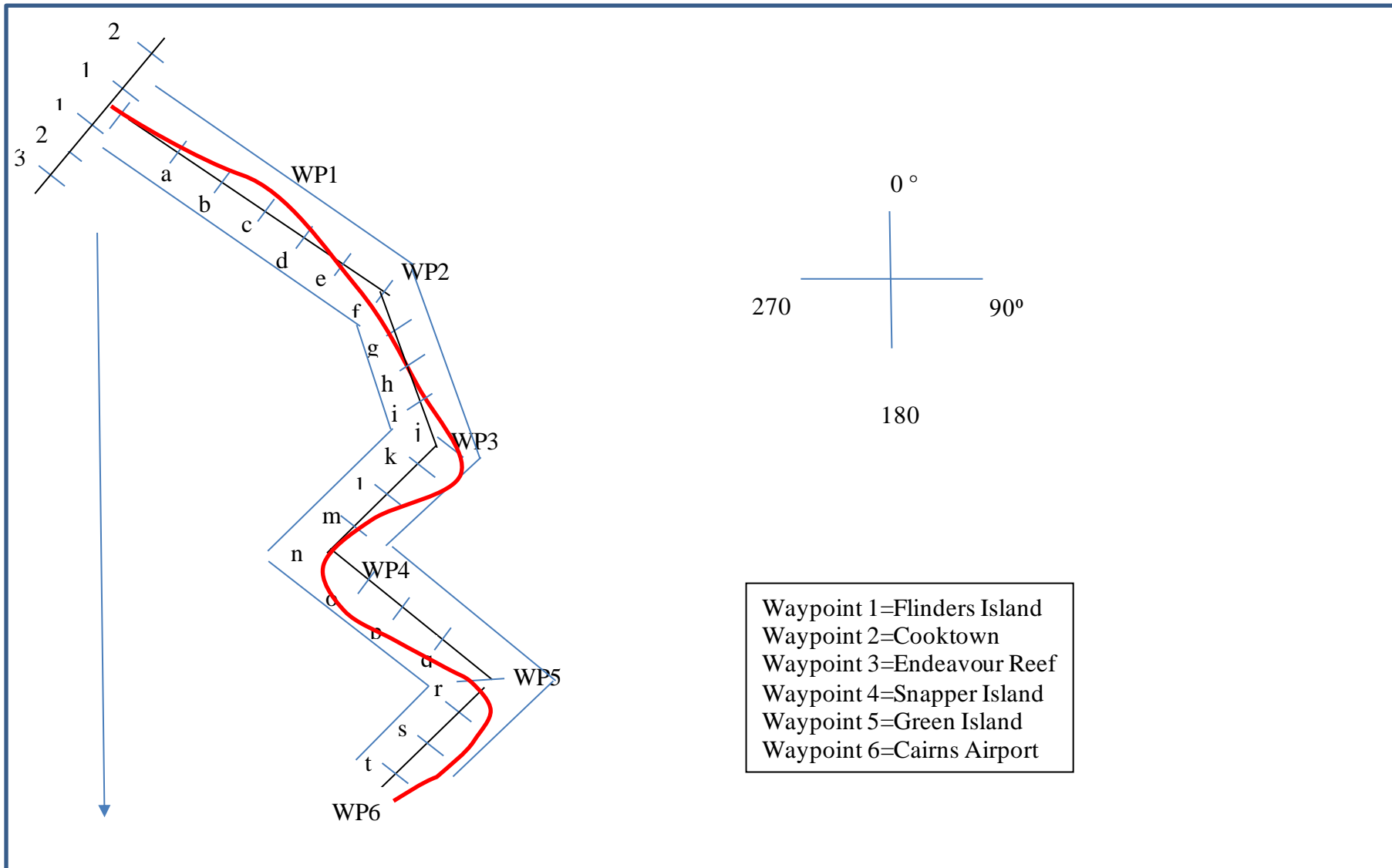


Figure 34 Participant 9 Flight Path

5.3.6.3 Error Measurement

Flight data was recorded at 2-minute intervals relative to the desired/expected position. The accepted flight path deviation was set at 1.5 off the course. Aircraft height was not recorded. The flight time was recorded but not considered for data analysis.

The below table shows the participants' flight data as recorded by the simulator indicating the relationship between the aircraft heading/position and size of deviation off the flight path. Any points where the aircraft position is outside of the acceptable corridor deviation of 1.5 is identified as a Gross Error (GE). The accumulative deviation size is then derived from the sum of the GE numbers.

Heading/Position	Deviation Size	Gross Error = 1
A=110°	0.2	0
B=109°	0.4	0
C=140°	1	0
D=148°	0.4	0
E=146°	0	0
F=148°	0.9	0
G=148°	0.2	0
H=147°	0	0
I=147°	0.2	0
J=150°	1	0
K=210°	1.5	0
L=240°	0.9	0
M=241°	0.1	0
N=181°	0	0
O=145°	0.8	0
P=119°	0.7	0
Q=115°	1	0
R=176°	1.1	0
S=230°	1.3	0
T=235°	0.4	0

Table 10 Participant 9 Error Measurement Data

Accepted Deviation = 1.5

Gross Error Count = 0

Deviation Accumulation Size = 12.1

Figure 35 below shows the participant error size and average deviation from the ideal flight path.

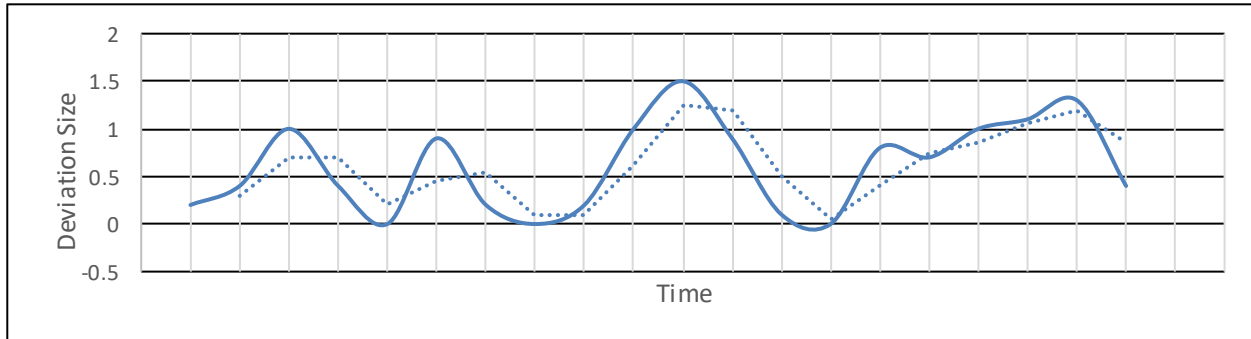


Figure 35 Participant 8 Error and Average Deviation Chart

Participant Questionnaire Data

The importance of scenery realism aspects on the ability to navigate to the various waypoints and the final destination:

- Scale: **0** = Not able to navigate successfully
 1 = Some degree of navigation possible with difficulty
 2 = Reasonable degree of navigation feasible
 3 = Navigation possible with some errors
 4 = Navigation possible with little or negligible errors
 5 = Navigation with high degree of accuracy

	0	1	2	3	4	5
Landmarks						X
Buildings						X
Roads and rivers						X
Terrain and topography						X

The ability to navigate to the various waypoints and the final destination:

- Scale: 0 = Not able to navigate
 1 = Some degree of navigation possible with difficulty
 2 = Reasonable degree of navigation feasible
 3 = Navigation possible with some errors
 4 = Successful navigation with little or negligible errors
 5 = Successful navigation with high degree of accuracy

0	1	2	3	4	5
					X

The importance of the following visual realism aspects on the ability to navigate to the various waypoints and the final destination:

Scale: **0** = Not relevant

1 = Successful navigate impossible

2 = Some degree of navigation possible with difficulty

3 = Reasonable degree of navigation feasible

4 = Successful navigation possible with little or negligible errors

5 = Successful navigation with high degree of accuracy

	0	1	2	3	4	5
Screen size						X
Displaying selected instrumentation on screen instead of actual physical instrumentation						X
Utilising multiple displays to represent internal and/or external visuals (scenery)						X
Terrain and topography						X

Effectiveness experienced during the simulator exercise:

Scale: **0** = Not Relevant/Applicable

1 = Not effective

2 = Some degree of effectiveness

3 = Reasonable degree of effectiveness

4 = Effective

5 = Extremely effective

	0	1	2	3	4	5
Visual elements						
Scenery					X	
Screen Size					X	
Screen Brightness					X	
Simulator Controls						
Switches					X	
Flight Yoke and Pedals					X	

5.3.6.4 Overall Conclusions from Data

This FTD configuration was the first to have zero gross errors. The flight path was still not 100% accurate, but this participant managed to stay within the accepted deviation parameter of 1.5.

This participant had a gross error score of 0 compared to the previous participant (3) and lower average deviation score (12.1) and the previous participant (14.1). This was first configuration that produced zero gross errors, and the average deviation score was within the accepted parameters as specified. Therefore, the conclusion was made that this configuration was the minimum required for successful VFR navigation for this type of FTD. The argument would of course be made that this configuration is not the *optimal* configuration, as further improvements can be made from this point to further reduce the deviation from the required flight path with the potential to eventually reach a much more accurate flight path with less deviation.

However, further exploration would inevitably require further investment in hardware components, additional peripherals and software, as well as additional test subjects for the testing. For this study the specific required parameter requirements were met, and the method for reaching the minimum effective configuration for successful navigation proved successful. Therefore, for the purposes of *this* study no further potential configuration improvements were explored, but the configuration could be used as starting point for such further research in the field.

As with all the previous participants, the anticipated issues of aircraft height, speed and simulator experience were not considered in determining the success of the navigational exercise.

5.3.7 Optimal Configuration Validation Tests

5.3.7.1 Flight Preparation

To assess and confirm that the FTD configuration setup is optimally configured, the exercise was repeated with a further 3 participants using the exact same method as before, but with the flight reversed. Using Configuration 9. No further adjustments were made to the simulator or exercise.

5.3.7.2 The Simulation Flights

The initial briefing and theory included a basic understanding of navigation, and how to operate the simulator, including familiarity of the flight simulator and flight controls. This took about 48 minutes to 1 hour in total. The participants flight data is depicted as indicated in Figure 36 which illustrates the following:

- The flight path from start in the top left corner through waypoints WP1 to WP6.
- A Corridor of 3 units to indicate the gross error size.
- The red line representing the actual flight path as flown by the participant.
- The alphabetical sequence indicates the 2-minute intervals used.
- The blue line represents the flight direction; and

in Figure 37 the error and average deviation of the participant flight path is illustrated.

Flight data was recorded at 2-minute intervals relative to the desired/expected position. The accepted flight path deviation was set at 1.5 off the course. Aircraft height was not recorded. The flight time was recorded but not considered for data analysis.

During the flights none of the participants (1 male, aged 24, 1 male aged 56, 1 female aged 36) went outside the accepted navigation corridor, although none of the participants were able to

replicate the ideal flight path 100%. This could be attributed to the participants experience level, but in reality, it is rare for any pilot to stay 100% on track flying manually without the aid of an autopilot.

There were no major issues with any of the 3 participants observed in their ability to navigate the waypoints successfully. No major errors were recorded on the flight data. (Refer to Figure 10)

5.3.7.3 Error Measurement

Flight data was recorded at 2-minute intervals relative to the desired/expected position. The accepted flight path deviation was set at 1.5 off the course. Aircraft height was not recorded. The flight time was recorded but not considered for data analysis.

The below table shows the participants' flight data as recorded by the simulator indicating the relationship between the aircraft heading/position and size of deviation off the flight path. Any points where the aircraft position is outside of the acceptable corridor deviation of 1.5 is identified a Gross Error (GE). The accumulative deviation size is then derived from the sum of the GE numbers.

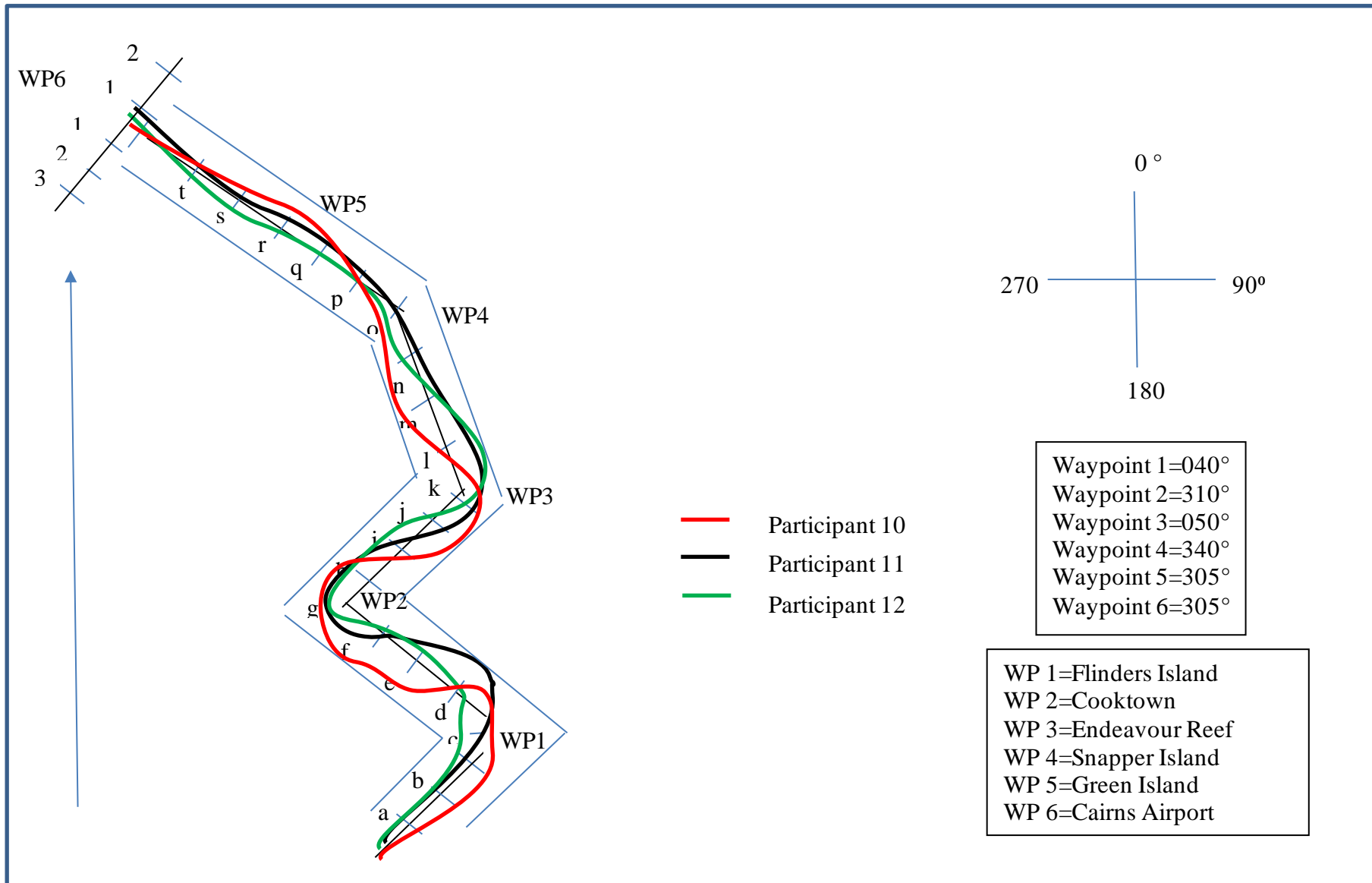


Figure 36 Participants 10-12 Flight Path

Optimal Summary Test Flight Data

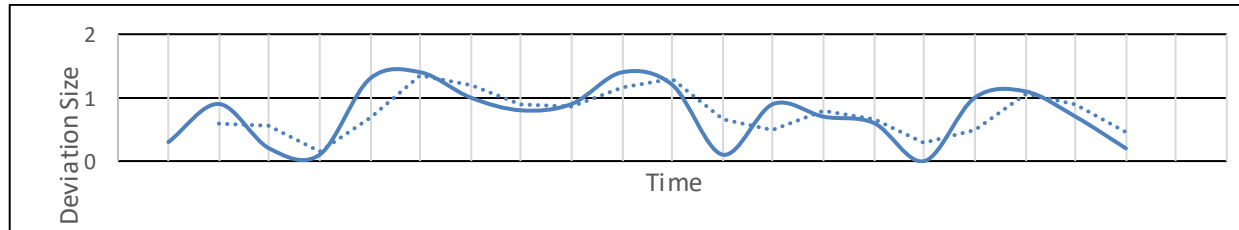
Heading/Position			Deviation Size			Gross Errors		
Participant 10	Participant 11	Participant 12	Participant 10	Participant 11	Participant 12	Participant 10	Participant 11	Participant 12
A=065 ⁰	A=041 ⁰	A=047 ⁰	0.3	0	0	0	0	0
B=056 ⁰	B=040 ⁰	B=047 ⁰	0.9	0	0	0	0	0
C=005 ⁰	C=001 ⁰	C=030 ⁰	0.2	0.2	1	0	0	0
D=270 ⁰	D=317 ⁰	D=0 ⁰	0.1	1.5	0.1	0	0	0
E=304 ⁰	E=305 ⁰	E=287 ⁰	1.3	1	0.2	0	0	0
F=320 ⁰	F=290 ⁰	F=269 ⁰	1.4	0.1	0.1	0	0	0
G=001 ⁰	G=011 ⁰	G=015 ⁰	1	1	0.9	0	0	0
H=085 ⁰	H=050 ⁰	H=050 ⁰	0.8	1.1	1	0	0	0
I=085 ⁰	I=050 ⁰	I=077 ⁰	0.9	0.3	0.9	0	0	0
J=085 ⁰	J=080 ⁰	J=079 ⁰	1.4	0.3	0.1	0	0	0
K=315 ⁰	K=020 ⁰	K=001 ⁰	1.2	1	0.2	0	0	0
L=315 ⁰	L=316 ⁰	L=330 ⁰	0.1	1.1	0.8	0	0	0
M=325 ⁰	M=316 ⁰	M=333 ⁰	0.9	0.2	0.2	0	0	0
N=346 ⁰	N=333 ⁰	N=332 ⁰	0.7	0.2	0	0	0	0
O=335 ⁰	O=340 ⁰	O=320 ⁰	0.6	0	0.3	0	0	0
P=323 ⁰	P=305 ⁰	P=310 ⁰	0	0.2	0	0	0	0
Q=320	Q=305	Q=306	1	0.2	0.3	0	0	0
R=294	R=290	R=290	1.1	0.2	0.1	0	0	0
S=299	S=305	S=309	0.7	0	0.2	0	0	0
T=300	T=316	T=310	0.2	0.1	0.1	0	0	0

Table 11 Participant 10 Error Measurement Data

Figure 37 below shows the participant error size and average deviation from the ideal flight path.

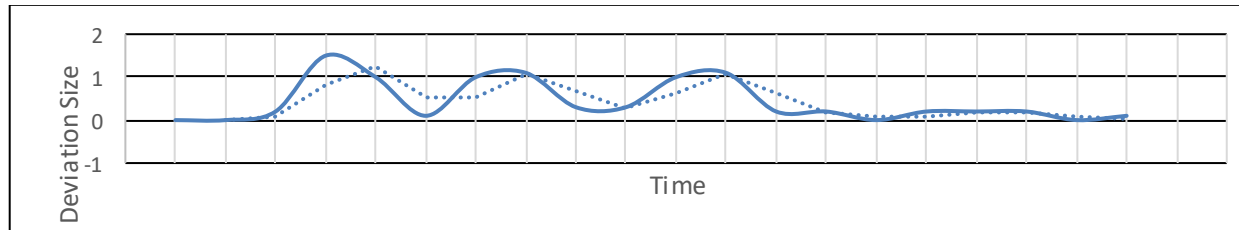
Participant 10

Accepted Deviation Size = 1.5 Accumulated Deviation Size =14.8 Gross Error Count = 0



Participant 11

Accepted Deviation = 1.5 Accumulated Deviation Size =8.7 Gross Error Count = 0



Participant 12

Accepted Deviation = 1.5 Accumulated Deviation Size =6.5 Gross Error Count = 0

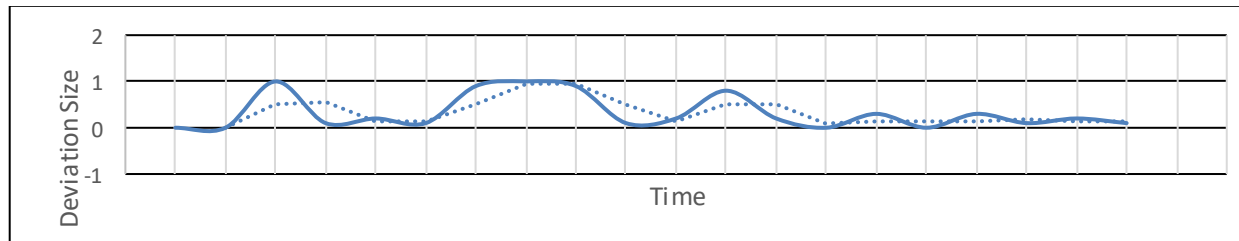


Figure 37 Participants 10-12 Error and Average Deviation Charts

5.4 Conclusion

This chapter discussed the process for determining the FTD configuration for successful VFR navigation using Design Science and applying the error measurement method as described earlier. In the next Chapter, the FDT simulator configuration process will be critically assessed and analysed with reference to relevant literature.

CHAPTER 6

SIMULATOR CONFIGURATION PROCESS

6.1 Introduction

This chapter answers research question 3 what the minimum Flight Training Device configuration is required for successful VFR navigation and describes the process of determining the configuration of a wider range of simulators than a FTD in 2 Phases, and as is illustrated in Figure 4, para 6.4.

6.2 Phase 1: Exploration

This study presents an error identification model method based on gross error calculation by using a significant smaller data sample set instead of a large data set requiring utilising patterns of small errors to indicate configuration efficiency, therefore minimising the number of participants needed to configure a simulator, resulting in a potentially more time efficient and cost-effective simulator design process.

Step 1: (Determine Learning Objective). During this step it is important to be clear on what the Learning Objective (s) are. This has to be determined and clarified before building the simulator to determine the Learning Objective requirements, it is advisable and important to consider relevant literature and industry requirements in the field. The Learning Objective needs to be specified before the process of configuring the FTD simulator and should not be changed after the configuration process has begun. If it is found that the configuration cannot be successfully achieved because the Learning Objective is not accurate or correct, then the configuration process should be stopped, and the Learning Objective revised before restarting the configuration process.

To correctly specify the Learning objective, Bloom's taxonomy (Bloom et al., (1956) can serve as a valuable tool in helping instructors think through their choices for both parts of the learning objective. By applying the 6 categories of Bloom's Taxonomy of Remembering, Understanding, Analysing, Evaluating and Creating, instructors would be better able to identify the required Learning Objectives. To assist further in determining the required Learning Objectives, (Anderson et al., 2001), revised the taxonomy of Bloom and specified 4 knowledge categories: Factual, Conceptual, Procedural and Metacognitive.

Krathwohl (2002) simplified the original Taxonomy of Bloom as a two-dimensional framework with Knowledge and Cognitive Processes, where Knowledge resemble the original Knowledge category, and the Cognitive Process resemble the six categories of the original Taxonomy with the Knowledge category (Remember), the Comprehension category (Understand), and Synthesis renamed Create, with the remaining categories changed to their verb forms: Apply, Analyse, and Evaluate. The Learning Objective for this study was determined on the basis of Bloom's Taxonomy, specifically the Procedural, Conceptual, Factual and Metacognitive aspects where the participants had to understand the navigational concepts through facts and then cognitively apply navigation procedures to complete the navigation flight path.

This combination should assist in determining the parameters required for the simulator configuration which can be tested by doing a pilot study to validate the simulator configuration requirements, and minimum initial Build to be used for Phase 2 in the actual Design Science process as presented in this study.

However, it is also important to recognise that the Learning Objectives need to recognise and consider individual differences as these differences could impact on the validity of the data collected during the configuration process. Each time the FTD simulator configuration is changed, the assumption can be made that the changes will be to the benefit of everybody, so if an individual performs poorly on a particular configuration, it is useful - before dismissing the configuration as ineffective - to consider if there are any individual factors affecting the data (E.g.: Age, gender, etc). The key issue here is to ensure that any configuration changes that are made is ultimately to the benefit of all and not just tailored to individuals.

Step 2: (Identify Error Measurement). Identifying the error measurement method and tolerances for identifying errors and accurate error measurement is crucial in determining successful FDT simulator configuration. The question therefore is raised as to how you know if the error measurement model works correctly to suit the purpose of the Learning Objective(s). To understand the importance and relevance of establishing an accurate error measurement method, the relevance of an appropriate pedagogical approach as described in Chapter 3 needs to be considered and an appropriate learning model determined. To address this, a combination of industry knowledge and experience can guide the initial starting base level configuration *before* the start of the FTD configuration process.

However, it will probably difficult to actually *know* if the error measurement method is correct until *after* the configuration process has started, but as a general guide any requirements and tolerances as set by industry standards or tolerances as set by standards would assist in determining the error measurement parameters.

In this study the general accepted industry practise was applied to set the allowable tolerance before counting as a navigation error as specified by CASA (2012) as follows:

- (a) a lateral navigational error of at least 5 NM;
- (b) a longitudinal navigational error of at least 5 NM;
- (c) a longitudinal navigational error of at least 3 minutes variation between the aircraft's estimated time of arrival at a reporting point and its actual time of arrival.

Grishin, (2018) presented a mathematical equation for identifying navigation errors whilst visually navigating shorelines and derives from the probability estimation of the error for calculating overall error size. This approach was not appropriate for this study for the following 2 reasons:

1. The intent was to find an easier approach to calculate navigation errors that is not based on error estimation; and
2. Mathematical probability calculations to determine error size was not useful to determine FTD simulator configuration.

However, the approach from Grishin would be good for potentially embedding in aircraft onboard navigation software to calculate and predict navigation errors. Therefore, for this study, a positive progression resulting from changes to the FTD simulator from one configuration to the next would indicate that the error measurement is sensitive/accurate enough – indicating an accurate error correction method of a systematic error as defined by Mazzei et al. (2014) in Chapter 5. Conversely, if there is no noticeable improvement and the same types of errors are being made during the use of the FTD simulator, then this would indicate that the error measurement method is not correct, the parameters set are not sensitive enough, or the participant individual characteristics are substantially different from the previous participant.

However, once it is determined that the error measurement method is correct, then it is important to keep the error measurement method throughout the FTD simulator configuration process and not change the parameters to validate the data. Once the FTD simulator is successfully configured, the error measurement method could then be used for actual assessment purposes (E.g.: to increase or decrease the tolerances for identifying errors.) This error measurement method could be applied to any simulator where data sets can be used against a baseline data set to determine an acceptable range of errors, as well as the gross errors to indicate effective simulator configuration.

Step 3: (Identify Configurable Hardware and Software): During this step the focus is to identify relevant configurable items (hardware and software), as well as the required in-depth knowledge of the simulator function.

Step 4: (Identify Acceptance Criteria): The acceptance criteria for meeting the required learning objective (s) are to be determined in this step. Each identified task will most likely have a different or specific purpose, therefore requiring different acceptance criteria to meet the learning outcome (s). The acceptance criteria will justify each step of the configuration process, drawing on existing knowledge. This involves the following:

- The ability to be used for meeting the learning objective,
- Validating the configuration; and
- Used to explain why each step is required drawing on existing knowledge and literature.

For this thesis, successfully navigating a flight path using waypoints was required, and only the navigation behaviour from the taxonomy of Barker (2018) of following fixed location instructions as described in Chapter 5 was used as a combination of information, received from both the internal aspects of the participant and the outside simulation environment.

This is because, in this instance, the flight path and waypoint information given to the participants was given by the researcher. Therefore, the participants did not provide the person source of information as identified by Barker.

Step 5: (Complete a Pilot trial) A rough pilot trial is to be completed in this step to determine the initial simulator configuration for the Design Science process to determine the final configuration build. As discussed in earlier chapters, research does not always require the use of a pilot trial even though it is commonplace for pilot trials to be conducted as an acceptable research approach to determine a solution that can be tested on many individuals, as is shown in the N-of-1 medical trials as described in the Introduction on p43 in Chapter 3. However, in contrast to the commonplace use of trials such as the n-of-1 trials, it is important to note that for this study it was necessary to use a pilot trial to only establish a baseline starting point for the FTD configuration process.

The participants used in the pilot study identified significant issues that needed to be changed (flight controls and minimum screen and software levels) to determine a workable configuration for Build 1 so that the remainder of the FTD configuration process could focus on navigation as that was the Learning Objective. In this study each participant did a mini research control trial, and the N-of-1 method could not be applied in its entirety since it was not possible to utilise control groups and pit hundreds of participants to demonstrate validation as the purpose of this process was to find a suitable configuration with the most efficient process utilising the smallest Build count possible.

6.3 Phase 2: Configuration

Step 6: (FTD Configuration). Recalibrate/reconfigure each build until an acceptable configuration is found. The approach from Khambete (2019) of application to practice by gaining data from experiments and other forms of data collection and measurement instruments such as surveys, modes (e.g. immersive observation, protocol analysis and participatory design was used in this Step to assess each build and backed by ancillary literature (e.g. CASA PPL navigation requirements) to define the aspects that indicate competent application of the methodology. The targeted evidence of successful configuration was based on systematic use of the data collection, analysis, simulator raw data, and factored in the forced exclusions (e.g. excluded variables, or real-life contexts and conditions), limitations of the research setup and setting in accordance with the Design Science approach from Khambete.

The N-of-1 approach was considered not to be appropriate even though N-of-1 trials are routinely used in education and learning settings Guyatt et al. (1990), and often in behavioural and psychological assessment settings. This is because that the N-of-1 method uses 1 person for the entire duration of the study, and this research required different participants to be used for each Build of the FDT simulator. Repeated use of the same participant would have resulted in gaining experience and familiarity of the navigation route that would inevitably reduce the ability to effectively evaluate the configuration accuracy to meet the Learning Objective by influencing the data. Furthermore, the N-of-1 trials requires that the results be repeated for many individuals to determine validation in medical terms, whereas in the context of the VFR FTD simulator the aim was to complete the configuration iterations with as few Builds as possible - therefore requiring the smallest number of participants possible.

6.4 Navigation FTD simulator Configuration Process

Figure 38 below presents the process for configuring the FTD simulator for this thesis:

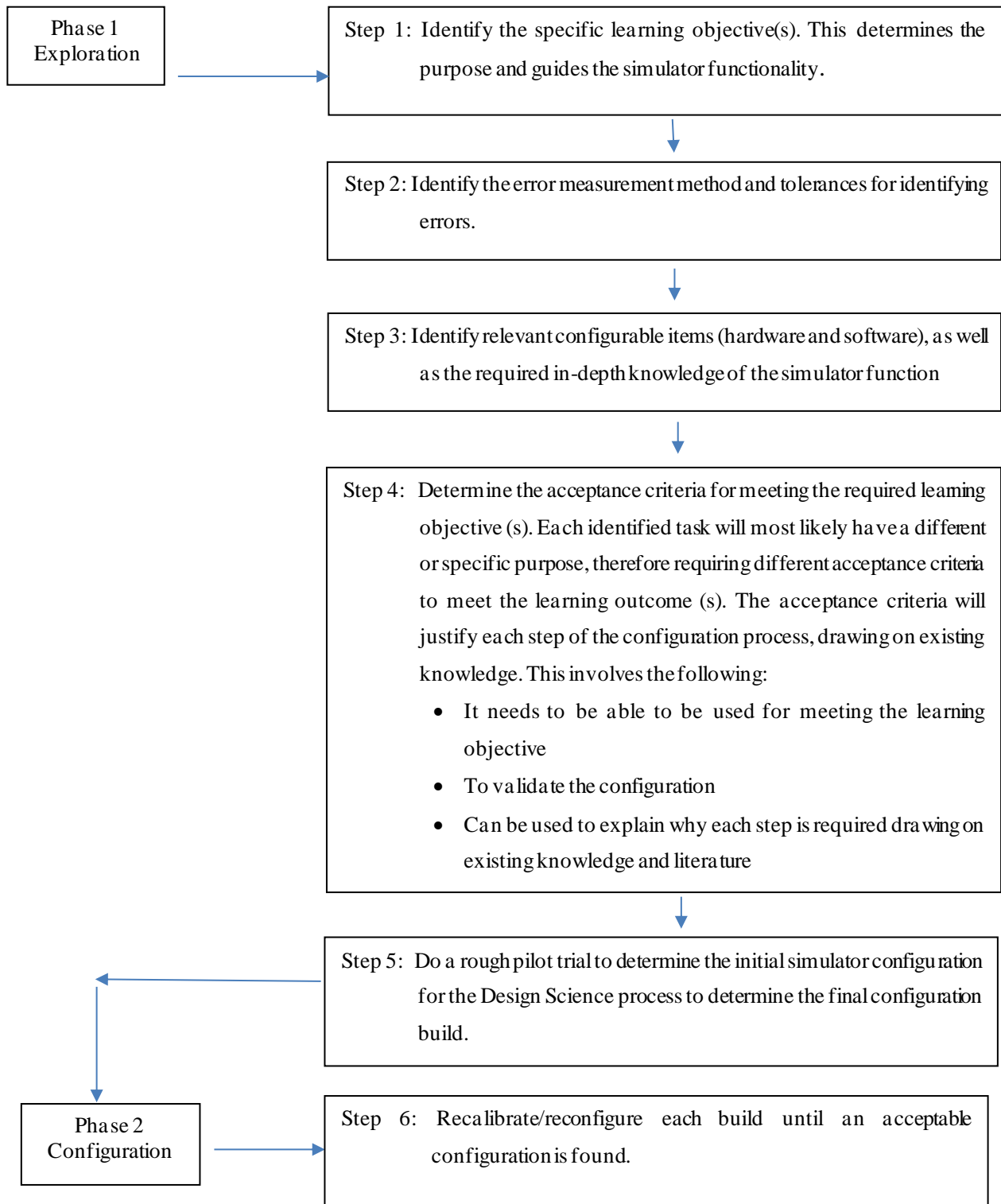


Figure 38 Process for Configuring Navigation FTD

6.5 Conclusion

This chapter discussed the minimum Flight Training Device configuration required for successful VFR navigation and described the process of determining the configuration described the process of determining the configuration of an FTD simulator for a FTD simulator suitable for navigation for a PPL licence.

However, this method could be used for different Learning Objectives with aviation by changing the Learning Objective and reconfiguring the simulator. The potential also exists to extend this method to a wider range of other types of simulators.

In the next Chapter, final conclusions and recommendations are identified.

CHAPTER 7

CONCLUSION AND RECOMMENDATIONS

7.1 Introduction

This chapter answer research question 3 what the minimum Flight Training Device configuration is required for successful VFR navigation and discusses the contribution this thesis makes in the field, the originality, significance and potential future research areas.

7.2 Overall Conclusions from the data collected

The final FTD configuration data from the final 3 participants validated the data from the configuration for participant 9 as none of the participant flight paths showed any gross errors. It is to be noted that none of the participants managed to accurately fly the desired flight path, but in an actual aircraft there is an allowance for small variances during flight to allow for factors such as wind drift and weather as long as the aircraft stay within the flight path corridor and the waypoint is reached. In an actual flight the flight path results from these participants would be considered acceptable and accurate enough for successful VFR navigation.

The results indicated that the error measurement as applied was sufficient to show the performance variations between the simulator configurations and ability to successfully navigate. The data sets showed areas with the limitations with respect to how effective the configuration of the simulator is to aid successful navigation, and the simulator configuration clearly impacted on the participants' ability to navigate to the various waypoints. The number of gross errors showed this association clearly. The allowed corridor of the ideal flight path allowed for an error deviation of up to 1.5 on the modified KS-test. Any number above that number was considered a gross error. The amount of gross errors and the size of the error was indicative of the simulator configuration. From this result

adjustments to the simulator setup/configuration were made to address the issues highlighted by the participant and the flight data, with the end result a more optimal configuration to improve navigation.

The results showed that overall the participant performed better with the maximum configuration, with the use of a single 1 x screen unacceptable as the outside field of view was too restrictive to facilitate effective VFR navigation for the participants. Only when the 3-x configuration and 4 x screen configuration were added with accurate visual terrain details and landmarks added did the participants manage to comfortably navigate successfully. The flight controls sensitivity configuration had to be adjusted to facilitate effective flight control. There was a clear correlation between the number of monitors and level of visual detail in the simulator and the gross errors up to a certain point, after which there was no significant improvement in the navigation. It is to be assumed that any further improvement in simulator configuration (I.e. larger monitor or more expensive flight controls) would not justify the extra simulator configuration cost in relation to ability to navigate with the simulator.

It is to be noted that the data showed an interesting phenomenon insofar as the correlation between deviation accumulation size and gross errors were not consistent. Some participants had a higher deviation accumulation size, but a lower gross error total. Since the ultimate criteria for the configuration as based on gross error – and not deviation accumulation size – the gross error indication implied a better configuration even though the deviation accumulation size was larger. As with all the previous participants, the anticipated issues of aircraft height, speed and simulator experience were not considered in determining the success of the navigational exercise. Therefore, the final configuration for this FTD could be considered acceptable as a *minimum* configuration for a FTD navigation simulator.

7.3 Contribution

a. Process: This study utilised the use of Design Science applied to identify a method for configuring a FTD simulator suitable for successful VFR navigation. Design Science offers a unique and efficient method of going through a step-by-step process to create an initial build for the FTD, followed by a process of evaluation of the build through testing, and utilising the results to configure the next build, following the same process until a final build is determined that meets the predetermined FTD requirements as illustrated in Figure 39.

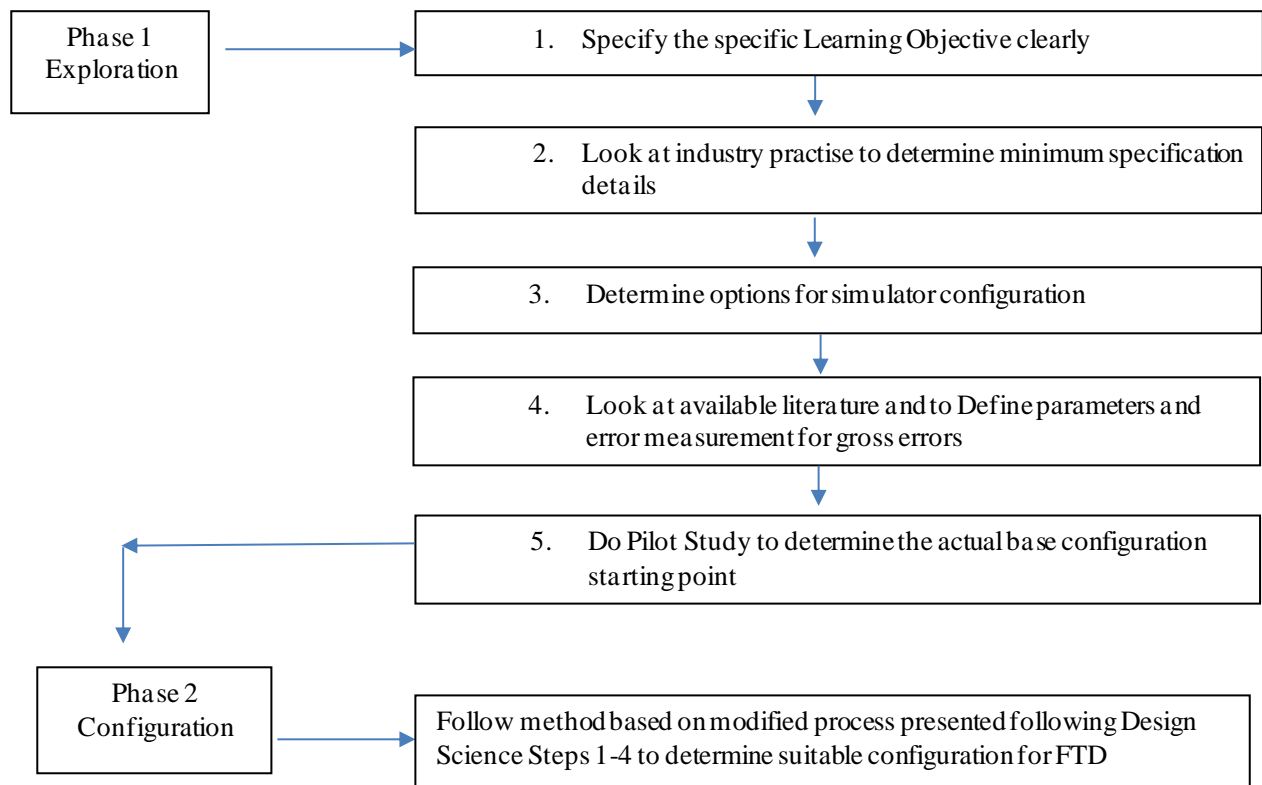


Figure 39 Process for Configuring a FTD Simulator

During Phase 1 it is important to be clear on what the Learning Objective is. This has to be determined and clarified before building the simulator to determine the Learning Objective requirements it is advisable and important to consider relevant literature and industry requirements in the field. This combination should assist in determining the parameters required for the simulator configuration which can be tested by doing a pilot study to validate the simulator

configuration requirements, and minimum initial Build to be used for Phase 2 in the actual Design Science process as was followed in this thesis.

- b. *Error Measurement:*** This study presents an error identification theory based on gross error calculation by using a significant smaller data sample set instead of a large data set requiring utilising patterns of small errors to indicate configuration efficiency, therefore minimising the number of participants needed to configure a simulator, resulting in a potentially more time efficient and cost-effective simulator design process.
- c. *FTD navigation simulator configuration:*** This study presents a FTD configuration suitable for VFR navigation. By using simulation-based learning, the required VFR navigation pilot skills require, could potentially be transferred onto real environments without the associated risks at an earlier stage of pilot training to enhance piloting skills. By considering the cockpit configuration when introducing new technologies in aircraft, this may result in improving the impact in the relationship between fidelity and the effectiveness of training simulators for pilot training. Making use of technological improvements and/or enhancements that could be configured in a simulation to improve pilot proficiency, it would be beneficial to the shift in focus of general pilot training within the current pilot training focus. Simulation-based training and associated assessment would be therefore beneficial in assisting in pilot training by utilising new technologies and training methods within simulators.

The final configuration is as follows:

Component	Minimum system requirement
Operating system	Windows XP Service Pack 2 (SP2)
Computer processor	Intel Pentium 3.0 gigahertz (GHz)
Memory	1 gigabyte (GB) RAM
Hard disk space	4 gigabytes (GB) available hard disk space
Video card	DirectX 9 (or later version)-compatible video card
	128 MB or more video RAM, Shader Model 1.1 or later version
DVD drive	32x speed
Sound	Soundblaster X Sound Card speakers/ headset
Pointing device	Keyboard and mouse
Internet connection	Broadband Internet access for Windows Live multiplayer gameplay Network adapter for software updates Broadband Internet access for Windows Live
Monitors	4 x 22" Monitors or 1 equivalent wide inch monitor
Additional Hardware Components	
Triple Head To Go 3 Monitor expansion box for 3 22" monitors. (If 1 equivalent monitor is used then not required)	
Flight Yoke USB	
Flight Pedals USB	
Throttle Controls USB	
Engine start-up controls USB	
Analogue or Glass cockpit instrument layout	
Microsoft Windows X	
Microsoft Flight Simulator X or Microsoft Flight Simulator 2020 (Maximum scenery settings)	
Scenery Add-on software: VFR Scenery Australia, Orbix FTX Global Scenery, Flight Environment X	

Table 11 FinalFTDComputer Configuration

7.4 Originality

From the literature review a gap was identified where there is a need for research in the utilisation of low-end, low cost flight simulator FTD in general Private Pilot training where personal computers have not had formal impact on the training of general aviation pilots, and specifically in the area of VFR navigation. This study attempted to contribute in this area by offering an innovative method for finding a suitable configuration for such a device.

7.5 Significance

This study attempted to offer an innovative process and method for configuring a FTD for successful VFR navigation, offering data that can be used as a basis for improving the process of configuring such a device.

The process presented in this study is an initial step in finding a suitable configuration for a low-end simulator which can be adapted for various other types of training simulators. The process aims to be flexible enough to adapt to various learning outcomes depending on the training purpose. However, a baseline configuration is required as starting point before a suitable configuration process can be attempted, and in order to determine the baseline configuration, a clear understanding of the learning outcome(s) is required.

Future research aims to extend to include navigation in different types of navigation spaces, including road navigation, and even in the area of air traffic control training, where air traffic controllers need to learn how to control and navigate aircraft in specific airspace corridors. If the adoption of new technologies emerging around simulation becomes more mainstream, the impact of configuring such devices for training in different environments become more important.

This research has the potential to contribute in the field of Virtual Reality simulation training in various fields not limited to just Navigation as discussed in Chapter 1, para 1.6.1, and para 7.6 below.

7.6 Future Research Opportunities

As a result of the findings from this study there are potential research opportunities that could be explored further in this field. The use of high-end virtual reality platforms offers research opportunities for the training of pilots where this study could be further extended:

1. The effectiveness of a FTD which has been configured using the method of this study could be verified by approved full simulators to expand to other areas in aviation beyond VFR navigation, for example research and development being undertaken by Boeing Australia at Brisbane Airport in building Virtual Reality flight simulators for the Cessna 172 and Boeing 737 aircraft, and new Part Task Simulators being incorporated at the RAAF for the new PC-21 training aircraft.
2. This study was applied to the field of aviation, but the exploration of the configuration of different types of other simulators is possible using this method but enhancing learning and teaching in other fields of simulation is also important as identified by Rewiti et al. (2017). Therefore, the configuration of different types of non-aviation simulators could potentially benefit from this study, in particular Part Task Trainers and other training devices. This includes exploring the use of simulators utilising various types of platforms such as PC, IOS and Android Tablet, Virtual Reality, PlayStation, Xbox, etc.
3. The results from this study may be useful for further research exploring opportunities in utilising and/or adapting the simulator configuration process in the use of software design and development separate from simulation. In this regard the various life cycle processes of designing a software build (Alpha, Beta, etc.) where each build is tested, errors identified, and changes are addressed before the subsequent builds until a suitable final software version is released.

7.7 Conclusion

This chapter identified the minimum Flight Training Device configuration required for successful VFR navigation, and discussed the contribution this thesis makes in the field, the originality, significance and potential future research areas.

Flight Simulator Relevance to Real Aviation

Jacobs (2005) stated that a “flight simulator with a few add-ons available from the many third-party designers, should be capable of giving a pilot familiarity with operations and familiarization towards a private pilot’s license.” To enhance the default commercially available flight simulator software, third party software applications are available to assist Student Pilots in many areas of aviation, and in Australia software for Visual Flight Rules (VFR) and Night Aeronautical Instrument Planning Systems has been developed by various commercial software developers such as Aerosoft Australia. (CarpAir, 2003). An example of such software has been developed by Getmapping and is used by professional flight simulation organizations such as QinetiQ and BAE Systems. The scenery enhancement software is “designed to give simulation pilots the same views from the virtual cockpit that real pilots enjoy in flight, allowing accurate VFR Navigation over realistic and recognisable terrain.” (Davis, 2004, p24)

There appears to be anecdotal evidence from flying schools that the physical and visual deficiencies of flight simulation could hinder training, and a person with thousands of hours of simulation time but no real-world time would not be able to claim to have real piloting skills. This perception is further enhanced with reliance only on flight simulation having the potential to learn bad habits, and it can be challenging to overcome these habits in the real-world cockpit.

In contrast Binder (2005) stated that “today Flight Simulator is being used by the United States Navy to train pilots. As part of Career Pilot Program at the Flight Safety International Academy in Vero Beach, Florida, students are required to complete 27 hours of instruction in a Microsoft Flight Simulator lab. The students work under direct supervision of Flight Safety Instructors to practice running checklists, following ATC clearances, performing basic manoeuvres, and improving IFR skills.” (p18) The results from Taylor et al. (2005) stated that the time to successful completion of a specific criterion was less for students using an FTD than for students who only trained in an aircraft. Their research proved that approximately 50% flying hours saving could be gained for cross-country flights by using a FTD. Further to this, research shows that positive transfer does occur from PC-based flight simulators. (Norman & Grierson, 2012). The research determined that flight skills acquired on PC-based systems successfully transferred to actual flying by using a candidate to simulate a flight and then fly the actual route afterwards. Specifically, the student was able to successfully navigate without assistance. (FAA, 1994). (Dennis & Harris, 1998) researched the benefits and advantages

of computer-based simulation as an adjunct to flight training and stated that reducing the cost of training is constantly being sought.

Therefore, a quantitative, predictive relationship between simulator fidelity and training effectiveness needs to be established. (Estock et al, 2006) identified a scientific, quantitative approach using the RELATE model. This is manifested in the simulator design and associated simulator configuration. They suggest that training effectiveness is influenced by three primary determinants:

- The training program itself (i.e. the material)
- The trainee (Characteristics and attitudes)
- The situational context in which the training takes place. (The equipment: simulator) This thesis focussed specifically on this issue.

One of the reasons for the lack of utilisation of FTD simulators is the impact of hardware limitations on flight realism.

The identified limitations of low-end desktop simulators are:

- Limited field of view: This relates to the amount of the outside world is visible within the simulator. This is usually measured in ° (Eg: 180°, 270°, 360°)
- The absence of vestibular cues and aerodynamic forces: This relates to physical cues of movement and G-forces
- The potential negative impact of low frame-rates: This relates to the rate at which the simulator processor can generate the graphical images on the screen. The slower the processor the less smoothly the simulator performs. (Drake, 1995)

Microsoft's Geographical terrain and land-object system

It is important to understand the relevance of how the simulator software can recreate the actual world environment to facilitate VFR flight representing actual real-world environments. Gaining an understanding of the technologies will assist in the configuration process, specifically knowing what parameter variables to configure.

In 1975 a computer software programmer Bruce Artwick showed that a personal computer processor was able to handle both the arithmetic and graphic display required for real-time flight simulation. This was effectively the first flight simulator created for the personal computer and proved to be the basis for the development of flight simulator software to today.

The scenery within Microsoft Flight Simulator is constructed upon a basic mesh grid that represents the height of the ground at any point in the world. This provides the 3-dimensional relief model on which all other scenery objects and ground textures are placed as layers.

Microsoft has created this layering system to render the default scenery and terrain. According to GesmbH (2004), to understand Flight Simulator scenery, one can split the scenery into five levels or categories as follows:

"Colour" or Land-class Scenery



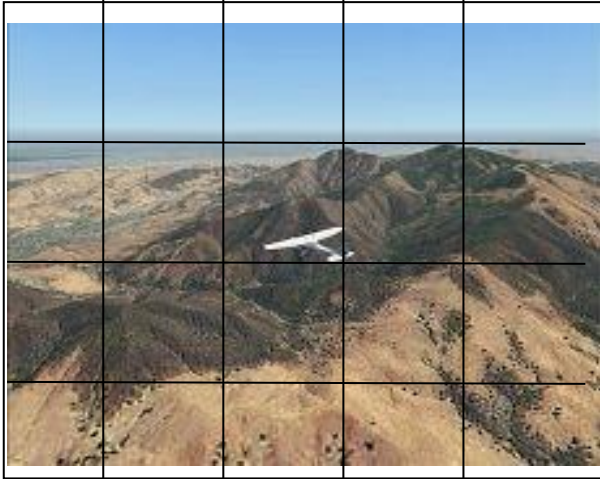
Initially the parameters differentiating the land and ocean areas are identified on a flat surface. This layer includes the data elevation model (DEM) with altitude data. (Figure 1)

Figure 1 Data Elevation Model (Land-class layer)

This scenery layer defines what each cell of the grid looks like as depicted in Figure 2. Microsoft Flight Simulator uses this information to load textures and to generate the generic scenery such as trees and buildings.

"Shape" or Elevation Mesh

This scenery layer defines the elevation of each point of a grid (or mesh), indicating how the surface and shape of the earth is defined. On top of this layer the geographical data gained from satellite imagery is placed, determining the topographical shapes and dimensions of the land areas.



The result is a 3-dimensional map created with shaped terrain containing hills, valleys, riverbeds, as shown in Figure 2.

This grid is then rendered with the image files into a mesh for ground areas.

Figure 2 Data Elevation Model (Elevation mesh)

The default terrain uses generic coloured squares that are tiled to cover the land areas. The smaller the squares within this grid, the more accurate the geographical data. (Scenery Design, 2004)

"Objects" or Vector Scenery

Scenery Design (2004) stated that this layer includes all coastlines, water bodies, rivers and roads. The objects are made of lines and polygons that are defined with distinct coordinates, and they may modify the shape of the terrain. As an example, a lake will flatten all the terrain it covers to one level, which is defined with the object.



On a more complex level, this category also includes buildings. Within this layer actual objects such as airports, buildings and other landmarks are placed as indicated in Figure 3.

Figure 3 Object Layer including airports & buildings

Microsoft further included a feature named *Autogen*. Autogen populates the ground surfaces with generic objects, including buildings, trees and power lines, as illustrated in the background terrain behind the football stadium in Figure 3.

Milne (2003), in his review of the default flight simulator scenery, mentioned “... these aren’t just randomly placed. Data is stored in scenery files that tells the Autogen system where towns, forests and farmlands are, and the system places the appropriate objects there to suit. It doesn’t recreate cities and towns to their exact layout at all, but it does make areas of terrain recognisable, and makes the entire experience of flight much more involving seeing more than just green tiles passing underneath you.”

Aviation Objects



Figure 4 Aviation Objects

To complete the static scenery, specific objects such as airports, runways, and instrument lighting beacons are placed on top of all the layers as shown in Figure 4. Aeronautical chart information is used for some of the major airports for runway placement, but for the majority of airports longitudinal and latitude points are used and are not always accurate.

(Scenery Design, 2004)

Dynamic Scenery

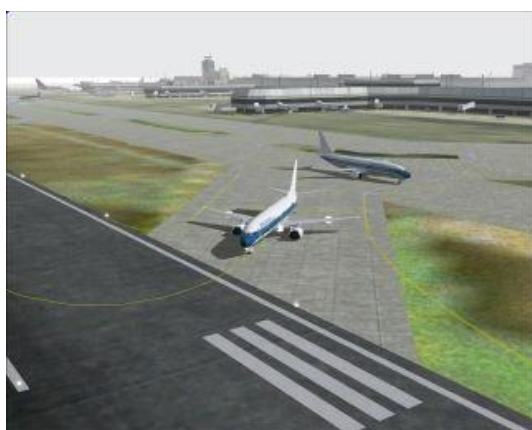


Figure 5 Dynamic Scenery

To complete the default scenery, dynamic scenery is added. This includes moving objects, such as other airplanes, vehicles or any other type of animated object as shown in Figure 5. Finally, all these components are combined seamlessly into one virtual world. (Scenery Design, 2004)

Default Scenery Limitations

The default level of detail within Microsoft Flight Simulator X cannot accurately represent the entire surface of the planet. This is because the amount of data required was too great to fit on most personal computer hard disks. As a result, compromises are made with the mesh grid reference points being 1223 meters between each reference point. (Microsoft, 2004), and a third party software developer creating scenery for the simulator stated “...there are no relief detail changes under 1.22 kilometres.” (JustFlight, 2004) Since the scenery grid between each reference point is so huge, it is not detailed enough to render the virtual flight simulator terrain realistic enough compared to the actual scenery for VFR flight.

(Davis, 2004) stated that according to Paul Chaney of Horizon Simulations Ltd. this results in shortcomings...largely in respect of accuracy of the terrain mesh, but with particular attention to the coastlines – areas traditionally forgotten about by most other product developers” (p24).

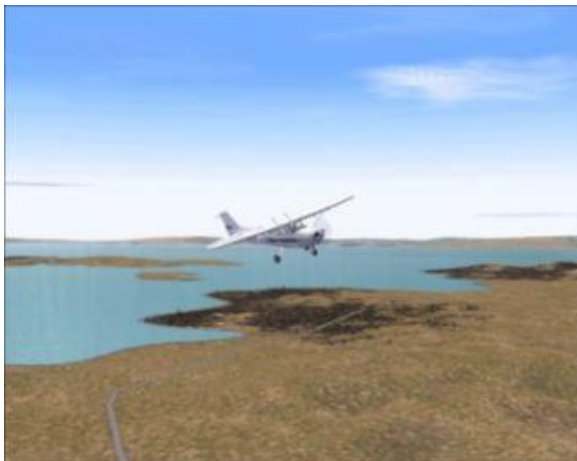


Figure 6 Default Land-class Scenery Layer

That means that ground elevation points in-between the grid reference points are missing, resulting in inaccurate scenery as illustrated by these screenshots of the Hauraki Gulf with Rangitoto Island in background in Figure 6.

The outline of the land is not accurately rendered, and the ground elevation is incorrect as well. In Figure 6 the coastlines are not accurately represented.



Figure 7 Higher Resolution Scenery Mesh Layer

However, by replacing the land-class and mesh layers with higher resolution terrain data using a smaller grid and combined with satellite images, the quality of the scenery is significantly improved to the level that VFR flying is feasible where the coastline corrected, and the ground elevation have been corrected as shown in Figure 7.

To address these problems, many software developers are creating add-on software to replace and enhance the default scenery of the visible land. Replacement scenery technologies are being developed to do just this, using various approaches to improve the scenery accuracy within the flight simulator world. Examples of geographical areas that have been remodelled for VFR flying in the simulator are the United States, England and Wales, and some areas of New Zealand discussed in the next section.

Replacement Scenery Technologies

GesmbH (2004) stated that their scenery is based on Shuttle Radar Topography Mission (SRTM) data. This data was obtained when a radar interferometry device installed on the Space Shuttle Endeavour gathered elevation data on a near-global scale to generate the most complete high-resolution digital topographic database of Earth.

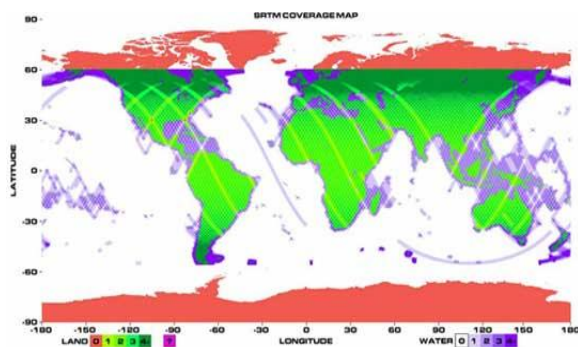


Figure 8 SRTM Data
Source: NASA, 2013

NASA (2013) explained “With its radars sweeping most of the Earth's surfaces, SRTM acquired enough data during its ten days of operation to obtain the most complete near-global high-resolution database of the Earth's topography.” An example of SRTM data is illustrated in Figure 8.

GesmbH (2004) further stated that the SRTM data is not directly compatible with any type of Flight Simulator or other widely available software in raw format. The data require software development for further processing. The Digital Elevation Model (DEM) data is resampled for use with Flight Simulator, compressed and then converted into scenery files, after which the whole process is repeated to compile the scenery at a lower resolution to provide correct views in the distance.

While the SRTM database is excellent on 99% of the terrain, it has voids (data holes), especially in rough alpine areas, and a correct calculation of the margin of error is required. To fill these voids a combined approach is used using three methods: interpolation, resampling of other data sources and manual rework with suitable 3D-software. For small voids they use the interpolation method. This method is quite sophisticated and recognises the shape and character of the surrounding terrain – such as ridges and valleys, average and maximum slope and roughness. It would be possible to close all voids absolutely seamlessly by this type of interpolation (NASA, 2013).

However, GesmbH (2004) stated that for large voids – where many square miles of terrain data are missing - the calculated error (or the possible deviation from real world terrain) would become too large. In such situations, they close the gap in the mesh grid using terrain data from other sources. However, most national datasets use different geo-reference systems and require a coordinate transformation before using them. To minimize the error both methods are combined: with increasing distance from valid SRTM points other datasets are gradually faded in, depending on their own quality or margin of error.

GesmbH (2004) further stated that for professional applications NASA combine SRTM data with expensive proprietary datasets and the SRTM data cover all landmass between 60 degrees north and south latitude. The missing areas are further resampled with lower resolution data to offer an improvement over the default scenery. Additionally, a "Double-render" method for flight simulator scenery is used. Flight Simulator loads scenery as needed during the flight, and it happens quite often that mountains appear suddenly out of nowhere. The "Double-render" scenery eliminates this problem and even at high distance the shape of the scenery is already correct. With "Double-render" scenery there are two sceneries running at the same time.

However, according to Flightsim (2004), the scenery is only a “snapshot in time” and the scenery for a particular area portrays the scenery only as it was when the picture was taken. This means that to make allowances for the seasons, or time of day, and recreate seasonal terrain changes, separate imagery must be created for each season. The scenery itself carries the marks of the land as well as shadows, which do not move with the sun. Flightsim (2004) state that photorealistic quality refers to the “technique of using samples of photographic textures to represent the landscape over a wide area. For example, a single photograph of a set of fields may be used to display fields in many different locations in a flight simulator.”



To create a more realistic scenery environment, the simulator uses actual photographs of each location to display the scenery at that location within the flight simulator as seen for the Wellington region in Figure 9. The result displays all the visible features in the real-world landscape in their true location in the flight simulator.

Figure 9 Satellite Images from a Space Shuttle Mission
Source: NASA, 2013

According to JustFlight (2004), a replacement scenery mesh covering the entire continental US has been created using Space Shuttle data “to dramatically increase the surface detail by up to 16 times with reference points 76 or 38 metres apart. Featureless areas are retransformed; mountains soar, and valleys plunge.” JustFlight stated that the FS Terra in relief model is set at a high resolution of 76 metres between each reference point.



Figure 10 MegaScenery textures
Source: Aerosoft, 2005

Aerosoft (2004) is creating photorealistic scenery that replaces the default US textures. This is called MegaScenery and is available for different geographical locations, utilising large-scale satellite photos as illustrated in Figure 10.

These satellite images create a resolution of 5 metres per pixel, which is good enough to accurately reflect real terrain, making it suitable for real VFR flying as seen in Figure 3.10 since “real rivers, real lakes, real mountains, real farmland, real towns and real cities are created. Aerosoft (2004)

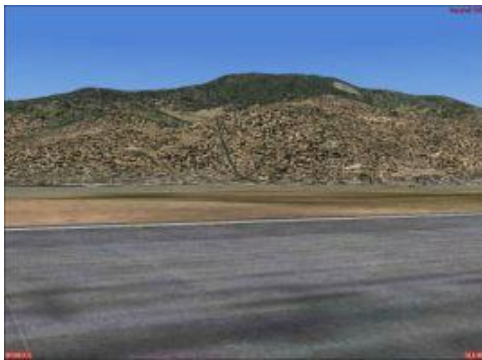


Figure 11 Default scenery textures

Aeronautical maps and charts needed to fly in these areas are supplied with the software, for both VFR and IFR Day And Night. Aerosoft (2004) stated that it is also possible to use real aeronautical charts to fly any VFR route within the scenery areas covered as illustrated in Figure 11.



Figure 12 MegaScenery replacement textures

The impact of this technology can clearly be seen in the screenshots of the mountains west of Palm Springs, California. In Figure 12 the replacement scenery detail is significantly more realistic than the default scenery.

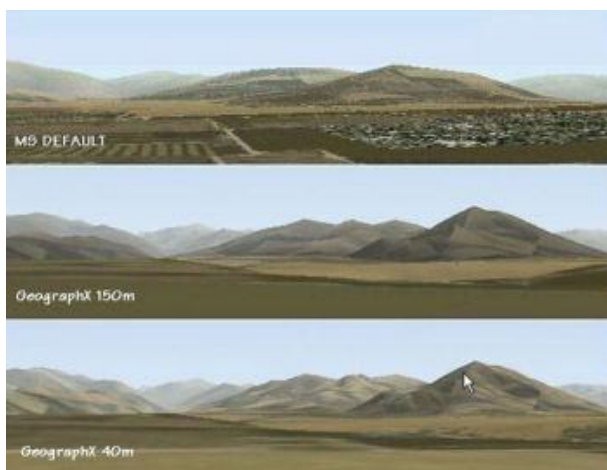
Aerosoft (2004) also stated that: “MegaScenery ... uses high resolution Digital Elevation Model data, that’s accurate within feet, to provide you with accurate elevation data across the entire area covered. Mountain flying is unlike anything you’ve ever experienced to the point where you can identify even the slightest ridge or mound and reference it on your aeronautical chart.”



Additionally, the scenery accurately depicts the areas defined as water. This means that water effects are simulated with waves and rippling effects. Therefore, only planes that can land on areas defined as water can do so, but other aircraft will sink as illustrated in Figure 13.

Figure 13 GodZone replacement textures for NZ

Various flight simulator enthusiasts, most notably Robert Corn from Windowlight, Christian Stock from GeographX, and Massey University, designing realistic scenery. They developed the new scenery using satellite imagery to replace the default scenery. Students from Massey Aviation developed a new land-class system, correcting placement of rivers, roads, and lakes for New Zealand. They further developed add-on scenery objects for New Zealand airports and these are then placed on top of the previous layers. Stock (2005) developed high resolution 20m, 40m and a lower resolution 150m-mesh replacement files for the entire geographical area of New Zealand. These correct the default mesh scenery as illustrated in Figure 14.



According to Stock, the New Zealand dataset of digital images consists of more than 300 seamless georeferenced graphic files, with the standard map sheet covering 40km x 30km (1200 sqkm).

Figure 14 Windowlight replacement textures for NZ

Each textured image contains approximately 24.5 mega pixels, with a pixel resolution of 7 metres square. Further to this, they state that enhancements include shaded relief, hypsometric colour ramping, and textured forests and water bodies.

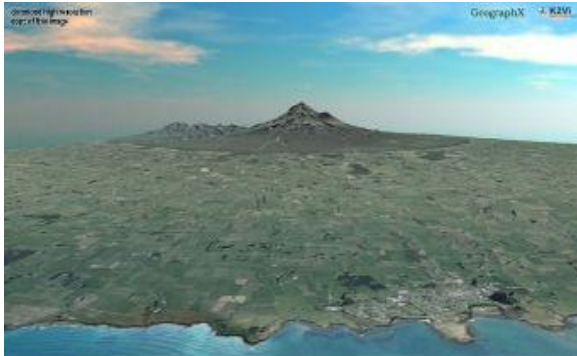


Figure 15 Windowlight replacement textures for NZ

It is on top of this new layer that the scenery such as that developed by GeographX and Windowlight is placed, using the satellite imagery with custom New Zealand textures as shown in Figure 15. These only cover selected areas of New Zealand at present.

Reviewing the Godzone scenery created by Corn, Milne (2003) stated that “each scenery set covers a limited area. For instance, the Taranaki scenery is 30x40 square kilometres. Beyond that, the default game textures kick in and there is a distinct and sometimes ungainly crossover. This detracts from the natural flow of the landscape unfortunately and can also influence realism. But within the bounds of the scenery is an environment that is 100% New Zealand as we know it.”



Figure 16 Default textures for NZ (Taupo)

It is clear from the example screenshots of lake Taupo the significant difference the replacement scenery makes. In Figure 17 the default scenery is flat, the waterline not very accurate and the terrain empty using generic textures as illustrated in Figure 16.



Figure 17 GodZone replacement textures for NZ (Taupo)

In Figure 17 the waterline and terrain elevation are corrected, and the terrain covered with accurate textures taken from satellite data with the replacement scenery layers. Even the roads are represented accurately.

Harvey (2003) stated that Flightsim Central mentions that the replacement photographic scenery used for England and Wales uses Get Mapping's Millennium Map™ aerial photography, which is based on photos taken from a aircraft flying at around 5000ft.



Figure 18 Get Mapping's replacement textures for the UK

The result is photorealistic quality scenery with seamless coverage of the entire United Kingdom. According to JustFlight (2004) "the photographic scenery recreates VFR flying in which navigation is by linear features such as motorways and railways, and reporting points are based on prominent visual features in the landscape. The resulting photographic quality and seamless coverage cannot currently be matched by satellite imagery." This is shown in Figure 18.



Figure 19 Get Mapping's replacement textures for the UK

Flightsim (2004) stated that "the photographic scenery is made by draping high quality aerial photography over a 3D model of the terrain so that it can be used by Microsoft Flight Simulator to display it as it might be seen from a plane in real-life". This is shown in Figure 19.

JustFlight (2004) explained the difference between photorealistic and photographic scenery as follows:

"Photorealistic quality refers to the technique of using samples of photographic textures to represent the landscape over a wide area. For example, a single photograph of a set of fields may be used to display fields in many different locations in a flight simulator." This results in the photographic scenery using actual photographs of each location to display the scenery at that location in the flight simulator. Further to this, JustFlight (2004) claimed that "This photographic scenery shows not just every major city, but also every town, village, hamlet, wood, field, copse, stream, river, road, railway, canal, shopping centre, factory, in fact every visible feature in between – right down to individual streets and houses."



Participant Email Invitation

Dear "Participant",

You are invited to participate as part of the data collection phase for the purposes of satisfying the requirements for a PhD at Mt Helen Campus, Federation University.

The intended participant numbers will be between 10-15 people. However, all attempts will be made to ensure that your privacy/anonymity will be maintained. You will not be identified in the research and all data will be removed/separated from all participants before being analysed.

Purpose and Aim of the Project

The purpose for this research stems from recommendations of previous research regarding the use of flight simulation technologies for the training of private pilots where no official use of simulator software is used as is in commercial and military pilot training. Since the flight environment in which a private pilot operates relies heavily on visual references, instrument flying skills do not have the same importance as in commercial aviation. In this regard the visual scenery should be vital, and the study compared the virtual world within the simulation software to the real world. The data from that study showed that personal computing flight simulation software has evolved to a level of complexity and accuracy such that it could be considered for use in the training and maintaining piloting skills of private pilots.

Therefore, this study aims to determine the process for identifying the optimal configuration for these personal computer flight simulation technologies to teach the required skills for Private Pilot training. To collect the required data for this research, a mixed research method using participants between 22 and 43 years of age with no previous flying experience, randomly selected, will be invited to perform a simulated flight using a flight simulator.

If you are interested participating in this research, please contact the researcher Mr William Harvey, via return email, or on 0424156904 before 28 February 2017.

Thank you and regards,

William Harvey



Consent Form

PROJECT TITLE:	Investigating the effect of PC simulation configurations on improving general competencies
RESEARCHERS:	William Harvey, A/Prof Andrew Stranieri, Dr Cameron Foale

Consent – Please complete the following information:

I, of

hereby consent to participate as a subject in the above research study.

The research program in which I am being asked to participate has been explained fully to me, verbally and in writing, and any matters on which I have sought information have been answered to my satisfaction.

I understand that: all information I provide (including questionnaires) will be treated with the strictest confidence and data will be stored separately from any listing that includes my name and address.

Aggregated results will be used for research purposes and may be reported in scientific and academic journals

I am free to withdraw my consent at any time during the study in which event my participation in the research study will immediately cease and any information obtained from it will not be used.

SIGNATURE:

DATE:



Flight Simulator Navigation Flight Exercise

Data Collection simulation flight exercise towards completion of a PhD research at Federation University conducted by William Harvey

Dear Participant,

Thank you for agreeing to participate in this research project. Your input and participation is a valuable contribution to the research findings. Your participation and involvement is as follows:

- You will be asked to do a navigation exercise using a basic flight simulator. The simulator will be set up with one of two basic configuration settings (scenery, cockpit and hardware) to assess the effectiveness of each configuration. The simulated flight will be recorded using Flight Simulator's built in flight recording features.
- You will be given basic background and instruction on how to use the flight simulator installed in the T Building of the Mt Helen campus. This process involves a Brief on the basics of handling and controlling the virtual aircraft, and how to understand the process of navigating and finding waypoints. This process should take no more than 1.5 to 2 hours.
- You will then perform a navigational exercise in the simulator to measure the impact of the simulator configuration on your ability to successfully navigate during the flight to the desired destination as specified. The duration of the simulator flight should be around 45 minutes to 1 hour.
- During the simulator flight the simulator will record the flight data while the PhD candidate investigator observes. Notes will be taken during this time and the researcher may communicate with you if deemed necessary to obtain further data/information. Should this occur it will in no way be a reflection of your personal abilities, but rather to gain a better understanding of how the simulator configuration is impacting on your experience.
- At the completion of your flight, you will be asked to complete a post-flight survey to solicit your specific views on the flight and simulator configuration and you will be invited to be interviewed by the PhD candidate investigator to solicit additional feedback. Notes will be taken from any verbal responses and recorded along with written question responses and analysed thematically afterwards.

Your participation will cease at the end of the interview and no further input or involvement will be required from you after that point. Keep in mind that the data collected will be anonymous and any personal details that could identify you will not be recorded at any stage. Should you wish to have access to the research findings, a Brief will be given to interested participants after the research findings have been published.

You are required to fly a simulated flight from an over flight starting position at Horn Island airport to Darwin airport far north Queensland, Australia. As you will not be fully skilled in aircraft take-off and handling manoeuvres, you will not be required to land the aircraft at Horn Island. Your flight will terminate when you reach the overfly point specified on the navigation map.

There are a number of waypoints marked along the flight route on the navigation map. You will be required to make any necessary alterations to your aircraft heading as required to find the landmarks identified on the navigation map, including the final destination of Horn Island. You may refer to the navigation map to assist in identifying and finding the visual landmarks, but the intent is for you to navigate using visual identification of the landmarks and utilising information given as per the cockpit configuration.

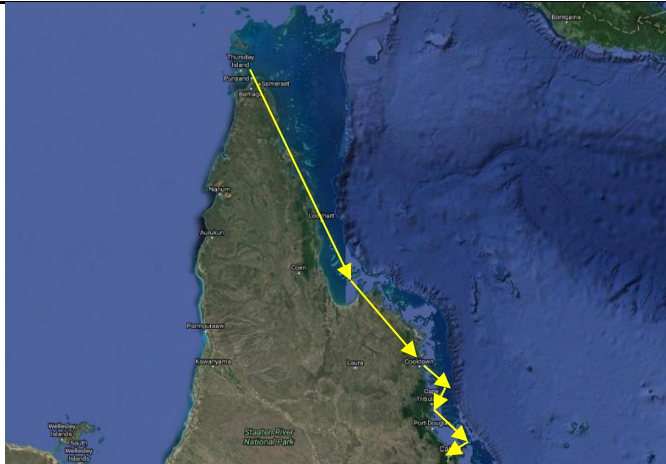
The flight time will be recorded, but you are not required to fly to each waypoint within a specified time frame. Should you find that you cannot find a particular waypoint, or that you are off course, you may make any flight path adjustments you deem necessary to get back on course. The intent of the exercise is not to measure flight time, but your ability to successfully navigate with the particular simulator configuration setup.

The flight path for your simulation flight is as follows:

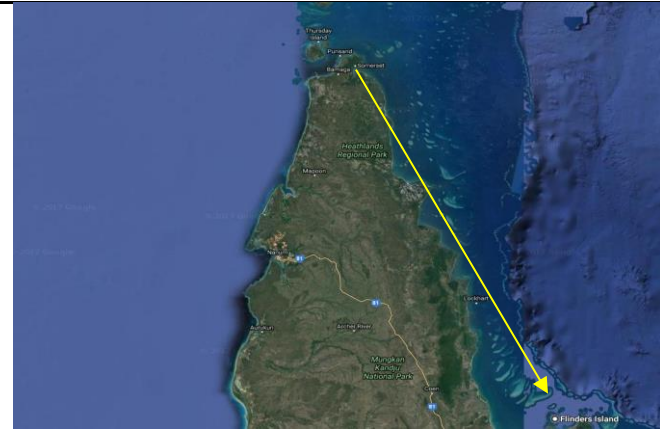
- Your aircraft will be positioned at the starting location of 1000 feet above ground level directly over the airport at **Horn Island**, far north Queensland. Look at the compass of the aircraft and familiarise yourself with the current aircraft heading. From the starting position at the over flight position at Horn Island airport, you will need to turn to heading **150 °** to fly to your first waypoint of **Flinders Island**.
- Press the Pause button on the keyboard located on top of the flight yoke. The simulator will start, and the aircraft will start flying. Establish a level flying altitude with a flying speed of 120 knots as soon as possible as briefed earlier. As soon as you have configured the aircraft to fly straight and level at the correct speed, turn to the specified heading of 150 °. This first leg of the flight to the first waypoint is quite long, so use this time to get familiar with the simulator and the aircraft. Make any required adjustments to the heading if required and practice to stay on the required heading. Look at the navigation map frequently and make sure you are able to identify any landmarks on the way that correspond with the simulator terrain. You should be able to know when your waypoint comes into view using this method.
- When you reach Flinders Island, turn to heading **140 °** and fly to the second waypoint, which is **Cooktown**. From here the remaining legs of the flight will be much shorter, so you will need to be more alert and aware of your surrounding in order to make quicker decisions and adjustments in between the waypoints.
- At Cooktown, turn to heading **135 °** and fly towards the third waypoint **Endeavour Reef**

- As soon as you fly over Endeavour Reef, turn to heading **195^o** towards the fourth waypoint and fly to ***Snapper Island***.
- When you reach Snapper Island, turn to heading 190 and fly to Port Douglas, the fifth waypoint. Look for the Marina. When you reach the Marina, turn to heading 115^o and fly towards the sixth waypoint. ***Green Island***.
- At Green Island, turn to heading 230^o and fly to your final destination of ***Cairns Airport***.
- Your flight will end when you overfly the airport. Press the Pause button on the keyboard to end the simulation.

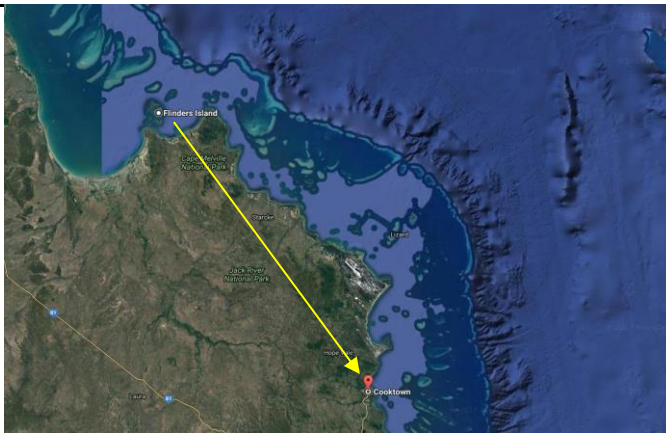
Flight Simulator Navigation Flight Exercise



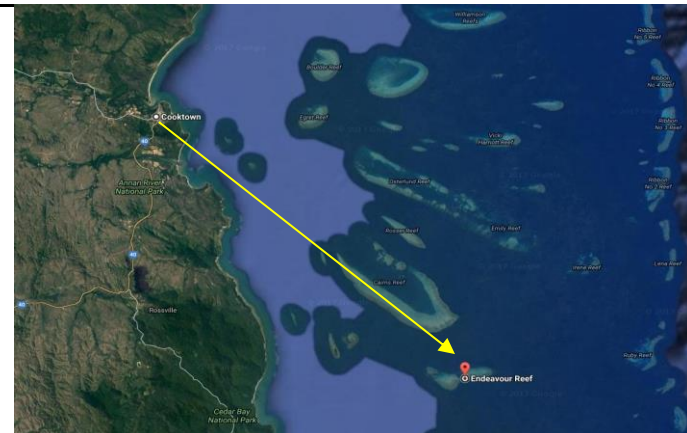
Navigation Map Overview



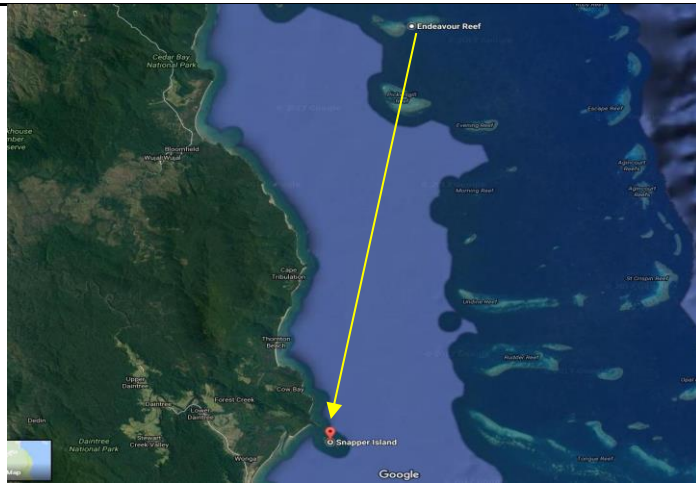
Waypoint 1, Flinders Island



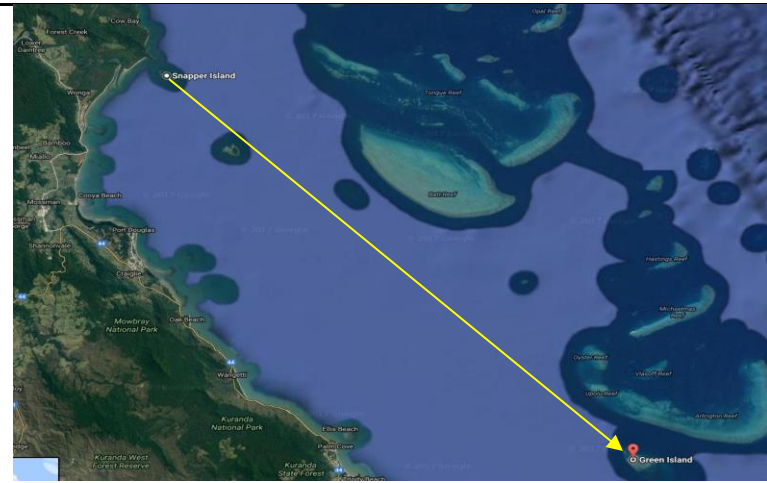
Waypoint 2, Cooktown



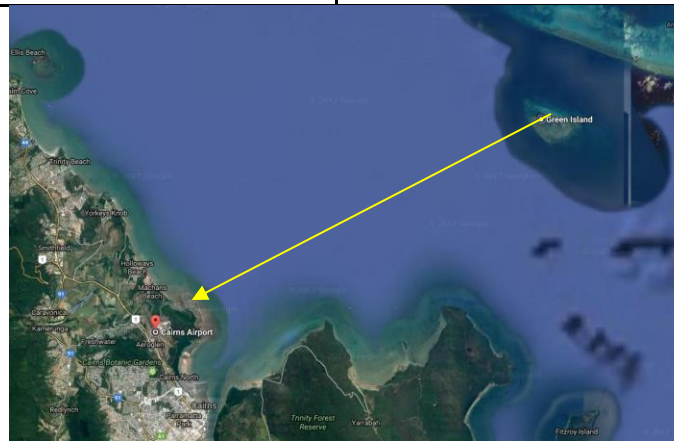
Waypoint 3, Endeavour Reef



Waypoint 4, Snapper Island



Waypoint 5, Green Island



Waypoint 6, Cairns Airport



Post Flight Survey Questionnaire

Please answer the following questions to reflect your experience and thoughts on the simulator configuration used.

Note: All of the questions will only cover your experiences and thoughts relating to the simulator configuration and will exclude any personal information from participants.

Based on the navigation completed in the simulator, rate the importance of the following scenery realism aspects on the ability to navigate to the various waypoints and the final destination: (Tick the appropriate box)

- Scale: **0** = Not able to navigate successfully
1 = Some degree of navigation possible with difficulty
2 = Reasonable degree of navigation feasible
3 = Navigation possible with some errors
4 = Navigation possible with little or negligible errors
5 = Navigation with high degree of accuracy

	0	1	2	3	4	5
Landmarks						
Buildings						
Roads and rivers						
Terrain and topography						

Based on the navigation completed in the simulator, rate the importance of the amount of scenery realism details aspects on the ability to navigate to the various waypoints and the final destination: (Tick the appropriate box)

- Scale: **0** = Not able to navigate
1 = Some degree of navigation possible with difficulty
2 = Reasonable degree of navigation feasible
3 = Navigation possible with some errors
4 = Successful navigation with little or negligible errors
5 = Successful navigation with high degree of accuracy

0	1	2	3	4	5

Based on the navigation completed in the simulator, rate the importance of the following visual realism aspects on the ability to navigate to the various waypoints and the final destination: (Tick the appropriate box)

Scale: **0** = Not relevant

1 = Successful navigate impossible

2 = Some degree of navigation possible with difficulty

3 = Reasonable degree of navigation feasible

4 = Successful navigation possible with little or negligible errors

5 = Successful navigation with high degree of accuracy

	0	1	2	3	4	5
Screen size						
Displaying selected instrumentation on screen instead of actual physical instrumentation						
Utilising multiple displays to represent internal and/or external visuals (scenery)						
Terrain and topography						

- Disregarding the effect of the scenery, what other aspects of the flight simulator made the navigation task easier?

- Disregarding the effect of the scenery, what other aspects of the flight simulator made the navigation task more difficult?

- Based on the navigation completed in the simulator, rate effectiveness experienced of the following during the simulator exercise: (Tick the appropriate box)

Scale: **0** = Not Relevant/Applicable
1 = Not effective
2 = Some degree of effectiveness
3 = Reasonable degree of effectiveness
4 = Effective
5 = Extremely effective

	0	1	2	3	4	5
Visual elements						
Scenery						
Screen Size						
Screen Brightness						
Simulator Controls						
Switches						
Flight Yoke and Pedals						

- Do you have any suggestions to improve the simulator configuration without adding further hardware?

- Overall in your opinion, how effective was the simulator configuration presented in your navigation exercise in successfully navigating to the nominated waypoints and final destination?

Thank you for your participation in this research project. Your valuable input will be analysed and correlated along with the data and input from the other participants. Any information that could potentially reference participants will be de-identified before analysis of the data.

GLOSSARY

ADF

Aircraft cockpit panel gauge: Automatic Direction Finder.

ATC

Air Traffic Control. A facility that regulates and ensures aircraft separation by way of radar.

A & SD

Aircraft and Scenery Design software tools.

CASA

Civil Aviation Standards Authority. The official body regulating aviation in Australia.

Cross Track Error/Deviation

The perpendicular distance between the planned flight path of an aircraft and the computed aircraft position as displayed by the aircraft's navigation instruments.

CAA

Civil Aviation Authority. The official body regulating aviation in New Zealand.

FTD

Computer Aided Flight Training Device

FAA

Federal Aviation Administration (United States of America)

Flight Plan

The details of a flight from one destination to another using aviation maps, fuel and load charts. This includes documentation required by CASA be filed for every flight extending beyond 50 nautical miles from any aerodrome.

Flight Simulation

The science of recreating a flight to be as realistic as possible without leaving the ground in an actual aircraft.

Flight Simulation Software

Software used to recreate various aspects of actual flight.

Fly-By-Wire Systems

A mechanical linkage system used in aircraft linking the pilot controls in the cockpit with other parts of the aircraft. These include the ailerons, rudder, flaps and tail of the aircraft.

Full Motion Simulator

A flight simulator station using an hydraulic powered moving platform to create a range of motion in real-time with associated simulation software.

Glass Cockpit Technology

Pilot cockpit instrument panel technology using computer monitors instead of analogue instruments within real aircraft. The instrumentation is driven by software through sensors on various parts of the aircraft linked to on-board processors.

GPS

Aircraft cockpit panel: Global Positioning System.

IFR

Instrument Flight Rules. Navigation relying primarily on flight instruments.

Mesh

A combination of different texture layers that combine to form scenery layers.

Flight Training Device (FTD)

A procedural training device used for training of aircraft systems

Private Pilot

A person who holds a current valid license to operate a rated aircraft with passengers without commercial benefit

Rendering

The process of drawing the textures and layers of a virtual world scene environment

Scenery

The result of object layers and textures that create a virtual environment

Scenery Layers

Layers included in a virtual three-dimensional world containing objects or textures to build scenery.

VFR

Visual Flight Rules. Navigation without relying primarily on flight instruments

VFR Flight

A flight using visual references to the ground and horizon to navigate

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