UK General Aviation Accidents:

Increasing Safety Through Improved Training

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The candidate confirms that the work submitted is his own and that appropriate credit has been given where reference has been made to the work of others

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Abstract

From January 2005 to December 2011 there were 1007 General Aviation, fixed wing accident reports published by the UK Air Accidents Investigation Branch. These ranged from minor events to fatal accidents, of which there were 55, killing 88 people. The data and information from these reports was collated and analysed to determine main and contributory causal factors with a view to formulating improvements to the current training and support mechanisms within the industry. A survey was also conducted among the UK General Aviation population to gauge the levels of experience, license level and other information with which the accident data could be compared, ultimately showing that although accident pilots were more experienced than the surveyed population of UK General Aviation pilots, they had less aircraft type experience. The accident data and survey results both mutually and independently highlighted areas of concern within General Aviation activities, such as the maintenance of flight currency, a lack of basic flight skills, poor decision making and an absence of any form of resource management. Some of these issues are more systemic in nature providing opportunity for additions and enhancements to be made to theoretical instruction, practical flight training and the support that General Aviation (GA) pilots receive, particularly those who fly with Private Pilot Licences, who make up the majority of this field of aviation. A rigid system of pilot monitoring to ensure currency is maintained and that appropriate procedures are followed prior to hire of an aircraft is also currently absent, being an area examined within the thesis. Proposals are presented to cover all these topics and conclusions drawn that whilst UK General Aviation is well regulated, the data and survey show there to be a need for improvements to be made, above and beyond the new syllabus being brought in under European Aviation Safety Agency regulations (EASA Part-FCL PPL, 2013).

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Chapter 1: Introduction

1.1 Reasons for the thesis

Within UK General Aviation (GA) there are approximately 20,000 pilots (CAA, 2009) flying a variety of aircraft from microlights to twin engine, high performance vehicles and myriad other types. Their license level ranges from those with the basic National Private Pilot License (NPPL) to those who hold an Airline Transport Pilot License (ATPL), students training towards all license levels also making up a proportion of the numbers. Experience wise, pilots range from novices who fly when time and money allow, to those who instruct and thus fly regularly, having accumulated hundreds or even thousands of hours experience on light aircraft. There are also Airline pilots who fly for recreation who may have thousands of hours on large airliners, but only a few hours on small piston engine aircraft.

Within this mix of individuals there are those who have received high quality, intensive training, due to the nature of the regular flying they do (Airline Pilots and Instructors for example) and there are those who have done just enough to secure their NPPL. Among all of these there are pilots who have chosen to learn to fly different types of aircraft such as vintage tail draggers, or take on the challenges of aerobatics.

This variety puts GA in a unique position in that regulation must be both rigorous and flexible to take account of the multitude of pilots and aircraft flying within its boundaries. Whilst this thesis does not purport to imply that the regulations are not stringent enough, it does seek to highlight areas that can be improved upon to enhance safety.

In the past, some studies have looked at areas of UK GA safety such as fatal accidents (e.g. CAA, 1997) or loss of control in specific aircraft types (e.g. Gratton and Bromfield, 2009), but none have sought to look at all accidents and incidents from the perspective of fundamental causes and underlying issues such as the support and monitoring a GA pilot is subject to after gaining their license, or the training given regarding emergency procedures. Furthermore, none have sought to compare the particulars of pilots involved in accidents with a representative sample of the UK GA pilot population to determine any correlations in pilot flight experience, culture or habits, such as has been the case for this thesis. There has also been no attempt to look at the diversity of accident types, where they happen in relation to the phase of flight or the relation between these, human factors and pilot experience. Additionally, the CAA review of fatal accidents (CAA, 1997) included a number of recommendations for improvements to the industry relating to training and safety, many of which were implemented. Since this time there have been no radical changes to the processes involved in obtaining and maintaining a pilot license, other than regulations which will become effective as of 1st September 2013 under the European Aviation Safety Agency, although it will be argued within the thesis that these do not go far enough.

Hence this thesis was undertaken to investigate and review UK GA accidents with a view to analysing comparisons with a representative sample of the population and the particulars of the pilots involved in each accident and the circumstances surrounding it.

1.2 The constitution of an aviation accident

Perhaps more so than in commercial operations, due to the sheer number of possible combinations of pilot, aircraft, license level, experience and conditions within UK GA, there are endless ways in which an accident can occur. There are, however particular categories into which one can place accidents, based on the primary cause(s) and contributory factors; human factors, technical, controlled flight into terrain, loss of control and airmanship being those defined in this thesis.

Human factors and the related field of human error is often cited as the major contributor to all aviation accidents and it will be shown that this is the case for UK GA. Mistakes are a normal aspect of human behaviour and thus it must be anticipated that pilots too will make mistakes, even at commercial level where they have received intensive initial and follow-up training (Murray, 1997). Commercial pilots also receive crew resource management (CRM) training which teaches them how best to use all available resources in both normal and ab-normal operations, as well as how to manage their time, skills and relationships within the cockpit to the greatest effect. In UK GA there is no precedent for this level of training, thus it must be accepted that there is scope for enhancements to reduce the incidence of human factor related accidents. To achieve this it is necessary to understand the reasons behind these accidents and make changes as required to not only prevent accidents of the same nature happening again, but to prevent other accident types from occurring also.

Where accidents occur for reasons other than human factors, pilots must be given the knowledge and skills to be able to manage the situation effectively. They need a brief but helpful tool to gain information, prioritise and make good decisions and within this thesis, it is suggested that CRM for single pilots (single pilot resource management; SPRM) is introduced as not just a concept, but a working principle that student pilots are taught and examined on.

To compliment this, despite the expanded range of theory examinations for (N)PPL students introduced by EASA, there is nothing specific within the modules that identifies and deals with threats and emergency situations, much of this instruction being saved for the practical flight training. Where a student is expected to understand the fundamentals of why a wing produces lift, or how a four stroke piston engine works, there will be little lost and much more potentially gained in expecting a student pilot to be able to explain, for example, the mechanics of a stall, how an engine failure might induce one and how to prevent it. Thus this thesis argues that a theoretical module specific to emergency situations on which student pilots should be examined is developed.

The nature of aviation dictates that an aircraft operates in flight phases; on the ground, getting airborne, en-route and getting down again. For the aforementioned module to be thorough and practical training to be relevant, accidents in all phases need to be examined, to determine causes specific to each phase. This thesis will show that accidents during take-off and landing in UK GA follow the traditional aviation pattern of being the most common, but accidents in the cruise prove to be the most serious in terms of injury.

1.3 The challenges

With so many variables in each accident, the main challenge was to develop more generic measures to improve safety, as opposed to seek to propose a different strategy for each main category of accident. To do this would not be practical as the resources within GA are much more limited than those in commercial operations and to impose restrictions and new regulations for each element identified within this thesis would simply not be possible.

Of course, in order to make improvements in safety, some changes and additions are necessary, but if they are functional and relatively straightforward to implement, then it is suggested they will be much more effective overall.

In bringing about changes that will increase a pilot's knowledge and make flying skills preventative rather than reactive, the industry will defer to Reason's model of prevention through a system of defensive layers, each in place to capture and stop the trajectory of accident opportunity (Reason, 1990). Knowledge and understanding make up one layer, targeted preventative practical flight training constitutes a second. A third would be to improve the support received by the pilot after gaining their license and employing a greater interest in their activities through augmented monitoring.

The more time that has passed since a pilot gained their license, the more likely they are to forget basic procedures for emergencies, given that they will not have been used, except in the event of an emergency. Whilst an experienced pilot with many years safe flying may have a skills set over and above that of a newly qualified peer, their familiarity with procedures in the case of an engine failure, for example, may be less and omissions and errors in executing them could be a factor that results in an accident over a safe emergency landing.

Accordingly this thesis will submit a proposal to introduce a post licensure monitoring system through which pilot skill levels will be better maintained and those at risk of accident involvement will be better supported.

1.4 The value of this thesis to the GA industry

It is hoped that the contents of this thesis will at the very least raise awareness of the issues within UK GA leading to many of the accidents that appear in the sample data. Included are minor accidents and incidents which, to date, have been overlooked as they are deemed insignificant, however it is argued that if highly experienced pilots can make errors of judgment resulting in minor accidents (which will be shown to be the case in several events), then there are latent systemic issues which, if not addressed could potentially lead to greater problems.

Within the 1007 reports reviewed for this thesis, there were 55 fatal accidents resulting in 88 deaths, thus it is also hoped that the proposals presented at the end of this thesis will have a positive effect on the fatality rate in UK GA, through reducing the overall number of serious accidents through better pilot training, support and monitoring.

Chapter 2: A Review of Literature Sources

Despite being a comparatively narrow academic field, aviation still elicits a broad range of individual topics from which a large number of research papers have been produced. The domain of aviation accidents is more specialised in its content, much of which can be reduced to four main areas; technical failures, meteorology, human factors and airmanship. The review of related literature gave credence to the research presented in this thesis, pilots in many of these situations demonstrating a lack of skills in an emergency situation, a lack of resource management to resolve the situation and an apparent lack of post license monitoring.

Accidents of a technical nature invoke little debate among academics, except where the pilot's actions following a technical failure can be linked to human factors. Technical failures are naturally investigated and as such the details are published in the associated accident report, occasionally prompting recommendations from the investigating body to prevent the same condition or fault occurring again. Thus the limit of useful literature concerning technical failures in UK GA is restricted to manufacturer specification manuals and accident reports. These enhanced the author's knowledge concerning elements of GA aircraft technical operation, allowing for a deeper understanding of some accident context than might otherwise have been possible.

Meteorologically influenced accidents are more commonplace; not unexpected given that flying is always undertaken at the mercy of the weather. Literature on aviation meteorology is similarly ubiquitous and works on associated accidents are available in academic journals, books and many other media formats. The variety of problems that can occur due to atmospheric conditions is wide; instrument failure, engine issues, control problems and loss of visual references. Academic papers referring to meteorological GA accidents demonstrate a predilection towards inadvertent flight into adverse weather conditions, being a widely berated act, but equally misunderstood. Examples include Wiegmann, Goh and O'Hare (2002) who looked at how situational awareness and flight experience influenced pilot decisions to fly into adverse weather, Wiegmann and Goh (2009) further looking into the causes of this phenomenon. Groff and Price (2006) looked at 72 GA accidents in degraded visibility and concluded that additional training for susceptible pilots is needed. Evidence in accident reports also indicates poor human factor traits such as decision making and violation of license restrictions prevail in UK GA, weather related accidents.

The preponderance of aviation human factors academic manuscripts relate to commercial operations, as do associated books and other publications such as government papers and regulatory reports. Despite the fact this thesis relates specifically to smaller private aircraft in the GA genre, much of what has been learned in commercial aviation can be applied to GA, particularly concerning human factors and accordingly this literature was deemed to be contextually relevant.

The field of human factors is wide, covering all aspects of human cognitive and behavioural characteristics, including psychology. These traits are linked to aviation accidents in the majority of cases, both in commercial and GA operations, thus making it an essential aspect of aviation safety research. More than half the data gathered on UK GA accidents indicates the pilot lost control of the aircraft in some form or another and that in the majority of cases an element of human factors was a main or contributory factor. Thus a review of both academic and industry studies on this phenomenon was imperative and encompassed the main areas of concern regarding loss of control (LOC) and other human factor accident causal or contributory factors; situational awareness, decision making, pilot skills and violations.

In commercial operations pilots are required to complete a course in crew resource management (CRM) to enhance and maintain safety from within the cockpit. It is designed to educate pilots on the value of team work and adoption of a positive safety culture within their employing organisation as well as in their work. The premise promotes the efficient and effective use of available resources through mutual cooperation and respect, minimising bad decision making and distributing the workload evenly, fairly and logically, not just in an emergency, but in every situation. There is no such requirement within GA, these pilots mostly flying without a co-pilot and thus not necessitating instruction in team work techniques. Nonetheless, there is evidence within the accident data to suggest a course on resource management for single pilots is needed. Academic papers also support this notion, although they are limited in number and do not formulate a viable proposal to address the issue. This gave direction for a simple tool to be devised and tested in laboratory conditions through use of a Flight Simulation Device (FSD).

Human factors also incorporates a component of accident causation not often referred to in a formal context; airmanship. Piloting an aircraft requires good levels of awareness, preparedness, common sense and appropriate knowledge (air law and aerodynamics for example). These attributes are the constituent elements of airmanship and if lacking in a pilot can be considered a threat to safety as much as any of the areas mentioned previously. Available literature specific to airmanship does not exist, academics and industry preferring to allude to it via the well founded science of human factors. However the review of literature concerning the aforementioned areas allowed the author to build a model of detrimental airmanship to compliment the traditional areas of human factors and measure its influence in UK GA accidents.

Despite the bias towards commercial operations, literature specific to GA accidents is not problematic to find and exists in the same formats as the more mainstream commercial offerings. Papers from four journals provided the mainstay of academic literature; Human Factors; The International Journal of Aviation Psychology; Aviation, Space and Environmental Medicine; Accident Analysis and Prevention. To varying degrees a further 26 journals provided several hundred other papers on associated topics ranging from safety research, neuropsychology and forensic sciences to transport management, aeronautical engineering, risk management, ergonomics and aviation medicine.

Given the nature of this thesis, accident reports were the most prolific form of literature used and included more than 1200 reports from the UK Air Accidents Investigation Branch (AAIB) as well as reports from around the world; France, Australia, Canada, Indonesia and the USA. Although demonstrating differences in compilation, content of accident reports from any country tends to remain constant, out of a necessity to determine facts about the accident and the particulars of the pilot(s) involved. Thus applying the findings of foreign investigative bodies to the research was useful in affirming its importance, given that the findings could be applied worldwide, increasing the potential for saving lives and limiting injuries and aircraft damage to a level beyond that initially envisaged.

Collation of data was procured from the AAIB reports which contain particulars of the pilot (age, level of license and experience), details of the accident (location, time, persons on board, injuries and damage sustained) and accident account narratives, describing the circumstances surrounding the event. Determination of accident types and causal factors was established from conclusions and recommendations of the AAIB, as well as human factors material such as journal papers and books.

Publications by regulatory authorities provided legal and procedural knowledge from associated documentation and technical papers, as well as advisory brochures and information for GA pilots. The US Federal and UK Civil Aviation Authorities (FAA and CAA) were of most benefit being most closely associated with GA in the UK, but reference was also made to the European Aviation Safety Authority (EASA) and Joint Aviation Authorities (JAA) for clarification and enhanced understanding of some topics.

In particular the American Federal Aviation Administration (FAA) produces numerous publications exclusively for GA, including safety brochures, technical reports and papers. Some, such as

'Aeronautical Decision Making' and various safety brochures were more pertinent to the research for this thesis, but all contributed to developing a thorough background knowledge of the subject area.

Aviation organisations were another reliable source of information relative to the thesis and beyond. Specific to GA, the General Aviation Safety Council (GASCo) and the Aircraft Owners and Pilots Association (AOPA) in particular represent GA pilots in matters of safety and regulation in conjunction with offering them support and advice, as well as a social outlet in the form of rallies and meetings.

The works of AOPA's Air Safety Institute (ASI) have particular association with this thesis, their safety reports reflecting the need for research into GA accidents; many discuss the most common causes of GA accidents in an attempt to better educate pilots, however these causes continue to be the most common and thus research needs to be performed and subsequent recommendations and changes to regulation made in order for the required effect to be achieved.

In addition to those works reviewed previously, AOPA produce annual reports on GA accidents, giving an in-depth appraisal of statistics and trends from the previous year. Referred to as 'The Nall Reports' they date back to 1997 and provide a reliable source of trend factors associated with GA accidents in the US allowing the data and causal factors researched in this thesis to be evaluated against, given that such concise information is not available from any aviation authority or government body within the UK. Material from the UK Civil Aviation Authority (CAA) is available; one paper refers only to fatal accidents from 1985 to 1994 and another is a regulatory review of GA completed in 2006. Whilst providing a forum against which to measure some of the data retrieved concerning fatal accidents and their causes, their content was too narrow to assist in the overall analysis of data for all the reviewed accident types, the pilots involved or the circumstances surrounding them.

An influential organisation in flight safety, the Flight Safety Foundation (FSF) provided general information, mostly pertaining to commercial operations, but still of benefit to GA pilots and those researching that particular division of aviation. Especially applicable to this thesis, the Approach and Landing Accident Reduction (ALAR) toolkit offered a thorough insight into problems associated by this phase of flight and how they can be reduced.

Other organisations contributing to background material included the Airline Pilots Association (ALPA) and the UK Royal Aeronautical Society (RAeS) as well as the Organisation for Economic Cooperation and Development (OECD).

Papers published by NASA, technical or otherwise, mostly referred to commercial aviation, but like the information on human factors, the content could be applied to GA situations. Examples include their work on single pilot operations, pilot error, flight cognition and stress. Just one paper specific to GA and relevant to the thesis material was located, but was a thorough investigation with solid, reliable information, data and theory.

To thoroughly understand the training process for pilots at both commercial and GA level, approved material for pilot training was reviewed, including theoretical knowledge content and regulatory procedures. Whilst theory content in the early stages of commercial training is similar to that of GA, it continues to include additional, more complex modules. Training manuals used by Oxford Aviation Academy were used to appraise this content, whilst the widely renowned Trevor Thom series of books were used for theoretical content at GA level. For the purposes of regulations, those pertaining specifically to GA as produced by the UK CAA, JAR and EASA were appraised.

Although not directly linked to the research performed for this thesis, it was considered useful to understand some of the performance limitations and general specifications of some of the aircraft involved in UK GA accidents, hence manufacturer manuals and publications were also reviewed. Making such enquiries allowed the author to better analyse accidents where aircraft performance, was an influential factor (for example where a pilot has attempted a take-off on a runway calculated as being suitable for a particular aircraft type, but the prevailing conditions were not accounted for, reducing the comparative amount of available power compared to an International Standard Atmosphere, resulting in a runway overrun). It also assisted in understanding some of the difficulties that may have been encountered by pilots in accidents where there was a technical failure or loss of visual reference, as in these situations; the performance and specifications of an aircraft (glide speed and rate of descent, turn and climb capabilities, equipment on board and other details) become of great importance in such circumstances and some aircraft are better than others.

The use of books extended to more than 40 carefully selected publications. Aware that books can present bias and opinions as well as potentially inaccurate facts in a non-peer reviewed milieu, those used were selected based on either the reputation of the author(s) or citations in journals. The extension of book topics closely corresponded to the journals cited previously, ranging from human factors and pilot error to meteorology and air crash investigation. Most were aviation oriented, but a few were from other industries such as engineering and medicine to provide a cross-referential forum for human error; looking at other industries can help evaluate how aviation has progressed its safety culture and influenced development of human factors and team work in those areas.

The internet is an easily accessible medium presenting hundreds of aviation based web sites and forums. The quality of information presented, however must be considered with caution as many sites are not procured by qualified professionals, but well-meaning enthusiasts. Whilst their knowledge and experience may be reliable and valuable, it cannot be verified and thus must not be wholly accepted as appropriate for academic purposes.

Those sites affiliated with or run by established aviation institutions and organisations can however provide reliable information, perhaps not otherwise available from academic journals or books. Moreover, internet sites are regularly updated and are the best source for reviewing the most up-to-date developments in all aspects of aviation. In a similar fashion to books, web sites were carefully selected by affiliation to a highly regarded professional body (e.g. NASA, CAA, FAA, EASA) to ensure that any information used could withstand the academic and professional evaluation of this thesis.

In total more than 1700 individual pieces of literature and material were used in the research and writing of this thesis, from background information to specific articles pertinent to an individual chapter. The material was selected on the basis of reliability and quality as well as relevance and usefulness with the aim of producing a thesis in which the reader can trust as representing facts to support the research, conclusions and recommendations presented.

This chapter has presented a review of the sources of literature used in the writing of this thesis and has demonstrated the broad nature of the subject. Sources have been shown to include academic journals, approved training materials, industry regulators, government departments, renowned professional societies and technical papers from world recognised research organisations.

Chapter 3: An Overview of General Aviation in the United Kingdom and the Associated Pilot Demographic

Within this chapter, the aim of part 1 is to familiarise the reader with the culture and structure of UK GA. A definition of GA will clarify the categories of aircraft and pilots included in the review of accident reports and data. The licensing structure in the UK will also be explained, as will the requirements for gaining a pilot's license. Furthermore privileges of a license, additional ratings and an introduction to operating as a GA pilot including the various possibilities for aircraft ownership and club membership will be discussed.

Additionally, as this thesis involves discussion about the particulars of accident pilots (their age, experience, license level etc.) it is important to apprise the reader on the range of different people flying within UK GA, beyond the generic description offered in part 1. Thus, in part 2, statistics derived from UK CAA published data will define the numbers of pilots involved, license levels held and ages of all UK pilots for the published dates. More detailed information on the GA population in particular will be communicated via a résumé of the author's 2011 survey, completed by more than 400 UK GA pilots. This will include means of four different categories of experience, age grouping, aircraft categories flown, frequency of flying and reasons for it. Combining the CAA information and survey results has enabled an estimated mean number of UK GA annual flying hours to be calculated which will be recorded here (including method and calculations).

3.1 An Overview of General Aviation in the UK

3.1.1 GA defined

The world of general aviation is a far reaching one and in theory can include all types of aircraft from gliders and microlights through balloons and airships to large airliners and even military fighters. The latter are rarely flown under the GA banner, qualifying only due to the nature of the flight in question which may include ferrying, test flights or private charters. The bulk of flights within UK GA take place in smaller piston engine aircraft, many with a single engine, seating two to four persons and requiring only one pilot. Some are of a moderate size, being powered by two engines and able to carry six to eight or more passengers additional to the pilot(s). The smallest aircraft within the category include microlights, very light aircraft, gyroplanes, gliders and hang gliders.

The category is not restricted to fixed wing aircraft and encompasses rotary wing vehicles (helicopters), also existent as single engine piston to multi-engine gas turbine forms. Again all forms of helicopter may theoretically fly within the definitions of GA, but lay outside the boundaries of this thesis which focuses only on fixed wing aircraft.

As a rule, for the purposes of airworthiness regulations, airfield landing charges, registration definitions and other classification requirements, aircraft are categorised according to weight in kilograms. As this thesis refers to UK GA, there was an inherent logic in deferring to the CAA's definition of the category, as used in their Review of GA Fatal Accidents (1997); an aircraft with a maximum take-off weight of 5700kg. Additionally, the CAA has defined GA as "a civil aircraft operation other than a commercial air transport flight operating to a schedule." (CAA, 2006, p1)

Further to this definition and reflecting the author's knowledge and experience, it was decided that only fixed wing powered aircraft would be included in the analysis, producing a thesis focused on the most common form of GA as opposed to a convoluted discussion thinly covering a large base of aircraft types. Ultimately, the range of aircraft accidents reviewed covered motor gliders, very light aircraft and both single and multi-engine light aircraft.

It should also be noted that the accidents in the sample were retrieved from the AAIB database under the selection criteria of *general aviation, fixed wing*, thus conforming to their definition of the term.

3.1.2 Pilot categories and associated licenses

Although there are only two categories of civil aviation (GA and commercial), there are four main levels of license available; National Private Pilot's License (NPPL), Private Pilot's License (PPL), Commercial Pilot's License (CPL) and Airline Transport Pilot's License (ATPL). Each requires a given number of theoretical knowledge examinations to be passed and a minimum number of hours flying to be completed, as well as the flight test and other ratings. At PPL and CPL level, additional ratings may be added to enhance the license, including Multi-engine Piston, Night rating, Instrument Meteorological Conditions, Instrument Rating and Flying Instructor, (Table 1, p33).

In GA a pilot may hold any level of license as long as it covers the legal requirements for the aircraft being flown. The NPPL is a restricted version of the PPL introduced in the UK on 30th July 2002 (CAA, 2013) allowing those who cannot achieve the required medical conditions for issue of a PPL to gain a pilot's license. Medical requirements are reduced to those necessary for driving a car, but the restriction prevents the pilot flying in anything other than UK airspace during the day, with good weather and cannot add any additional ratings. The most restricted version requires that a safety pilot fly alongside the NPPL pilot at all times (CAA, 2013).

The most common license is the PPL, which can be modified to include the aforementioned ratings, allowing the PPL holder to fly in a greater variety of conditions and aircraft, to a broader range of destinations. More commonly, the license is used for pleasure flying in good weather with the use of two or four-seat single engine aircraft.

The PPL is the license most specific to GA and according to a survey by the author in 2011 (to be discussed in detail in Chapter 3.2), 72.2% of GA pilots fly with a PPL. Figures from the CAA also reveal that from 1994 to 2008, 64.8% of all pilots in the UK held a PPL (CAA 2001, 2005, 2006, 2009). As the requirements for issue of an NPPL are very similar to those of the PPL, from herein in this thesis, these licenses will be considered as the same license and referred to as (N)PPL.

The absence of commercial operations in GA does not preclude commercially qualified pilots from operating within its boundaries. Although flying is their job, many Airline Pilots also enjoy flying in their spare time and do so in GA aircraft. Some aerial operations falling under the remit of GA require that a pilot be commercially qualified. Examples include parachute dropping, glider towing, business jets, surveying and aerial photography.

The most discernible job within GA requiring a commercial license is that of an Instructor, which also necessitates gaining the appropriate rating and qualification through completion of an approved Flight Instructor course. There are different levels of Instructor, from one who can only instruct at (N)PPL level and cannot send a student solo without higher authorisation, through to those who instruct future Airline Pilots. Additionally flight Examiners also work within GA and tend to be highly qualified commercial pilots with many years of experience.

Table 1: Minimum Requirements for UK Pilot License Issue

License Type	**Theoretical knowledge Instruction and Examinations**	**Flight Training**	**Optional Ratings**	**Medical Certificate**
National Private Pilot's License (NPPL) Minimum age: 17	Aviation Law Operational Procedures Human Performance & Limitations Navigation & Radio Aids Meteorology Aircraft General Knowledge Principles of Flight Flight Performance & Planning Communications	Minimum 32 hours flight time including 22 hours dual instruction and 10 hours solo flight time which must include 4 hours solo cross-country time with one flight of at least 100nm having full stop landings at two aerodromes other than the departure aerodrome.	None	Medical Declaration
Private Pilot's License (PPL) Minimum age: 17	AS Above	Minimum 45 hours flight time including 25 hours dual instruction and 10 hours solo flight time which must include 5 hours solo cross-country with one flight of at least 150nm having full stop landings at two aerodromes other than the departure aerodrome.	Night MEP IMC IR CFI	Class 1 or Class 2
Commercial Pilot's License (CPL) Minimum age: 18	Minimum 300 hours instruction: Air Law Aircraft General Knowledge x 4 Flight Performance & Planning x 2 Human Performance & Limitations Meteorology Navigation x 2 Operational Procedures Principles of Flight Communications	Minimum 150 hours including 80 hours dual instruction and 70 hours pilot-in-command (PIC) of which 20 hours must be cross-country including a flight of at least 300nm in visual flight conditions, having full stop landings at two aerodromes other than the departure aerodrome, 5 hours shall be carried out in a complex aircraft type, 5 hours shall be flown at night and 10 hours instrument flight instruction.	MEP IR CFI	Class 1
Airline Transport Pilot's License (ATPL) Minimum age: 21	Minimum 750 hours instruction: Subjects as above	Minimum 1500 hours flight time including 500 hours multi-pilot operations (transport or commuter aircraft category), 500 hours as PIC under supervision, 200 hours cross-country of which at least shall be as PIC, 75 hours instrument flying, 100 hours night flying as PIC or co-pilot.	Inclusive CFI	Class 1

In order to gain a license, a prospective pilot must demonstrate they can fly an aircraft unaided and alone. Much of this is done within the confines of their airfield's circuit pattern, but flights in the surrounding area for solo navigation training and flights away to other airfields for experience are also required. As such, student pilots make up a small proportion of GA flying, specifically 5.3% according to the 2011 survey.

The nature of GA resulted in the data gathered from UK GA accidents for this thesis comprising information pertaining to many levels and mixes of license and experience, as well as many different aircraft types. GA is an industry where a less qualified pilot (a PPL with 2200 hours) may actually be more experienced than a highly qualified pilot (a newly qualified ATPL with 1650 hours). The training they will have received and the nature of their flight experiences mean they are in many ways mutually exclusive to each other, yet still have many common traits. This not only presented a challenge in the analysis of the data, but also proved to highlight how experience can be a good indicator of skill and knowledge, but should not be the only consideration when determining accident causes.

3.1.3 Training for the (N)PPL

Regulations require pilots to fly a minimum of 45 hours (32 hours for the NPPL) including 10 hours solo time (CAA, 2013). In most cases more than the minimum is required in order to reach the standard required to pass the flight test. Training is structured into 19 individual exercises, some of which contain their own separate sections (Table 2, p35).

Enrolling on a full time training course abroad where good weather can almost be guaranteed reduces the time taken, a typical course lasting six to eight weeks. Training in the UK can be intermittent, weather unsuitable for learning to fly frequently interrupting, delaying and cancelling lessons. These delays extend the time and cost of gaining the license as lessons need to be repeated and refreshed following each delay. Depending on the prevailing weather conditions during the period of training, the number of lessons taken per week and the natural aptitude of the student, gaining an (N)PPL in the UK may take a few weeks or several months.

Table 2: PPL flight exercises (Adapted from Thom, 1994)

Exercise number and contents

1. The Aircraft
   - Familiarisation with external and internal parts and functions of the aircraft
2. Before and After Flight
   - Pre-flight preparation
   - Starting and stopping the engine
   - Post-flight actions
3. Experience Flight
   - Experience some of the sensations of flying in a light aircraft
   - Familiarisation with basic procedures
   - Gain a visual awareness of the outside environment
4. Effects of Controls
   - Primary and secondary effects of each control
   - Trimming
   - Effects of airspeed and slipstream
   - Effects of power changes
   - Effects of flaps
   - Use of carburettor heat
   - Mixture control
   - Use of the Radio
   - Cabin heating and ventilation
5. Taxying
   - Use of power and brakes to control taxying
   - Turning
   - Ground surface
   - Wind effects
   - Taxying rules
   - Marshalling
6. Straight and Level
   - At constant power
   - At a selected airspeed
   - Cruising with flap extended
7. Climbing
   - Forces acting on the aircraft in a climb
   - Balancing power and aircraft attitude in a climb
   - Angles, rates and speeds in different climbs
8. Descending
   - Glide descent
   - Powered descent
   - Use of flap
   - Sideslipping
9. Turning
   - Medium level and rate one turns
   - Climbing turns
   - Descending turns
   - Turning onto selected headings
10. Stalling and Slow Flight
    - Theory of stalling
    - Practise stall recovery
    - Associated checks
    - Theory of slow flight
    - Use of power
    - Control effectiveness in slow flight
11. Spin Avoidance
    - Theory and causes
    - Recognition and awareness
    - Recovery techniques (theory only)
12. Take-off and Climb
    - Wind direction on take-off
    - Runway surface, condition and length
    - Use and effect of flaps
    - Setting attitude and speed in the climb
13. Circuit, Approach and Landing
    - Introduction to the circuit, normal approach and landing
    - The go-around
    - Departing and joining the circuit
    - Flapless approach and landing
    - Glide approach and landing
    - Crosswind operations
    - Short-field operations
14. First Solo
    - First Pilot-in-Command flight
    - One circuit and land
15. Advanced Turning
    - Steep level turns
    - Recovery from unusual attitudes
    - Steep descending turns
16. Forced Landing
    - Landing without power outside the circuit
    - Selecting appropriate landing site
    - Emergency checks and radio call
    - Making the landing
    - Ditching in water
17. Precautionary Landing
    - Landing with power as a precaution
    - Selecting appropriate landing site
    - Overflying the landing site to check suitability
    - Making the landing
18. Navigation
    - Flight planning
    - Take-off and setting initial heading
    - Flying headings to keep track considering wind velocity
    - En-route navigation, speeds, ETAs, checks and corrections
    - Turning points
    - Radio use
    - Arrival at the destination
    - Diversions
    - Emergency and lost procedures
19. Instrument Flying
    - Instrument appreciation
    - Controlling the aircraft
    - Sensory illusions
    - Straight and level, climb, descent, turning and unusual attitude recovery
    - Introduction to partial panel

3.1.3.i Theoretical examinations

Prior to flight training, whichever course is chosen, preparation must be undertaken for the theoretical examinations. The requirements are the same for both the NPPL and PPL, students being expected to achieve a minimum pass mark of 75% in each of the nine mandatory theoretical modules, divided into two sections: a) common subjects; Air law, Meteorology, Communications and Human performance; b) Specific subjects concerning the different aircraft categories; Operational Procedures, Navigation, Aircraft General Knowledge and Principles of flight, Flight performance and planning, Communications. These can be studied concurrent with flight training as long as they are completed within 18 months and the PPL applied for within 24 months of passing the final examination taken. Many clubs and schools prefer that Air Law and Navigation are successfully completed before the pilot can make their first solo flight and first solo cross country flight respectively. Furthermore, it is a requirement to undertake a minimum of 100 hours study and instruction, as stated by EASA (2011, p115):

"An approved course shall comprise at least 100 hours of theoretical knowledge instruction. This theoretical knowledge instruction provided by the ATO should include a certain element of formal classroom work but may include also such facilities as interactive video, slide or tape presentation, computer-based training and other media distance learning courses. The training organisation responsible for the training has to check if all the appropriate elements of the training course of theoretical knowledge instruction have been completed to a satisfactory standard before recommending the applicant for the examination".

Module content is designed to give pilots a solid working knowledge of all aspects of commanding an aircraft, including technical operation, the atmosphere in which it is operated and the potential physiological and psychological effects associated with flying an aircraft. This knowledge is imperative if a pilot is to fly safely with the minimum risk of accidents and falling foul of the law.

The routine of practising examinations from a bank of current and previously used questions is commonplace at many flying schools and results in some students learning the answers to set questions, without necessarily understanding the theory behind them. This practise of rote learning is conducive to the material, given the fact that examinations are multiple choice in nature. For students who use this method of learning, whilst it may allow them to pass the examinations, their lack of understanding can be dangerous and the consequences are potentially fatal; lack of knowledge in any of the modules could compromise a pilot's ability to make good decisions whilst flying in either normal or abnormal situations, the latter providing the most opportunity for an under prepared pilot to make mistakes. The new EASA regulations, however, provide an opportunity for flying schools and instructors to ensure that the basics at least are taught in a constructive and effective manner.

3.1.3.ii Medical requirements

Prior to the first solo flight, a medical certificate for a PPL or a medical declaration, endorsed by a General Practitioner (GP) for an NPPL must also be obtained. For the NPPL, if the pilot's GP considers the individual to be sufficiently fit to comply with the UK Driver and Vehicle Licensing Agency (DVLA) requirements for professional driving, they endorse the declaration, form SRG 1204, as group 2 and the pilot may fly solo upon receipt of their license. If the pilot is only considered fit enough for private driving, it is endorsed as group 1 and, as stated in 3.1.2 (p31), they will be required to carry a safety pilot at all times (CAA, 2013). For all other licenses, there are two main classes of medical certificate; class one and class two. Class one is a thorough examination including audio and cardio tests carried out initially at the CAA headquarters and is only required for a commercial license. The class two medical is less intrusive, but still assesses a pilot's health and fitness against minimum standards and is required for issue of the PPL. As the examination is specific to aviation, only Doctors authorised to practise as an Aviation Medical Examiner (AME) may perform it. The appropriate medical certificate must be obtained prior to a student pilot making their first solo flight (no medical is required whilst flying with a qualified Instructor).

3.1.3.iii The flight test

Following completion of flight training to the satisfaction of their Instructor, a student pilot is required to take a flight test with an authorised CAA Examiner. The test is designed to determine the applicant's suitability to command a light aircraft in line with the privileges of the license being applied for and must be carried out in the same type or class of aircraft in which the student received instruction (CAA, 2013). The Examiner assesses not only the student's ability to fly the aircraft accurately, but also safely, the latter tending to carry more weight than precision at PPL level. Lasting approximately two hours, the student may be asked to demonstrate any or all of the skills they have learned within the training curriculum, including planning, aircraft handling, navigation, emergency procedures and circuit flying. Only if the student completes all manoeuvres to the standard required, will the examiner pass the candidate and release them to apply for their license to be ratified by the CAA. It is possible for a student to fail one section of the test and gain a partial pass, but the failed section must be repeated in a separate flight test (CAA, 2013).

3.1.3.iv License privileges

Once an individual has obtained a medical certificate and successfully passed the theoretical examinations and the flight test, they are free to fly according to the privileges of their license. Each pilot is trusted to remain within the boundaries of those privileges with minimum supervision and monitoring and to undertake the responsibility of commanding an aircraft in a professional and sensible manner. Deviation outside the privileges of their license could result in punishment ranging from a fine and revocation of the license to potential criminal proceedings, depending on the severity of the offense.

Details of license privileges are stated in the Air Navigation Order (ANO), Schedule seven, articles 64 to 71 and 78 (CAA, 2009), but in brief the holder of an (N)PPL:

- Cannot receive any form of remuneration for any flying done.
- Must remain clear of cloud and in sight of the surface at all times, only in the specified hours of daylight and outside designated controlled airspace.
- Within the hours of daylight, must not fly in any circumstances requiring flight on instruments, concurrent with the need for an instrument rating.
- Before carrying passengers must, within the preceding 90 days have performed a minimum of three take-off and landing manoeuvers as pilot in command.

Holders of an NPPL will not be able to digress from these regulations as the license cannot legally accommodate additional ratings and endorsements; it is purely a license for pleasure flying in daylight and good weather conditions. As indicated in Table 1, there are a number of possible additions to the PPL which, if the license holder wishes to obtain them, will revoke some or all of the restrictions listed above. Each requires the pilot to undertake approved training with a qualified Instructor and comes at additional cost. Furthermore, as stated in the ANO, should the pilot undertake the Instructor rating, they may then receive associated remuneration for services provided in that context.

3.1.4 Becoming a Commercial Pilot

The number of commercially qualified pilots in UK GA as shall be described in 3.2.4 (p46) and the influence they have on its demographic and culture warrants a description to provide a deeper understanding of the different qualifications of pilots flying within UK GA.

There are two main routes to becoming a Commercial Pilot in the UK. The first is the modular route, which can result in the student learning to fly at a number of different schools, although this is not always the case and the second is the full time integrated course which can only be undertaken with one Approved Training Organisation (ATO).

3.1.4.i The modular route

A full time, 18 month ab inito ATPL training course can cost in excess of £100,000 when considerations for accommodation and living expenses are taken into account in addition to the training. Thus the modular route provides a financially less intensive method of achieving the goal of a commercial license; the individual starts with a PPL, builds their experience to a minimum of 200 hours and subsequently adds a multi-engine piston rating (MEP), night rating and instrument rating (IR) before taking the CPL flight test. Approved CPL and CPL/IR courses are also available for pilots wishing to upgrade in a more structured, briefer time period. If pursued in a considered manner, the modular route is not necessarily deemed to be a lesser path, but there is more consistency and apparent commitment in following an integrated course.

3.1.4.ii The integrated course

To train on an ab initio course, a candidate must, in most circumstances, pass a rigorous selection procedure, usually consisting of tests in mathematical thinking, coordination, a psychometric assessment and an interview. These are conducted by EASA Approved Training Organisations (ATO) and are the only institutions authorised to provide ab initio training.

The student then embarks on a 14 month continuous programme of both theoretical and practical flight instruction, only usually breaking for a short period over Christmas. Some ATOs perform in-house progress tests to assess student development and insist these are successfully completed before being allowed to sit the official examinations. Successful completion of the 14 month course leads to the final stage where training is undertaken in simulators to bring the student to an advanced level of training pertinent to becoming a First, or Second Officer within an Airline. Whichever direction is preferred, in order to gain a commercial license, the ATPL theoretical examinations must also be completed.

3.1.5 Post licensure flying in UK GA

For the most part, GA flying in the UK is done from local flying clubs where pilots pay a fee to become a member and make further payments for the hire of aircraft. Clubs may be small with only a handful of aircraft or large where training as well as private hire is advocated from a fleet of different aircraft types and sizes. It is common to find more than one club at any given aerodrome, particularly those that are larger and well equipped with long asphalt runways and radio aids for more advanced flying. Correspondingly, some smaller aerodromes are wholly owned by one club and are the only users (except for visitors), tending to be those with limited facilities and shorter, grass runways.

Club flying, beyond training and licensing includes a wide range of activities and will depend on the aims, interests and financial circumstances of the pilot. In the 2011 survey, 93.5% of PPL holders stated they fly mostly for the purposes of pleasure, this being the reason for 94.5% of all license holder respondents. The term pleasure is very generic and again, depending on the individual can mean very different things, from leisurely sight-seeing flights to challenging routes abroad.

Restrictions to the PPL mean, in general that the favoured activity is a route from the departure aerodrome to a second for refreshments and either returning via a different route (if possible) or perhaps a third aerodrome. Given that the survey revealed less than 40% of PPL holders to have either a night or IMC rating, most pilots are restricted to performing these flights in good weather conditions during the prescribed daylight hours (this changes daily, 'night' being officially defined as when the sun's disc is 6° below the horizon at sunset until it is again 6° below the horizon at sunrise (Oxford Aviation Services, 2007); at PPL level this is translated to being 30 minutes after the published time of sunset until 30 minutes before the published sunrise time (Thom, 1994). Similarly, with only a small percentage (<6%) recording an MEP rating, the majority of this flying is done in single engine aircraft.

The skill of flying a light aircraft is not in itself an overly demanding one, assuming the individual has received a reasonable standard of training and has followed all procedures with diligence. The challenge comes in using that skill to safely get the aircraft from point A to point B, the latter providing more complexity in that it is less or even unfamiliar territory. It is the reward of achieving this that drives the enthusiasm for many, but to attempt such a flight, one must first be able to afford it.

3.1.6 The cost of UK GA flying

Depending on where an individual learns to fly, how quickly they can pass the flight test and to an extent, the weather, a PPL issued in the UK can cost upwards of £10,000. To many, this is a substantial investment which has been made through savings, loans and other financial avenues. Before, during or after gaining a license, pilots must also purchase at least the basic equipment to be able to fly; maps, flying guides, navigation equipment, flight bag and a headset. The outlay for these items (assuming a reasonable quality) could be in excess of £400 or even more. Club membership is typically around the £50 to £200 per year mark, depending on location, size and facilities and the remote location of some results in additional travel expenses.

The biggest outlay for a UK GA pilot over the period of their licensure is aircraft hire. Again this varies from club to club, but typical costs will be £150-170 per hour for a two-seat, single-engine trainer and up to £180-200 per hour for a four-seat touring aircraft, such as the Piper PA-28. Multi-engine aircraft can be in excess of £300 per hour. Complimentary to regulations as laid out in FCL-740.A, (b) of CAP 804, most clubs stipulate a minimum number of hours that pilots must fly per month in order to retain a minimum level of currency. The regulations state that to retain automatic revalidation of their license, pilots with a single engine rating must:

"within the 12 months preceding the expiry date of the rating, complete 12 hours of flight time….including 6 hours as PIC; 12 take-offs and landings; and a training flight of at least 1 hour with a flight instructor." (CAA, 2013)

Further to this, it is stated that unless a pilot can maintain the given level of currency, they must pass a relevant proficiency check flight with an examiner (CAA, 2013). Thus in order to maintain currency (which will be shown in this thesis to be an important factor on UK GA accidents) a club member must fly and therefore pay for a minimum of one hour's flying every month. Because of the financial burden, there are a number of pilots who will allow their currency to lapse and instead opt to fly with an Instructor immediately before making a pleasure flight.

For an initial outlay of several thousand pounds, a pilot may decide to buy into a syndicate who jointly own and run an aircraft. Often involving a small monthly fee for hangarage, maintenance and additional costs, the hourly rate can be substantially less and thus overall can be much cheaper. Some syndicates will request a minimum level of experience before a pilot is allowed to buy a share of their aircraft and most will abide by the regulations in terms of ensuring members maintain minimum currency in the same manner as a club. It is of course conceivable that a number of groups do not and will operate under a 'self-regulated' system whereby the individual is responsible for their own currency. This self-regulation is potentially dangerous, as alluded to previously and of course, those who do not maintain minimum currency are also violating regulations. This practise would be difficult to monitor and police, more so where an individual owns an aircraft and, for example, operates from a private airstrip.

Although GA has been shown here to be an expensive pastime, Lober (2004) determined the employment status of most UK GA pilots to be biased towards higher social economic groups, 92% being in either managerial, professional or semi-professional/technical positions. Thus an extraction could be made that only those with higher than average incomes partake in GA activities.

3.1.7 Summary of Part 1

The first part of this chapter has given a broad overview of the general state of UK GA; who operates within it, the level of license they carry, the aircraft they fly, how they gained their licenses, where they fly and type of flying undertaken, the costs involved and the potential dangers that lead from those costs. The aim was to give the reader an understanding of the culture within UK GA and the paths taken by those involved to be a part of it. Later in the thesis, as accidents and their causes are discussed, this understanding will help the reader envisage the environment surrounding the accidents and the pilot involved and have a clearer insight as to the possible circumstances surrounding the event.

The second part of this chapter introduces the UK GA survey, performed as part of this thesis to gather information on the specifics of pilots partaking in GA activities within the UK. This information was needed to perform both comparison to and statistical analysis with the data collected from the AAIB accident database.

3.2 The UK GA Survey and Pilot Demographic

3.2.1 Reasons for undertaking the survey

In researching UK GA accidents, it became evident that no current data exists on the particulars of pilots within the UK GA population, beyond their age and level of license. This information is only published in CAA records up to 2008, but is not provided for consecutive years; it is given as a split of pilot sex and license annually from 1994 to 2000, then for age and license for 2004, 2005 and 2008. Furthermore, the figures presented are based on those with a valid medical certificate, thus cannot be assumed to be wholly accurate as there may be a (small) number of pilots who continue to fly without one (indeed accident reports used in the research for this thesis cite pilots who did not have a valid medical at the time of the occurrence). This information is insufficient to allow any analysis of accident pilots compared to the population, the data given in AAIB accident reports containing specifics of the pilot's experience.

Only one other survey has captured any information pertaining to UK GA in recent years; Lober (2004) undertook the General Aviation Small Aerodrome Research Study (GASAR) in a similar attempt to outline the demographic of GA pilots. Although useful for comparison, the data within Lober's survey was gathered over a period of approximately 8 months from October 2002 to mid-2003 and as such is more out-dated than the latest CAA figures. Thus it was deemed necessary to devise a questionnaire, approved by the University Ethics Committee to establish this information. It was also seen as an opportunity to find out more about the UK GA population in terms of licenses and ratings held, frequency of flying, how various factors affect that frequency, self-assessment of ability and other pertinent information.

3.2.2 Gathering and using the data

After determining the information needed, a survey was compiled and submitted through the University of Leeds' ethics approval Committee, which approved the content and method. It was subsequently uploaded to a commercial survey web site in preparation for volunteers to complete it (Appendix A). Pilots were asked to declare their age group, license and ratings held, reasons for flying, main type of aircraft flown and experience levels before answering more specific questions concerning other information.

As the target demographic was UK GA pilots, the survey was advertised to 120 UK flying clubs and schools mostly via e-mail, a few selected organisations also receiving a letter, asking that the associated URL be forwarded to members. Each e-mail and letter (Appendix B) was accompanied by an information sheet giving background reasons for the survey and information as required by the Ethics Committee (Appendix C). An initial poor response prompted follow up e-mails, but unfortunately little impact was noted. As an alternative method, the information sheet and URL were placed on a forum for one of the UK's best-selling GA magazines. This prompted a much better response, ultimately resulting in a total of 403 participants recording their details during September and October 2011.

Assuming a mean membership of 100 pilots per school/club, this represented a disappointing return rate of 3.4%. Whilst the return rate was deemed to be unsatisfactory the actual number of returns was considered adequate to be a representative sample of the population given the broad spread of responses received and thus was accepted for analysis. Lober (2004) also received disappointing return rates, ultimately receiving 719 responses from an estimated target audience of 40,000 pilots (the approximate number of all licensed pilots in the UK), giving just a 1.8% response rate. Despite the disappointing responses from both surveys, given that no other such data on UK GA exists in the public domain, both surveys should be considered as valuable resources.

Once the data had been collated it was analysed using both quantitative and qualitative methods. Quantitatively the data was separated into its various categories and where possible, cross analysed with CAA data for 2008 (the most up to date) and the accident data sample to determine similarities and differences and whether any were statistically significant. Comparison, where appropriate, was also made to Lober's findings. As the qualitative data had been gathered through use of Likert scales, this was translated into graphical representations for ease of evaluation.

3.2.3 Pilot age

Age groups were found to be representative of the 2008 population in terms of distribution, but were positively skewed by 10 years (Figure 1), the greatest concentration of age for both being between 41 – 60 years.

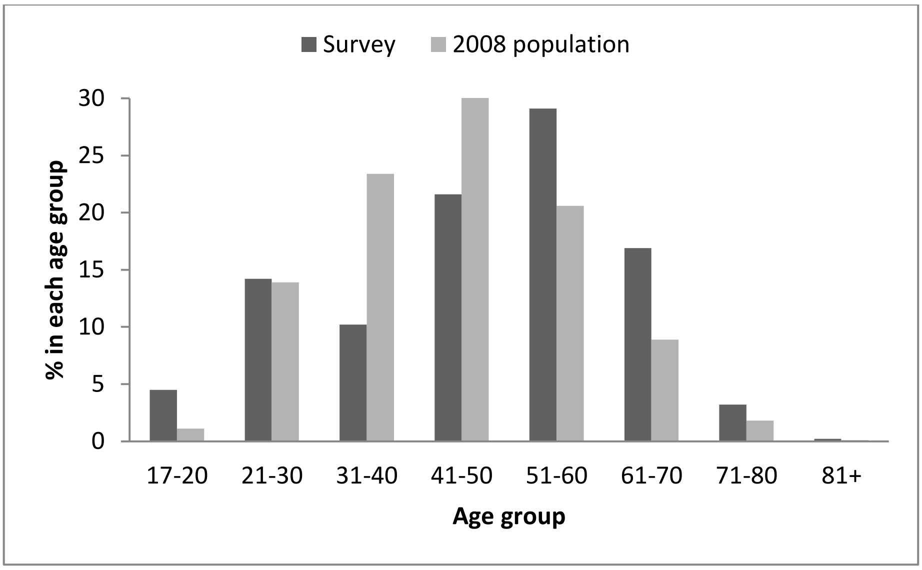

Figure 1: Distribution of age groups for both UK pilot population and survey pilots

As a note of interest and continuity, Lober (2004) calculated the mean age of pilots from the GASAR survey to be 50.7 (N=719, SD 11.66). The calculated mean age of the population as at 2008 was 45.1 years (N = 37371) and by license level was 46.5 (N = 20136) for (N)PPL, 40.7 (N = 4664) for CPL and 48.8, (N = 12411) for ATPL.

Regarding the relationship between age group and level of license held, no discernible distribution pattern was noted for any one license but it was noted that due to the prominence of the (N)PPL within the survey sample, this license distribution closely resembled that of the overall survey results (Figure 2).

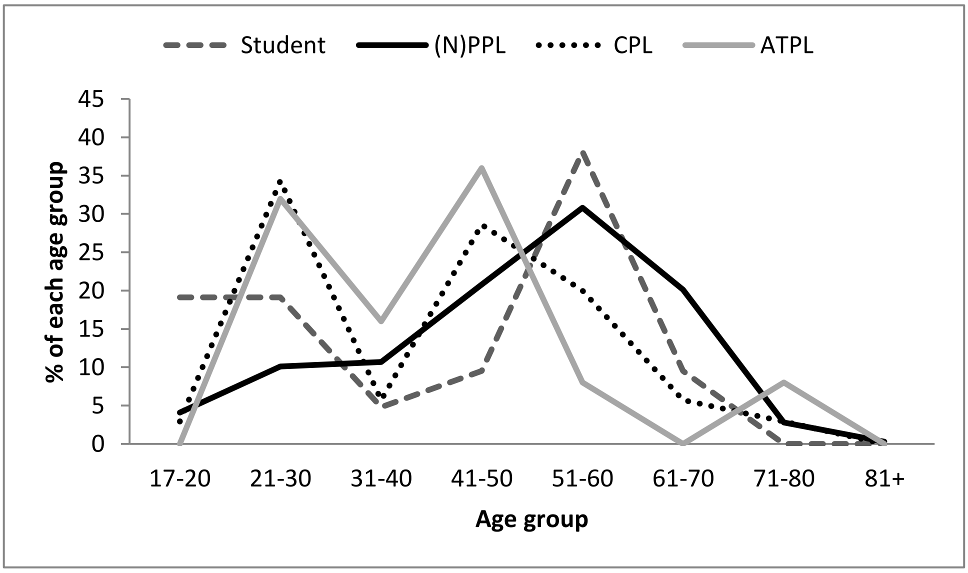

Figure 2: Survey distribution of license level by age group

Of interest was the mirroring of distribution of CPL and ATPL level licenses, both showing a dip in representation for 31 – 40 year olds compared to those either side. This dip was also repeated for students, only (N)PPL showing an increase for that age group. These drops in representation for CPL and ATPL license levels in this age group explain the dip apparent in the overall distribution histogram, Figure 1. A potential reason for this, which will be explored later in this Chapter are the terrorist attacks in the USA on September 11th, 2001.

3.2.4 Licenses and ratings

By far the most prolific license held was the(N)PPL by 79.7% of respondents. The two main commercial licenses, CPL and ATPL accounted for 8.8% and 6.3% respectively, whilst 5.2% declared themselves to be student pilots

Additional ratings to each license gave an insight into the reasons for some of the commercial level licenses apparent in UK GA, 68.8% of CPL holders and 44% of ATPL holders having Instructor ratings, suggesting they work in the GA industry (Figure 3).

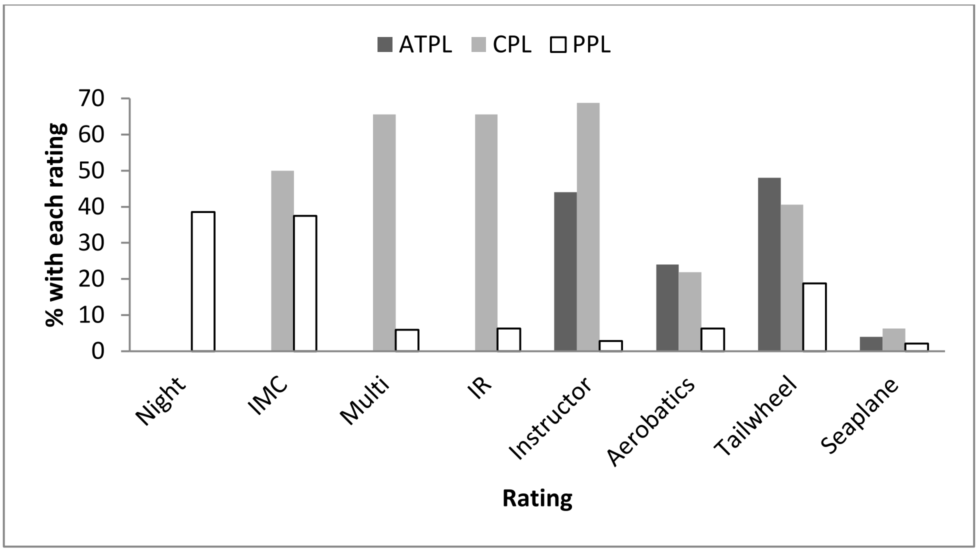

Figure 3: Ratings additional to basic Licenses held

Whilst more than a third of PPL holders added a Night and/or IMC rating to expand the envelope of restrictions on their license, few had opted to be rated on multi-engine aircraft or to take the Instrument Rating. More than two thirds of CPL holders added multi-engine and Instrument Ratings in addition to their Instructor rating, possibly as they were taking the modular route to becoming professional Pilots. The aerobatics, tailwheel and seaplane additions are seen more as recreational in nature, although aerobatics is widely considered to be beneficial in improving an individual's overall piloting skills. It is surprising therefore to find that these ratings are favoured more by commercially licensed pilots than PPL holders, considering that figures following will demonstrate most (N)PPL holders fly for pleasure.

3.2.5 Reasons for flying

From statements made earlier in Chapter 3 concerning the broad nature of GA, it might be expected that pleasure does not necessarily hold a monopoly in reasons for people being part of it. That said, the survey was distributed only to flying schools and clubs, thus the opportunity for those operating in other forms of GA was strictly limited. Pleasure was stated as the main reason for partaking in UK GA by 93.5% of respondents, despite the fact this part of the questionnaire allowed for multiple reasons.

Of those who stated instructing to be one of their main reasons for flying within GA, 32.4% said it was their only reason. The category of 'other' included personal flying for business, aerobatic displays and ferrying aircraft.

3.2.6 Aircraft classification

This refers to the class of aircraft flown by pilots in UK GA; fixed wing or helicopter, powered or un-powered, single or multi-engine and other categories as shown in Figure 4.

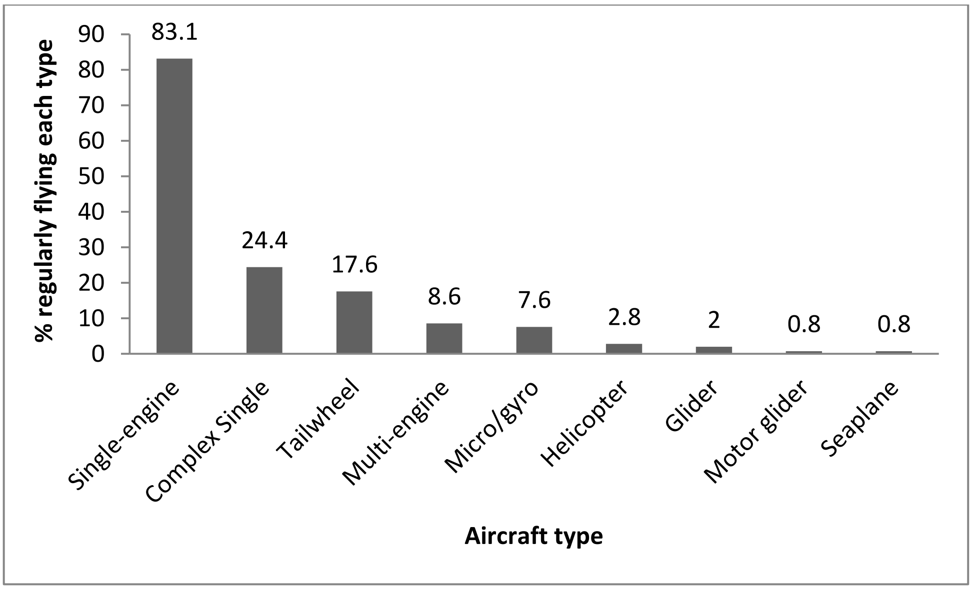

Figure 4: Type of aircraft regularly flown by all pilots in UK GA

As the cheapest and most accessible aircraft at most clubs, single-engine aircraft are predictably the most common type flown. Whereas multi-engine aircraft are very expensive to hire (£300+ per hour), complex single-engine aircraft, although relatively expensive compared to their basic counterparts, are a cheaper way to enjoy a more powerful aircraft, with retractable undercarriage and variable pitch propeller (for improved performance and efficiency). Hence nearly a quarter of all GA pilots have up-graded to this variant. Tailwheel aircraft are not as expensive as complex singles, but are notoriously difficult to control on the ground and comparatively few in number. Despite this almost a fifth have declared it to be a type they regularly fly. Figure 4 above relates to the various types flown by all pilots within UK GA, however figures for (N)PPL alone show little change, with the exception of multi-engine aircraft, where only 2.8% of PPL fly them regularly, compared to the 8.6% seen here.

3.2.7 Frequency of flying

To assess how well UK GA pilots are able to maintain minimum currency, the survey requested information on how often they are able to fly; their frequency of flying. Initial results showed that more than a third of UK GA pilots fly less than once a week, but more than once a month, more than 40% fly once a week or more and around a quarter fly once a month or less. These figures however, were skewed by those with commercial license who fly regularly in their jobs (mostly as Instructors). This does, however, represent the data gathered from accident reports as these also include professional pilots.

As will be discussed in Chapter 6, currency is an issue of safety and commercially licensed pilots working in GA will not be exposed to the dangers of a lack of currency, but (N)PPL holders are, thus it was important to look solely at their frequency of flying. As can be seen from Figure 5, 29.5% fly once a month or less which, regardless of the length of each flight, puts them at risk due to low currency.

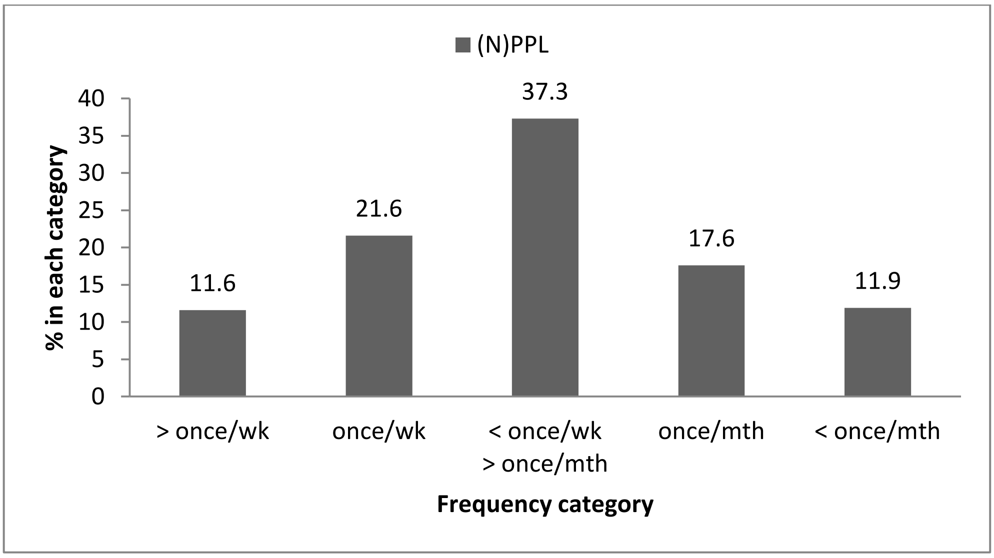

Figure 5: Frequency of flying, (N)PPL holders only

Compared to all pilots, only a third of (N)PPL pilots manage to fly once a week or more, a further third flying two to three times a month. When put into the context of age groups it was noted that whilst younger pilots (age group 17 – 30, N = 45) are evenly distributed in terms of flying frequencies of less than once a week, they are the fewest in terms of those flying once a week (Table 3). The peak observed in Figure 5 results from a preference for pilots aged 31+ to fly two or three times a month, 39.3% (N = 272) stating this to be their habit.

Table 3: Percentage of pilots in each frequency category by age group (N = 317)

	Age group/% in each category			
Flying frequency category	**17-30**	**31-50**	**51-70**	**71+**
	N = 45	**N = 100**	**N = 162**	**N = 10**
> once/wk	13.3	5	15.4	0
once/wk	15.6	21	22.2	20
< once/wk > once/mth	24.4	42	37	50
once/mth	24.4	17	15.4	20
< once/mth	22.2	15	8	0

Considering how cost affects the frequency of flight, there is disparity between those aged 17 – 30 and those in the 51 – 70 age group, just 4.4% of the younger group declaring that cost does not affect them at all, compared to 25.3% of those aged 51 – 70 (Figure 6).

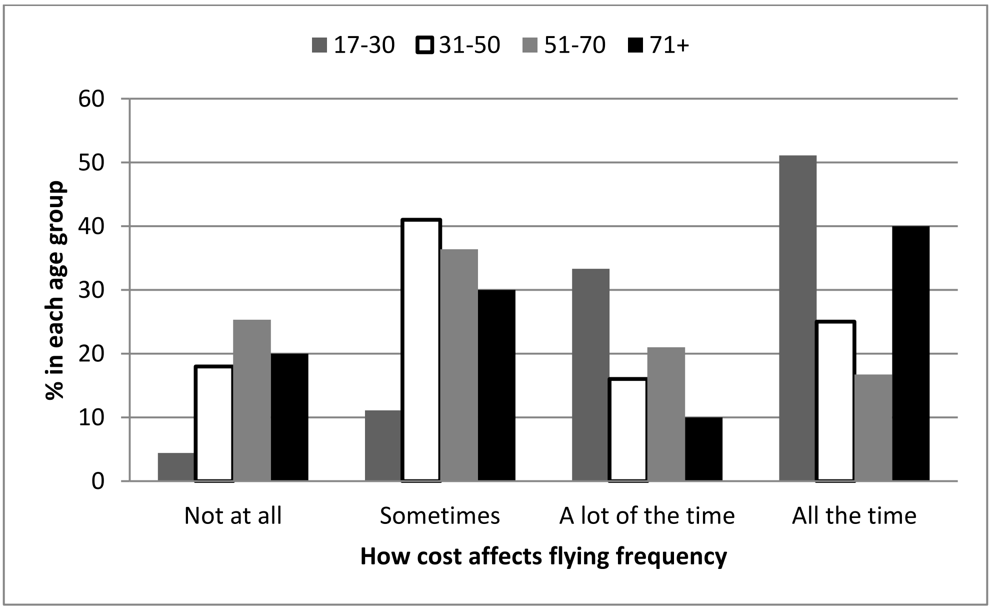

Figure 6: Extent to what each age group is affected by cost on frequency of flight

In contrast, 51.1% of 17 – 30 year olds state that cost is an issue all the time, just 16.7% of the 51 – 70 age group agreeing with that statement. This can be directly linked to frequency, where it was demonstrated that 51 – 70 year olds are those who fly most often (Table 3).

3.2.8 Pilot flight experience

There are two main categories of experience in aviation, each of which is split into two further types. Flight experience is classed as total or type, *total* being all flight hours logged and *type* being hours logged on a specific type (make and model) of aircraft. Currency is split into hours flown in either the preceding period of 90 days, or 28 days. Where pilots in the survey had experience on more than one type of aircraft, they were asked to provide their hours on the type most often flown. The broad nature of activities in UK GA and a contribution from all levels of license resulted in a wide range of experiences (Table 4).

Table 4: Maximum and minimum levels of survey pilot experience by experience category

Experience category	Survey Minimum (hours)	Survey Maximum (hours)
Total	6	25000
Type	0.5	5000
Last 90 days	0	300
Last 28 days	0	103

Students and some (N)PPL pilots account for the lower end of flight experience and commercially qualified pilots plus a small number of PPL holders the top end. In terms of currency, the lower end is predominated by (N)PPL holders, but includes a small number of CPL and ATPL holders, the reverse being true of the top end.

The overall mean levels of experience are given in Table 5, Standard Deviation demonstrating the wide range of values found for each category. It should be noted that not all respondents gave complete information, thus ‘N’ is not consistent with the total number of returns.

Table 5: Mean levels of all survey pilot experience

	Total	Type	Last 90	Last 28
Mean	982.6	305.1	26.9	9.5
SD	2340.03	508.335	47.114	17.145
N	399	309	401	396

Eliminating CPL, ATPL and student pilots, reveals the mean experience levels of the majority of UK GA users, showing it to be considerably less than for the whole survey sample (Table 6). This demonstrates the influence the experience of commercial level pilots has on the overall data, given there are only 60 in the sample. However, as an integral part of UK GA, this does not in any way suggest that it taints the survey sample data, especially given that, as will be shown in the accident data, CPL and ATPL holders are also prone to accidents.

Table 6: Mean levels of (N)PPL survey pilot experience

	Total	Type	90 days	28 days
Mean	620.8	255.8	15.3	5.4
SD	1338.977	405.890	18.737	7.428
N	317	241	316	313

A point of interest noted during analysis of the data was for those aged 41 – 50 to have considerably more experience than other age groups, with the exception of the oldest, particularly in terms of total and type experience. Accordingly the specifics of experience versus age was further evaluated, resulting in the information in Table 7, which also shows the split between students, (N)PPL and commercial license holders for added clarity.

Table 7: Mean experience levels, all survey pilots, by age group, with license level split

Age group	Mean Experience by Category (hours)				License level		
	Total experience	**Type experience**	**Last 90 days**	**Last 28 days**	**Student %**	**PPL %**	**Commercial %**
17-20	85	54.8	11.5	3.4	22.2	72.2	5.6
	SD 55.6	*SD 46.5*	*SD 8.7*	*SD 3.3*			
21-30	522.6	207.7	57	20.3	7.1	57.1	35.8
	SD 867.7	*SD 308.9*	*SD 85.5*	*SD 31.4*			
31-40	474.7	147.9	22	7.5	2.4	82.9	14.7
	SD 1082.5	*SD 147.0*	*SD 32.0*	*SD 11.1*			
41-50	1565.2	374.8	34.8	12.1	2.3	75.9	21.8
	SD 3109.5	*SD 709.3*	*SD 56.7*	*SD 19.8*			
51-60	845.5	328.2	19.5	7.0	7.0	85.2	7.8
	SD 1545.9	*SD 506.1*	*SD 25.2*	*SD 9.7*			
61-70	946.9	362.5	15.4	5.7	2.9	94.1	3.0
	SD 2197.1	*SD 503.6*	*SD 15.2*	*SD 7.4*			
71-80	3153.5	434.1	10.8	3.7	0	75	25
	SD 6743.0	*SD 480.1*	*SD 6.5*	*SD 3.0*			

For comparison to these figures, Lober (2004) calculated pilots in his survey to have a mean level of total experience totalling 514.6 hours (SD 576.2) after excluding 10% of respondents as they had excessive commercial experience, which he felt skewed the figures outside the bounds of a representative figure for UK GA. Having determined a mean period of licensure for these pilots (14.7 years for all respondents) he estimated a mean of 46.4 hours flying per year, equating to a value much less than that for the (N)PPL pilots in this survey (62.1 hours using last 90 days data, 70.4 hours calculated from last 28 hours data).

3.2.9 Discussion

The data presented here is an overview of the situation regarding pilots within UK GA for the two month period of September and October 2011, thus can only be accepted as a snap shot of the industry within that period. In order for the data to be substantive, the survey would need to be carried out on a regular basis over a sustained period of time; annually over five years for example. Without some form of authoritative support, from the CAA for example, there is likelihood that any such venture would not yield the kind of response rate required to allow the data to be considered as either representative or definitive, given the responses received in both this survey and that of Lober.

The trends that might be revealed from such a study would be invaluable to those who wish to improve safety within GA both in the UK and further afield. Accident statistics in various forms are available on GA in the USA through the Nall report; an annual summary of GA accidents produced by the Aircraft Owners and Pilots Association (AOPA). They are also available in a generic form from the CAA, such as the Regulatory Review of General Aviation in the UK (CAA, 2006) or more detail in CAP 667 (Review of General Aviation Fatal Accidents, 1985 – 1994) (CAA, 1997). There is also the Strategic Review of General Aviation in the UK (CAA, 2006) which discusses the social and economic trends along with the structure of UK GA, some of which has been extrapolated from Lober's GASAR survey. The Effect of JAR-FCL on General Aviation Safety (CAA, 2007) is another publication where some aspects of UK GA safety have been reviewed, but the specifics of accidents are not determined and again, a generic presentation is given on the types of occurrence that took place and how often, concluding that licensing changes introduced in 1999 did not affect safety. Useful and interesting as they are, these documents are now outdated and the information given does not attempt to link accident trends to current population trends with a view to exposing any weaknesses in the system and strengthening them.

Certainly the data in these documents can be used in a number of different ways, but unlike commercial aviation where pilot training and refresher training is strictly regulated and properly recorded and their hours monitored, when it comes to accident investigation and prevention, in GA there is no set of reliable data against which to measure the specifics of accident pilots or their experience; compared to the population, are these pilots less experienced, lacking in currency, younger or do they hold a lesser qualification and so on. If this information were available and accessible, it would be easier for regulators, flying clubs and schools (including ATOs) as well as pilots themselves to target training and improve post licensure support to address the highlighted issues.

Accordingly, the data here has been used, where appropriate to make the aforementioned measurements in the analysis of the gathered accident data, details of which will be given in the following chapter. It is acknowledged that the survey data presented here is not of the quality and consistency necessarily required to make definitive judgements, but it is the only and most up-to-date data of its kind and as such should be recognised as beneficial to the industry.

The data itself shows UK GA pilots to be generally middle aged and above, the greatest concentration of ages falling in the group aged 41 to 70, a peak evident in the range of 51 to 60 years. Taking into consideration that those from the older age groups fly most frequently and have the least issues with the barrier of cost, it is suggested that these are individuals who find themselves in a position to not only finance the flying, but who have sufficient spare time to do it; possibly retired or semi-retired mid-to-senior level professionals. This corroborates Lober's (2004) findings that the majority of UK GA pilots fall into the top three bands of employment and is also supported by a small number of this survey's respondents stating they fly in GA for personal business reasons.

Those not in a position to be able to fly as often as those in the older age groups, tend to fly two or three times a month, which more than satisfies the regulatory requirements for currency. For 30% however, the risk of losing legal currency is real which not only has added financial implications in having to fly with an Instructor before being able to command an aircraft, but puts them at potential risk of accidents (as will be discussed in chapter 6) through a decline in their flying skills. This would particularly affect those who remain at the edge of minimum requirements by flying once a month (for a minimum of one hour). For the reasons explored above, the survey reveals those most likely to fall into this category are the youngest and oldest members of the UK GA community.

It is generally accepted that flying in GA is expensive and the perception is that GA is a leisure pursuit of the wealthy (CAA, 2006), but behind the financial concerns, it has been estimated that the UK GA industry contributed £1.4 billion to the UK economy in 2005 (Lober, 2006)

Some information gathered in the 2011 survey was unsurprising, but had never previously been confirmed, only ever having been assumed through observation. Specifically, the majority of UK GA pilots hold a (N)PPL license, fly a single-engine aircraft and fly purely for pleasure. Those with a PPL who decide to add to their license mostly prefer to add a night and IMC rating. This is logical as both of these ratings allow a PPL holder to expand the usefulness and value of their license through relinquishing many of the restrictions on times they can fly and the weather conditions they can fly in. Almost a quarter have upgraded to more complex aircraft, likely for similar reasons that some add night and IMC ratings; a complex single allows a pilot to fly faster and further allowing for advancement in their flying skills and opportunities to visit aerodromes further afield, possibly abroad.

Through analysing the data on licensing and age groups, it was noted that an unexpected dip in the number of students, CPL and ATPL holders was evident for those aged 31 to 40. As suggested previously, there is a possible link to this anomaly with the attacks on the USA on September 11th 2001 using aviation as the weapon. Following these events, there was a noticeable drop in air travel for a sustained period (US Department of Transportation, 2005). This subsequently affected the rate at which pilots were recruited and trained in late 2001, most pilots entering the industry around the ages of 21 to 30. Thus ten years later, when the survey was undertaken, the same group of pilots, now aged 31 to 40, are fewer in number than those in age groups above and below.

Even regarding the most basic of information, this survey has confirmed previous assumptions about GA pilots, given a sample of pilot flying experience in the four main categories, demonstrated one of the impacts of ‘9/11’, shown how cost can affect currency and thus, potentially safety and established the broad nature of UK GA at its core. Where appropriate, further information, not detailed in this Chapter, will be referred to in subsequent Chapters of this thesis.

3.2.10 Summary of Part 2

This chapter has shown a small, but representative number of UK GA pilots to have a concentration of ages consistent with those found from the CAA figures and the GASAR survey (Lober, 2004) and confirmed a number of important factors concerning license levels, ratings, pilot experience and potential safety issues arising from the expense inherent in UK GA.

The following Chapter will explore the process of decision making, its importance in aviation and how it can influence the occurrence of accidents

Chapter 4: Decision Making in an Emergency

In the previous chapter an overview of UK GA was presented, including the steps required and different methods involved in gaining a pilot license. Additionally, the best representation of the current UK GA population was imparted from data gathered from a nationwide survey.

Within the main data sample of UK GA accidents, as shall be presented in due course, poor decision making was found to be a recurring problem and is likely to have been influential in some of the fatal occurrences. This chapter explores the mechanics of decision making to demonstrate that it is a complicated process requiring inputs of good information and experience to produce a decision with positive results. Furthermore, this chapter will discuss the decision making process, how it is affected by external factors and looks at examples from the accident data where bad decisions have resulted in an accident; reflective analysis will explain how alternatives could have minimised the severity of the situation, or prevented the accident in the first place.

4.1 Decision making and its importance in aviation

Considered as one of four sub-sets in stage one of the Human Factors Analysis and Classification System structure (HFACS; Wiegmann and Shappell, 2000), (Table 10, p70), decision making, specifically Aeronautical Decision Making (ADM) and associated errors are fundamental in every accident, whether precipitated by human error or not. O'Hare, Mullen and Arnold (2010) remarked that most aviation accidents are in fact contributed to in some way by deficiencies in pilot decision making, Murray (1997) asserting that poor decision making is a significant contributor to aviation accidents. How the pilot choses to manage the event will ultimately determine the outcome, or at least the severity of it. In accidents following Visual Flight Rules (VFR) flight into Instrument Meteorological conditions (IMC), it is the decision of the pilot to continue the flight which will have been determined as the main cause of the accident. Further decisions made once in the bad weather will have been contributory, problems such as icing, disorientation, Loss of control (LOC) or Controlled Flight into Terrain (CFIT) being the resultant consequences. How decisions are made and how they are affected by stress is an important issue to consider, particularly concerning GA pilots who at PPL level will not have had any formal training or instruction in how to formulate contingency plans to aid decision making in an emergency. They will also be lacking in the knowledge of how best to make use of the available resources to gather sufficient quality information upon which they can devise and execute good decisions.

4.2 The decision making process

To most people the act of making a decision is something that just happens. They do not recognise or understand that a complicated psychological and neurological process has taken place. For pilots, being able to understand the process is important, as the concept is based on the processing of information, thus if they can identify the key elements and enhance their information gathering, then there is a heightened probability they will make better decisions. Making decisions requires the individual to have sufficient information upon which to make the decision, the errors manifesting themselves as poorly executed procedures, improper choices, or misinterpretation or misuse of relevant information (Shappell & Wiegmann, 2009).

The basic model of decision making begins with perceiving information through a number of cues (visual, aural, vestibular etc.) which are compared to experiences held in the long-term memory and possible hypotheses derived by comparing those to the cues received through the working memory (Wickens & Flach, 1988). Perception in this sense refers to the information being recognised as relevant to the task and that the resultant decision depends on past experience, the pilot's expectations and whether or not they are able to cope with the received information (Croucher, 2007).

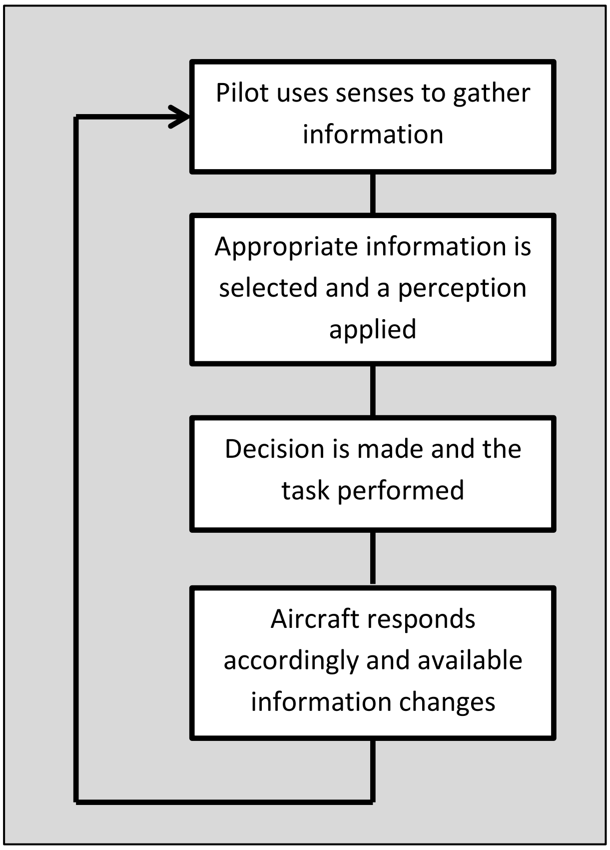

Figure 7: Simplified diagram of the closed-loop decision making process, source Gratton and Bromfield (2009)

A simplified diagram of this closed-loop process can be seen in Figure 7. Thus for GA pilots, particularly low hour PPL holders, it may be more difficult to make a good decision based on the information available as they may not have the relevant experience, so cannot formulate expectations; their decisions must be based on knowledge alone.

This may provide an explanation for why some of the 21 pilots in the sample continued flight from VFR into IMC, Goh and Wiegmann (2001) suggesting this action may result from an error in assessing the situation and that they misdiagnosed the severity of the weather presented to them at the time. Although the mean level of total experience of these pilots (812.4 hrs) suggests they should have had the knowledge to make an accurate assessment, there is no evidence to suggest that their level of flying experience denotes their level of meteorological knowledge. With the exception of three, all of these pilots had PPLs and thus it can be realistically assumed that none of them had ever encountered bad weather before, as flying in such conditions is outside the privileges of their license. As AAIB reports do not intend to apportion blame, they do not reveal the reasons why the pilots continued their flights. Furthermore any such information would be incomplete as nine of the flights ended fatally.

4.3 The effects of stress

Lack of experience is only one of a number of reasons for poor decision making; incorrect or misinterpreted information will have a detrimental effect on the process. As information is gathered through the human senses, there will always be the possibility of error. For example, on approach to landing, a pilot is in a state of high workload and cognitive stress (CAA, 2002). The effect of stress on performance has long been understood and the performance/arousal curve (Figure 8) demonstrates the relationship between the two.

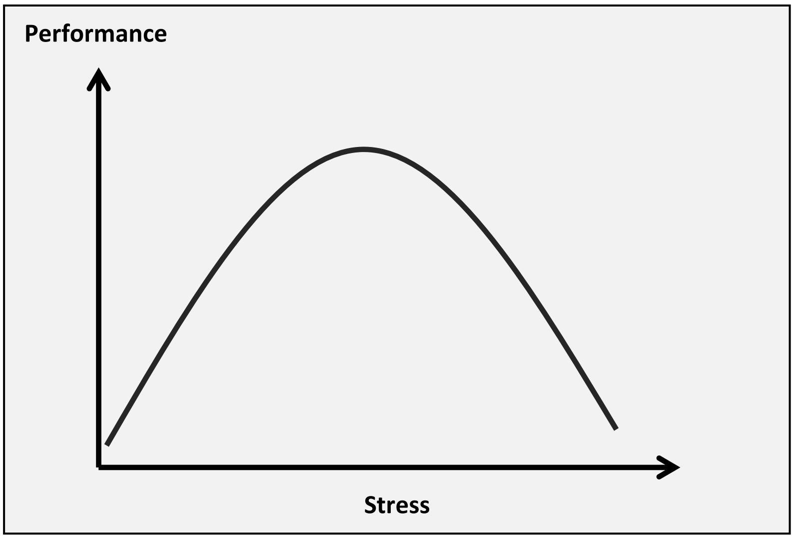

Figure 8: The relationship between performance and stress

Up to a given amount of stress, human performance will increase, the amount of stress required for maximum performance being dependant on an individual's perception of the stress and how they manage it (Murray, 1997). In the landing scenario, particularly in windy conditions, stress levels may be too high for a given individual and they experience a reduced attention capacity, ignoring additional inputs vital to the task in hand (Oxford Aviation Services, 2007) such as wind information received from ATC. This information may be acknowledged as a matter of routine as it is generally received concurrent with clearance to land and so it forms part of the pilot's expectations. The content of the message will however be lost and the pilot does not realise the wind is too strong and/or not from an appropriate direction for the landing to be carried out safely. The sunk-cost effect describes how the closer to a set goal someone gets, the more likely they are to consider any action other than achievement of the goal as a loss (Wiegmann, Goh & O'hare, 2002), thus they disregard any other information and focus on completing the task. Combined with cognitive stress symptoms, the pilot on approach to land is likely to continue and risk an accident rather than the alternative which is to either go-around and try again, or to divert to an alternative airfield where the wind conditions may be more favourable for a safe landing. This situation is a distinct possibility for many of the 143 sample accidents where wind was cited as a causal factor in landing accidents.

During any emergency, stress levels are liable to be high and the same psychological and processes as described here may take hold, affecting the decisions made by the pilot. As discussed previously, GA pilots may not have the experience or knowledge necessary to either interpret sensory information or determine a course of action based on any information they receive. It is surprising, then that structured decision making training is not routinely given to student pilots, nor is it provided later in their flying career; instead it has been assumed they learn the techniques as their experience grows (Jensen, 1997).

Jensen (1997) cites four types of experience that could augment the decision making process; training, hours, recency and variety. Training should be sufficient enough to prevent bad habits from forming and provide a solid knowledge base, which should in turn be periodically refreshed and updated. Number of hours flying, Jensen (1997) suggests, is the single best predictor of decision making performance, recency complimenting this as procedures are forgotten faster than control functions. Flying in a variety of different aircraft, in different conditions (weather, night) and in varying locations are all essential to decision making expertise according to Jensen, (1997) but it is argued here that whilst that may be true, until those varieties have been experienced sufficiently, in each of the given conditions, pilots will be at risk of making poor decisions, for the reasons outlined.

Decision making is a continuous process in aviation as it is in everyday life; what clothes to wear for a pleasure flight, what route to take, what height to fly at, when to perform en-route checks, whether to have tea of coffee at the destination and so on. During an emergency, however, whilst the regular decision making process continues, a secondary process of problem solving develops which the pilot uses to return the aircraft to normal conditions (turning around, making a precautionary landing or resolving the issue in flight).

4.4 Situational awareness

The dynamic nature of flying requires that pilots retain a high level of situational awareness (SA), being the concept of maintaining an accurate mental model of their environment (Green et al, 1996). Shook et al. (2000) cited Trollip and Jensen (1991) who attributed 85% of GA accidents to the primary cause of decision making, Shook et al. maintaining that SA problems are at the root of these errors. Maintaining SA through any one of three levels (monitoring, evaluating, anticipating) (Croucher, 2007) means the pilot is sustaining a flow of information which in the event of an emergency is invaluable as time need not be spent in gathering information.

4.5 Crew and single pilot resource management

The three concepts of decision making, situational awareness and problem solving are techniques covered in Crew Resource Management (CRM) training (CAA, 2006), effective use of which results in expertise in ADM (Jensen, 1997). In commercial aviation operations, pilots are required to undergo CRM training in an attempt to enhance safety (CAA, 2006), but as mentioned earlier in this chapter, no such training is required or encouraged for UK GA pilots. CRM is essentially a tool for multi-crew commercial operations, but there are no reasons why the concepts cannot be adopted for single pilot use at GA level in the form of Single Pilot Resource Management (SPRM).

Indeed single pilot operations for commercial operations has been researched, Deutsch and Pew (2005) writing a paper for NASA's Aviation Safety Programme on the subject which they stated to be a challenge in preparing for such operations to achieve the levels of safety and efficiency reached in multi-crew flying. The CAA have recognised the need for SPRM and it is now included in CAP 737 (Crew Resource Management Training, CAA, 2006), Griffiths (2004) acknowledging that CRM applies to single pilot operations. Despite referring specifically to public transport operations, it is recommended that they are used as best practise in GA (CAA, 2006). Whilst this is a worthy objective, this has not been appropriately filtered down to training schools, flying clubs or GA pilots themselves.

4.6 Summary

This chapter has highlighted the importance of good decision making in all aviation operations, but points out that often the fundamentals of good decision making are absent from UK GA pilots, namely experience, knowledge and training. It also expresses the need for pilots to maintain a high level of situational awareness in order to facilitate the decision making process. Along with problem solving, these concepts are taught to commercial pilots in the CRM training they are required to do, training which can be adapted to GA operations, the principles for which have already been laid out in CAA documentation (among others). It is suggested that proper integration of SPRM in (N)PPL training will go a long way to enhancing safety and reducing the UK GA accident rate. The principles of SPRM and how it can aid UK GA safety will be discussed in more detail in chapter 9.

The following Chapter will examine the accident data gathered from the Air Accident Investigation Branch's database. It will discuss the methods used to analyse and interpret the data and how elements of the research were derived from it.

Chapter 5: UK General Aviation Accident Data Summary

Chapter 4 introduced the concept of decision making in aviation, the processes through which it is achieved and how it is affected by factors such as stress.

This chapter will provide a summary of the sample accident data collated including; the date period it covers, the number of accidents reviewed, the methods used to gather the data analyse and categorise it and an introduction to the main causes, contributory conditions and accident categories. The main findings will briefly be presented to provide the reader with a basic outline of the actual data results following its analysis. To understand the operation involved in compiling accident reports, the roles and functions of the Air Accidents Investigation Branch (AAIB) in both accident investigation and report publication will be outlined.

5.1 An introduction to the AAIB and the accident reporting process

The UK AAIB was initially established in 1915 when Captain G. B. Cockburn was appointed as Inspector of Accidents for the Royal Flying Corps, but has been under the jurisdiction of the Department of Transport (now the Department for Transport) since 1983 and its name changed to the current title in November 1987 (AAIB, N.D). Its purpose is to determine causes of aviation accidents and make recommendations as necessary with a view to preserving life and avoiding future occurrences; it is not to apportion blame (AAIB, 2010).

The processes involved from an accident taking place to the report being published are straightforward in principle. On notification of an accident, normal procedure is to dispatch an Operations and an Engineering Inspector to examine particulars such as procedures, human factors, weather, aircraft systems and engines, maintenance records and so on (AAIB, 2010). The investigation will include inspection of the wreckage, interviews with witnesses (including the pilot if they are able), obtaining records relating to the pilot's training and experience and other data as appropriate, following which the Chief Inspector of Air Accidents decides how to proceed (AAIB, 2010).

The report can take several months or more to produce, depending on the nature of the accident and any unforeseen complications. For most minor events, the pilot involved is requested to fill in a standard form and provide details of their own experience and ideas as to the causal factors. This is then checked by an Inspector who will produce the formal document. Where a report is produced through a field investigation, a draft copy is sent to the pilot (or their representative), as well as persons whose reputations may be adversely affected by publication of the report and are given 28 days to make representations before the report is finalised (AAIB, 2010).

A report generally contains three main sections consisting of preliminary accident/pilot details, narrative and analysis/conclusions but this may vary depending on the accident severity, unusual circumstances, evidence available and other variables associated with accident investigation.

The first section contains details of the aircraft involved, the date and location of the accident, injuries and damage sustained, type of flight (training or private) and details concerning the pilot, including their age, level of license and experience.

The second part discusses the events leading up to the accident, the accident itself according to witnesses and evidence and determines probable causal factors. The amount of detail given varies, depending on the severity of the event and the author of the report. Common sections include a synopsis and where appropriate, a more in-depth appraisal of the aircraft, pilot, airfield and the weather. If necessary, commentary is given on topics specific to the accident and may include medical/pathological information, aircraft performance calculations, operational information, engineering analysis, wreckage details, radar track recordings and eyewitness accounts.

Analysis is often, but not always included. It serves to interpret the information given in the preceding part of the report and offer both causal and contributory factors of the accident without apportioning blame. Similarly, conclusions are not always presented as a separate section, but are contained within the analysis. Only where they are deemed to be beneficial to the future safety of aviation and practical enough for implementation will recommendations be given by the AAIB, but as the AAIB is not a regulatory authority, it has no power to enforce any that are made (AAIB, 2010).

The final section can be presented either as a summary or a conclusion. Preliminary details are presented as shown in Table 8 and are common to all reports, regardless of severity.

Table 8: Initial accident details as presented on an AAIB accident report or bulletin

AAIB Bulletin: Designated title code for the bulletin/report
INCIDENT (or ACCIDENT as determined by the AAIB)
Aircraft Type and Registration: G-AAIB
No & Type of Engines: 2 Generic 01-01-AA piston engines
Year of Manufacture: (of aircraft)
Date & Time (UTC): (of event)
Location: (of event)
Type of Flight: (private, training)
Persons on Board: Crew – 'X' Passengers – 'X'
Injuries: Crew – 'X' Passengers – 'X'
Nature of Damage: (Brief summary)
Commander's Licence: (PPL, CPL, ATPL…etc)
Commander's Age: (years)
Commander's Flying Experience: 'X' hours (of which 'X' were on type)
Last 90 days – 'X' hours
Last 28 days – 'X' hours
Information Source: (one or more from:)
AAIB field investigation
Aircraft Accident Report Form submitted by the pilot
ATC reports
Airport operator reports

Due to their factual nature, reports do not allow for any inference concerning issues such as individual pilot skill level, attitudes towards safety, pilot mental or physical condition, the quality and/or duration of training received, or levels of situational awareness at the time of the event. Whilst these variances may influence accident causation or outcome, they cannot be included in any analysis being merely supposition and conjecture.

Variations between reports may occur due to them being written by different accident investigators who have different styles in the way they present their findings. Reports are also tailored to each accident, different accidents producing different information and conclusions, thus not always necessitating the same format. Disparity in reports will also occur for less serious accidents where the information was presented by the pilot. Despite being reviewed, edited and published by the AAIB, individual opinion, personal ideology and human uniqueness will result in a varying amount and type of information.

5.2 Gathering the sample data

Data collation began in January 2010 and continued through to June 2012. It was decided to start gathering data from January 2005 in order to allow for a larger sample than might otherwise be achievable and to take into consideration any long-term investigations that may have taken months or more to compile and publish, thus furnishing the data sample with a range of fully investigated accidents. The cut-off date for published accident reports to be utilised was 31st December, 2011, thus providing seven years of continuous accident activity within UK GA and resulting in 1007 reports. It should be noted at this point that due to some analysis being performed before all data had been collected, a variance in 'N' will be evident in certain results presented. The same methods of analysis were retained in each instance.

Whereas previous Authority and academic publications had dealt purely with fatal accidents, in order to provide the fullest possible picture of UK GA safety matters, it was deemed appropriate to include both accidents and incidents for this thesis. According to ICAO Annex 13 (ICAO, 2001, p 1-1) an accident is defined as:

"An occurrence associated with the operation of an aircraft which takes place between the time any person boards the aircraft with the intention of flight until such time as all such persons have disembarked, in which:

a) a person is fatally or seriously injured as a result of:
— being in the aircraft, or
— direct contact with any part of the aircraft, including parts which have become detached from the aircraft, or
— direct exposure to jet blast,
except when the injuries are from natural causes, self-inflicted or inflicted by other persons, or when the injuries are to stowaways hiding outside the areas normally available to the passengers and crew; or

b) the aircraft sustains damage or structural failure which:
— adversely affects the structural strength, performance or flight characteristics of the aircraft, and
— would normally require major repair or replacement of the affected component,
except for engine failure or damage, when the damage is limited to the engine, its cowlings or accessories; or for damage limited to propellers, wing tips, antennas, tires, brakes, fairings, small dents or puncture holes in the aircraft skin; or

c) the aircraft is missing or is completely inaccessible."

An incident is regarded as "*An occurrence, other than an accident, associated with the operation of an aircraft which affects or could affect the safety of operation.*" (ICAO, 2001, p 1-1)

It was also considered appropriate that only powered, fixed-wing aircraft be included, given they make up the majority of UK GA activity and the performance and operation of helicopters is different to fixed wing aircraft due to the aerodynamics, mechanics and human factors involved. Furthermore, the number of published GA helicopter accidents is small compared to those of powered fixed-wing aircraft, the total for the research period being just 123, the impact of excluding them thus being deemed as negligible. Although more closely related than helicopters, the operation of non-powered fixed wing aircraft (gliders) was also concluded as being sufficiently diverse to warrant their exclusion. In addition, the Author's experience in gliding and helicopters is limited and does not carry the necessary expertise to make judgments and considerations in terms of the facts presented in the accident reports, unlike powered, fixed-wing GA in which the Author has more than 15 years' experience supported by piloting qualifications and a relevant University Degree.

5.3 Separation and categorisation of data

The nature of AAIB reports is such that both quantitative and qualitative data exists and thus a challenge lay in how best to utilise it. The most logical process was to present all the data in an Excel spread sheet in the order in which it generally appears in the reports with a few minor modifications to enable easier categorisation and thus easier retrieval when required. The result was a 15 column spread sheet, the first of which stated the aircraft registration, followed by the year of the accident and subsequently all other data as presented in Appendix D. Details specific to each of these categories will be discussed in subsequent chapters; the aim in this chapter is to introduce the reader to the main concepts for each, including associated phraseology and definitions as required.

Quantitative data concerns experience levels of the pilot in all four categories as described in Chapter 3, namely total experience, experience on the accident aircraft type, hours flown in the preceding 90, hours flown in the preceding 28 days as well as the pilot's age. Subsequent data was mostly qualitative in nature, requiring interpretation and abbreviation to be recorded, particularly determination of causes and pertinent information. It should be noted that some reports did not contain enough information to determine contributory causes beyond primary and secondary ones, thus it was not always possible to produce statistical data for this sub-set of causal factors.

5.4 Sample pilot experience and age

Means for pilot experience and age are shown in Table 9. This data was used in combination with that gathered from the 2011 survey and CAA to determine whether or not there are any trends in the age and/or experience of accident pilots compared to the population. The results of these analyses are discussed in Chapter 6 and go some way to laying out the need for improved post licensure support as proposed in the title of this thesis. The data shown is for all pilots within the sample, including commercially licensed individuals.

Table 9: Mean and Standard Deviation for categories of pilot experience and age (N = 1007)

Category	Total	Type	Last 90	Last 28	Age
Mean	2064.1	264.1	29.8	10.9	53.0
SD	4154.912	645.770	44.754	15.450	13.161

5.5 Injuries sustained

In each report, the AAIB states the level of injuries sustained as being none, minor, serious or fatal. These are not random determinations, fatal and serious injuries having specific definitions according to ICAO rules. Any injury falling outside these definitions is classed as minor, unless no injury was recorded, in which case the classification of 'none' was entered. An injury is only classed as a fatality by ICAO if death occurs within 30 days of the date of the accident (ICAO, 2001), a serious injury being defined in Annex 13 (ICAO, 2001, p1-2) as:

"An injury which is sustained by a person in an accident and which:
a) requires hospitalization for more than 48 hours, commencing within seven days from the date the injury was received; or
b) results in a fracture of any bone (except simple fractures of fingers, toes or nose); or
c) involves lacerations which cause severe haemorrhage, nerve, muscle or tendon damage;
d) involves injury to any internal organ; or
e) involves second or third degree burns, or any burns affecting more than 5 per cent of the body surface; or
f) involves verified exposure to infectious substances or injurious radiation."

In collating this data, where there were two or more levels of injury, the most serious was taken as the descriptor for that accident. From the 1007 reports reviewed, 803 (79.7%) involved no injuries, 108 (10.7%) reported minor injuries, 41 (4.1%) resulted in serious injuries and 55 (5.5%) were classed as fatal.

Initially this appears to be a relatively acceptable fatality rate, but closer inspection shows it does not compare favourably to commercial aviation. From 1959 to 2011 there were 603 fatal commercial aviation accidents from 1084 million estimated flight hours (Boeing, 2012), calculated to be 0.55 fatal accidents per million flight hours. Using the estimated number of GA pilots in the UK from CAA data (2009), a mean number of flight hours calculated from the GA survey for the preceding 90 and 28 days and the number of fatal accidents from the accident data, a fatal accident rate of 3.34 per million flight hours was derived for UK GA, more than six times that for worldwide commercial operations. The calculation was performed as below:

- Estimated GA pilot population: 20127
- Mean flight hours by GA pilots: 9.5 (preceding 28 days), 26.9 (preceding 90 days)
- Fatal GA accidents: 55 from 2005 to 2011 inclusive = 7.85/yr
- Using 28 days factor: 365/28 = 13.04; 20,127 x 9.5 x 13.04 = 2,493,332.8
- Using 90 days factor: 365/90 = 4.06; 20,127 x 26.9 x 4.06 = 2,198,150.2
- Mean flight hours per year = 2,345,741.5
- Fatal accident rate = 7.85/2.35m = 3.34 per million flight hours

5.6 Licenses held by sample pilots

Of the 1007 reported accident pilots, 715 (71%) were (N)PPL holders, including two that had lapsed, 115 (11.4%) were CPL holders, 91 (9%) carried ATPLs, 8 (0.8%) were military pilots and 78 (7.8%) were students. Although not an exact match, these statistics closely resemble those obtained from the GA survey, suggesting at an early stage that pilots of all licenses have an equal propensity of being involved in an accident in GA.

Of the commercially licensed pilots, 47.8% of CPL pilots and 33.0% of ATPL pilots were instructing a student, but as they are classed as the aircraft commander and not the student, it is their details that are entered into the report, even if they were not the handling pilot at the time of the accident.

5.7 Human Factors

The topic of Human Factors (HF) in aviation is central to safety, various statistics proposing elements of human error in around 70% to 80% of commercial accidents. Further discussion on HF can be found in Chapter 6 where the concepts are used to determine the relationship between experience and HF in UK GA accidents. Here, the emphasis will be on the determination of whether or not the accidents in the sample could be classed as HF or non-Human Factor (NHF; i.e. having no human input in the cause or contributory factors). To do this a concept conceived by Wiegmann and Shappell (2000) was used; the Human Factors Analysis and Classification System (HFACS) is an established and accepted format for classifying the main subsets of human error types by defining them and breaking them into four distinct levels, from corporate culture at level four to basic skills at level one (Table 10).

Matching causal and contributory factors as determined by the AAIB to the HFACS hierarchy aided the classification of the reviewed accidents as either HF or NHF. Although biased more towards commercial operations, the conditions in the subcategories up to level 2 can easily be applied to GA and in some cases up to level 3. There is no reason that level 4 should be excluded, but any GA accident involving these conditions would be difficult to establish, as AAIB reports do not apportion blame to any individual, organisation or institution, but purely set out to establish the facts and probable cause(s).

This method revealed 63.4% of the reviewed accidents to be HF and 35.7% as NHF. A small proportion of the accidents (0.9%) were not able to be classified due to the complicated nature of the accidents and the lack of definitive conclusions from the AAIB. These figures do, however echo the widely accepted fact that the majority of aviation accidents both in GA and commercial sectors are attributable to human factors.

Table 10: HFACS table of hierarchy; adapted from Wiegmann and Shappell (2000)

HFACS Level	Subcategory	Description
Level 4: Organisational influences	Organisational processes. Organisational climate. Resource Management.	Corporate decisions and rules on every day operations. Working atmosphere within the organisation. Allocation and maintenance of organisational assets.
Level 3: Unsafe supervision	Supervisory violation. Failure to correct known problem. Planned inadequate operations. Inadequate supervision.	Rules broken by supervisors. Known deficiencies continue unabated. Unacceptable operations/ crew scheduling. No provision for the opportunity to succeed.
Level 2: Preconditions for unsafe acts	Technological environment. Physical environment. Personal readiness. Crew Resource Management. Physical or mental limitation. Adverse physiological states. Adverse mental states.	Equipment design, checklist layout, automation. External (weather, altitude) and ambient environments. Rest, alcohol, personal performance levels. Coordination, communication, planning. Flight requirements exceed the pilot's capabilities. Medical/sensory conditions precluding safe flight. Loss of situational awareness, distraction, pernicious attitudes.
Level 1: Unsafe acts of operators	Violations. Perceptual errors. Skill-based errors. Decision errors.	Routine/habitual or departures from authority. Degraded sensory input, illusions and disorientation. Autonomous stick and rudder/basic flight skills. Behaviour based on inappropriate knowledge/poor choices.

5.8 Causes, accident categories and additional information

Because they are the result of a chain of events which may include a multitude of factors, accidents never happen in exactly the same manner for exactly the same reasons. There are often similarities in causation such as weather conditions, phase of flight, pilot experience etc., but the details will ultimately vary. As stated earlier, accidents could simply be categorised as HF of NHF, but without further investigation there is no possibility for preventative measures to be devised.

Potentially accidents could be sorted into hundreds of different categories and measures devised to prevent each one happening again, but this fails to acknowledge that where there are similarities, there may only be one or two measures required to cover the full spectrum presented. Hence in this thesis accidents were grouped into five main categories; airmanship, controlled flight into terrain (CFIT), loss of control (LOC), meteorology and technical. A small number of accidents (26) did not fit into any of these categories due to the unusual nature of their cause and to avoid forcing them to fit, it was deemed more appropriate to create a category of 'other'. It must also be noted that many accident causes could be equally attributed to more than one main category and as such, 17% of the sample was dual-categorised (e.g. LOC/technical). Further to this, additional causal factors and information was captured on the spread sheet to assist both further analysis and categorisation.

It is important that the reader is able to distinguish between these various accident categories and understand what each one entails. It should be noted that the accident category does not automatically imply a specific cause, it is merely a description of what the main event entailed; causal factors will be discussed within the bounds of each accident category sub-section and in further detail in subsequent chapters.

It is intended that clarification of accident categories at this stage of the thesis will prevent subsequent confusion and will also give an indication of the kinds of accidents that can and have occurred in UK GA.

5.8.1 Airmanship

In the traditional sense, airmanship encompasses 'gentlemanly conduct' and common sense, but moreover is concerned with professionalism in a non-professional industry, executing appropriate diligence in procedures and making best use of skills and knowledge in a disciplined manner (Croucher, 2007). Where a pilot does not treat flying in accordance with these principles, they are putting both themselves and other aviators at risk, as has been proven in the sample data.

A total of 154 accidents involving detrimental airmanship were recorded, 11 of which were fatal. This category elicited a large array of secondary and contributory causal factors, the most prolific of which were collisions, accounting for 35.1% in total. Whilst the majority (63%) took place on the ground during taxiing, seven of the fatal accidents in this category resulted from collisions. Two incidences of collisions during aerobatics, one on military training exercises and two in the cruise were recorded. In one of the aerobatic collisions neither pilot incurred any injuries, but in the other both pilots were fatally injured. Four pilots were killed in the military collision as students were undergoing instruction and in the cruise collisions, one aircraft landed safely while the occupants of the second aircraft were fatally injured.

Although spanning the full consequence spectrum, many pilots in these accidents demonstrated the same poor levels of situational awareness, judgment and lookout. In the cruise, high levels of vigilance are required as even in light aircraft, closing speeds of two on a collision course can be in excess of 200 knots (230mph) and size of these aircraft can mean they are difficult to see. On the ground, pilots must remember that although travelling at relatively slow speeds, the tips of their wing can cause severe damage to buildings and other aircraft, the Cessna 172 having an 11m wingspan (Cessna, 2013) for example.

Other recurrent contributory causes included failure to make proper use of check lists, mis-management of fuel, distraction from essential tasks and neglecting to perform a go-around (where the landing is rejected and the pilot flies around to make another attempt) when evidently flying too low on approach.

5.8.2 Controlled flight into terrain

The simplest definition of this category is where an aircraft, under positive control by the pilot and in good working order flies into terrain, whether that be a mountain, a body of water or a field. It is a recognised phenomenon in the accident investigation domain and despite the fact that all but one of the CFIT accidents in the sample occurred in poor visibility, it is not classed as a meteorological accident because up to the point of impact, the weather was not directly affecting the performance of the aircraft.

In commercial aviation accidents, CFIT often occurs at night and in poor visibility, but the accident is categorised as CFIT. For example, the loss of an American Airlines Boeing 757 in Colombia on 20th December 1995 when it flew into a mountain occurred at night in visual meteorological conditions (VMC) due to a number of factors including time pressure and situational awareness (Aeronautica Civil, 1996). Despite the contributing factors, the accident was still classed as a CFIT occurrence and at no point in the investigation’s conclusions were the darkness or weather suggested as contributory factors, although it is perfectly possible to argue that had it been daylight and good, or better weather, the accident would never have occurred.

Within the sample there were 15 CFIT occurrences, 14 taking place in VFR into IMC situations, where the pilot has inadvertently, or otherwise, strayed from visual flight rules (VFR – where the pilot must have good visibility, remain clear of cloud and in sight of the surface) conditions into instrument meteorological conditions (IMC – where the pilot should be appropriately qualified to fly solely by the use of instruments). As AAIB reports do not always state the ratings pilots held in addition to their license, it is impossible to know whether or not the pilot had the appropriate qualification to fly into IMC, but regardless, they ultimately flew into terrain, 42.9% of these accidents being fatal. In one CFIT occurrence, the pilot was performing aerobatics, but did not follow the set routine, resulting in a miss-judged manoeuvre and a fatal CFIT accident.

5.8.3 Loss of Control

By far the greatest cause of accidents, LOC accounted for 49.7% of the sample and 41.8% of all fatal occurrences. If for any period of time an aircraft performs manoeuvres or movements not explicitly demanded by the pilot, the pilot is deemed to have lost control. In most circumstances, control can easily be regained and there are no adverse consequences. Where no attempt to regain control is made, or recovery is either difficult or not possible, there is a likelihood that an accident will ensue.

LOC can be induced by the pilot or by external influences. Within the sample 65.8% of accidents were categorised as pure LOC, 90.6% of which were attributed to HF. More than one quarter (25.5%) of these resulted from the pilot bouncing the aircraft on landing. This can happen for a number of reasons, including poor technique, poor judgment and simple lack of skill. The results of a bounce can be severe if it is not countered effectively, ranging from damaged aircraft to serious injury; the initial LOC (the bounce) may induce further LOC in terms of directional control, or overrunning the runway and collision with vehicles, buildings or other obstacles.

Similar and arguably transferrable from the bounce category, the approach profile of the aircraft was attributable to 24 accidents. The approach profile is the speed, rate of descent and horizontal accuracy of the approach path in relation to the runway centre line. If these are not properly managed, the aircraft can enter a number of undesirable conditions, including excessively high rate of descent resulting in a heavy (and damaging) landing, a stall and/or an undershoot (where the aircraft contacts the ground and/or obstacles before the start of the runway.

Management of the flight and other controls contributed to 45 LOC accidents, all of which occurred during either the take-off or landing phases. Light aircraft are generally sensitive to movements of the controls and thus do not require much physical effort to fly normal manoeuvres. When reacting to external forces such as the wind, it is quite possible to make excessive inputs to the yoke or rudders and subsequently lose control. Similarly, insufficient inputs, particularly at vulnerable times such as take-off or landing can allow an aircraft to enter a loss of control situation, although this is less common than over control.

For student pilots, high stress situations such as take-off and landing can induce simple mistakes, as they are not yet familiar with the aircraft or the process of operating them. One student with just 20 hours experience (all on the same aircraft type), in an attempt to maintain the aircraft on the runway centre line made a rudder input in the opposite direction to that required, turning the aircraft in the opposite direction from that expected and ultimately lost full control.

In addition to flight controls, inappropriate inputs on other controls such as the throttle or flap levers can also have an unfavourable effect on the controllability of a light aircraft and such events are recorded in the sample data.

Among other contributory causes to LOC, the most notable ones involved overrunning the runway due to poor decision making and/or planning and accidents where condition of the runway resulted in aircraft veering off, landing gear collapsing and ‘nose-overs’ where the aircraft overturns in a longitudinal direction due to the nose wheel either snapping off or digging into soft ground.

Although not so numerous, unsecured aircraft resulted in 16 LOC accidents, usually due to the parking brake not being set whilst starting the engine, or by pilots not noticing their aircraft moving whilst distracted by other tasks such as talking on the radio or performing pre-flight checks. One occurrence however resulted in an un-piloted aircraft taking off and crashing into nearby woods. This extreme case was caused by the pilot not having positioned chocks under the wheels and leaving the throttle in a position so as to elicit an unexpected engine start whilst turning the propeller (some aircraft require the propeller to be turned in order to move oil through the engine prior to starting).

The most lethal form of LOC is that of stalling and/or spinning. Stall recovery techniques are both taught and examined at PPL level, but spinning in the 1990s was removed due to safety concerns, namely that the instruction was causing more accidents than were ultimately being prevented. Whereas a light aircraft is relatively easy to un-stall, (most training aircraft such as the Cessna 152 having a natural tendency to return to controlled flight themselves, given sufficient time and associated height), a spin is more difficult to recover due to the rotation involved, essentially being a condition of stalled flight in which the aircraft enters a spiral descent due to disproportionate amounts of lift being produced by each wing (Thom, 1994). In the sample there were 48 accidents induced by stalling, 10 of which were fatal. Only six accidents were officially categorised as spin occurrences, but all resulted in fatalities. These events took place for a number of reasons ranging from incorrect configuration of the aircraft through poor techniques in landing or taking off to poor management of speed.

The dual categorisation of LOC and meteorology accounted for 33.2% of accidents, 86.1% of which involved movement of the air; wind gusts, crosswinds, turbulence, down draughts. All but two of these accidents took place on or near the ground in either the take-off or landing phases. Maintaining positive control of the aircraft at these times is crucial as the available time for recovery is severely limited and high levels of awareness and skill would be required to effect a successful recovery.

On take-off or landing, any kind of air movement can put the aircraft into a critical condition in an instant; turbulence or gusting winds can almost instantly starve the aircraft's wings of the airflow they need to produce lift, thus entering it into a stall requiring a quick response to recover. Similarly, an aircraft can easily be swept across a runway in a crosswind, particularly once airborne and failure to counter this or indeed an excessive motion in an attempt to counter it can lead to LOC. Whilst normal practise is to take-off and land into a head wind, up to specific limits as prescribed by the manufacturer, an aircraft is capable of taking off when the wind is blowing across the runway, but the pilot must use techniques taught in training to keep the aircraft in a straight line. Poor technique or ignoring manufacturer's recommendations can result in LOC in the aforementioned manner.

5.8.4 Meteorology

In terms of aviation, GA is not as affected by meteorology as commercial aircraft. Firstly as there is no schedule for them to adhere to and no passengers to inconvenience, it is easy to cancel a flight when weather conditions are not suitable. Secondly, the majority of GA pilots, as has been demonstrated in Chapter 3 are only qualified to fly in good weather conditions. The majority (93.8%) of meteorologically influenced accidents, therefore have already been discussed in the previous section on LOC, a further 5.1% coming under the dual category of technical and meteorology (icing, which will be discussed in the following section).

Only two pure meteorologically influenced accidents were recorded, both where the pilots were forced to make a precautionary landing (where the pilot decides to land before the situation becomes dangerous), due to unexpected bad weather closing in, the accident occurring upon landing.

5.8.5 Technical failures

Due to the nature of this category, of the 310 incidence of technical problems causing an accident, 8.7% were contributed to by HF. Close to half (49%) of all technically induced accidents were caused by engine failures or associated problems (power loss and/or rough running engine). With an engine failure a pilot is forced to land wherever they can find suitable land. Although it could be argued that HF issues occur on landing, without the initial failure, the pilot would not have to have made an emergency landing and the accident would not have occurred. Nonetheless, this most prolific of technical problems resulted in nine fatal accidents, four of which involved HF.

Where contributory causes were able to be established, the majority fell into two main categories; fuel starvation and carburettor icing. For the most part, fuel starvation occurred due to contaminants in the fuels producing restrictions in the fuel flow, but myriad possible reasons were additionally given such as vapour lock, incorrect mixture and faulty selectors and carburettor jets. Often the reasons for the fuel starvation were based on the description of the problem given by the pilot as upon testing, the system in question was found to be working correctly. This led to some statements suggesting icing issues, as on the ground the ice would have melted and thus the system returned to full working order. The specifics of fuel starvation and carburettor icing will be discussed more fully in Chapter 7, but suffice to say that regardless of the reason, the fact is the engines in question suffered a failure, requiring the pilots to make emergency landings, which in most cases is where the accident occurred. Other more definitive reasons for engine problems included failures of the crankshaft, cylinders, magnetos, gearboxes, gaskets and spark plugs.

Failures of the landing gear caused 111 accidents, 85.6% of which took place during landing, the remainder whilst taxiing. Landing is the phase in which the landing gear is most stressed, having to absorb the impacts of an aircraft weighing in the region of one tonne, the Cessna 172 having a maximum landing weight of 1,157 kg (Cessna, 2013). Often, runways are not completely smooth and particularly grass strips may have ruts, bumps and small holes which the gear must be able to handle. On eight occasions in the sample, the landing gear succumbed to these flaws in grass runways and either collapsed or were torn off.

It is true to say that hard landings can damage landing gear, but for properly maintained aircraft, landings need to be excessively hard before significant damage occurs. A pilot should be able to make a hard landing without concern, although it would be considered prudent to inspect landing gear after every such event and get an engineer involved if there are any doubts. No such landings were documented in the sample, all the gear failures being associated with poor maintenance and/or structural, mechanical, hydraulic and electrical problems.

Structural failure was the final area of concern being directly attributable to 24 accidents, exactly half of which were serious enough to have potentially resulted in a more profound accident than was actually the case. These included propellers detaching in flight and failures of control surfaces such as rudders and ailerons. Two further catastrophic failures resulted in fatalities.

In the same manner as LOC, some technical difficulties either resulted from or induced conditions as stipulated by other categories, specifically meteorology (icing) and LOC (engine failure leading to a stall due to ineffective management of the problem).

5.9 Phase of flight

In aviation there are three main segments of any flight; take-off, the cruise/en-route and landing. Additional flight segments can further be added, being the climb, cruise and descent. For the purposes of analysis in this thesis, take-off was separated into the take-off run (including unsticking from the runway; lift off) and the initial climb up to 100 ft. Landing was also divided into the approach, the landing itself from round out to touchdown and the roll out. Due to the numbers involved, additional phases were devised for the go-around (aborted landing) and aborted take-off manoeuvres, as well as for taxiing and the engine start process.

Concurring with data presented by Boeing (2012), the sample data showed landing to be the most prolific accident phase (53.3%) the cruise and take-off accounting for 14.2% and 13.4% respectively. Despite these statistics, landing only accounted for 7.3% of fatal accidents, the cruise proving to be the most deadly phase with 60% of fatal accidents happening at this time.

5.10 Summary

This chapter has provided basic information concerning the data gathered from the sample, how it was categorised and summaries of each category. It allows the reader to gain a basic understanding of the information which will be presented in subsequent Chapters, but also includes some minor details not discussed later due to their relative triviality, but nonetheless add to the readers understanding.

The following chapter will look explicitly at the elements of UK GA accidents identified from the data sample as being influenced by the condition of being human; the role of age and experience; the relationship between human factors and experience, detrimental airmanship.

Chapter 6: The Influence of Human Traits on UK GA Accidents

The previous chapter presented the data gathered and analysed from more than 1000 UK GA accidents, forming the basis upon which this thesis has been produced.

The discussion in this chapter will be presented in three parts. Part 1 will centre on the ideology surrounding the effects of age and experience and the influences they can have on the propensity for pilots to be involved in accidents. Part 2 will present evidence for a relationship between human factors and pilot experience, whilst Part 3 will discuss those accidents resulting from a lack of good airmanship techniques.

6.1 The Role of Age and Experience in UK GA Accidents

6.1.1 Introduction

The general assumption is that younger people tend to be more reckless, greater risk takers and thus more prone to accidents. The opposite is presumed of older people as is the notion that they are slow to think and react and their carefulness is negated by this function of ageing. It is also felt that age and experience are intrinsically linked (i.e. increase in age equals an increase in experience). In the sample accident reports, casual factors cited include meteorology, technical problems and human error, but age is not deliberated. The first part of this chapter investigates correlations between age and accident involvement, how it combines with experience to reduce accident risk and whether it also influences human factors, accident type or injuries sustained.

6.1.2 Previous deliberations over age and experience

From January 2005 to December 2011 there were 55 fatal and 952 non-fatal GA accidents in the UK involving pilots aged 16 to 88. Although it has been argued by some (e.g. Li et al, 2003) that aging may bring greater expertise and enhanced safety behaviour, there still remains the notion that as individuals age their cognitive functions may decline and vulnerability to health problems increase, potentially impairing piloting skill and increasing the risk of accident involvement. Furthermore, age may also bring bad habits and complacency, previous research showing that in commercial aviation where continuous assessment and on-going training is considered vital for safety, habits tend to remain and are evident in flight test performance years after initial training (Jensen, 1997). In the United States, Baker et al (2001) found that older pilots made fewer errors, Baker and Li (1999) finding fatalities to be confined predominantly to those under the age of 60. Also in the United States, Bazargan and Guzhva (2011) found pilots over 60 to be more at risk of accident involvement, but there is no evidence to suggest these figures reflect the situation in the UK. Accordingly this chapter applies these notions to UK GA pilots to verify whether or not the results can be transposed.

6.1.3 Reasons for comparative discussion on experience

Reference to age ultimately leads to discussion about experience, the two frequently thought of as synonymous. Experience in aviation is however a complicated area, there being four categories of flight experience to draw information from and different levels of license involved, producing different types of flight experience from different periods and intensity of training. To enter into too much detail on the subject would detract from the aims of this chapter in measuring the influence of age alone as an accident causal factor, but to ignore it completely would be somewhat nonchalant, hence it is discussed at a fundamental level to acknowledge its relationship with age and the potential added impact it has on accident vulnerability.

As seen in Chapter 3, pilot experience is measured in flight hours for which there are four categories; total experience, type experience, hours flown in the past 90 days and the past 28 days, collectively referred to as currency. Pilots keep a personal flying log of all the hours they have flown, when they flew them and in which type of aircraft.

In terms of licence level, private license holders receive comparatively rudimentary training and for reasons such as cost and available free time, many people choose to gain their license later in life, also indicated in Chapter 4. Conversely, due to the preferences of many airlines to support younger candidates through flight school, or select younger pilots post qualification, most airline pilots commence training whilst still quite young and receive intensive training for up to two years. Thus a situation arises where age and experience do not necessarily correlate. For example an ATPL pilot with 1500 hours experience may be considered to be a better pilot than a 1500 hour private pilot due to the type of training and flight experience gained, but the ATPL pilot may be much younger than the private pilot. Although this is just one example which alone has myriad interpretations concerning experience, it highlights the complexities of combining age with experience in such a study. Although (N)PPL is more common in GA, those with a CPL or ATPL also operate in GA as Flight Instructors, Examiners or indeed, for pleasure.

6.1.4 Other considerations

Age was additionally assessed in terms of its impact on the involvement of human factors in accidents using basic categorisation adopted from HFACS. Human factors are widely accepted as being the biggest causal factor in aviation accidents, but in terms of GA, little has been statistically confirmed regarding its relationship with human factors.

Another evaluated aspect related to the influence of age on the type of accident, the three main accident categories identified being LOC, technical and airmanship (airmanship being broadly defined here as a function of a pilot's awareness, preparedness, knowledge, attitude, skill and judgement).

A further consideration was how representative within both the population and the sample pilots of a given age are. Calculation of means gives a value based on the number within either the sample or population, but does not take account of how many pilots there are within a certain age group. For example, a higher proportion of human factor (HF) accident pilots aged 41-50 may only result from there being a greater proportion of pilots within that age group flying within GA and not due to them being particularly unsafe pilots.

Previous research such as that by the Organisation for Economic Co-operation and Development (OECD, 2001) has suggested that older people are more susceptible to serious injury or death due to their physical frailty compared to their younger peers, thus pilot age was referenced against the severity of injuries received in each accident to determine any truth in this claim within GA.

6.1.5 Gathering and analysing the data

The UK Air Accidents Investigation Branch (AAIB) produces reports on all accidents occurring to UK or foreign registered aircraft within UK airspace. These range from minor incidents where little or no damage occurred and no injuries sustained, to serious accidents where substantial damage and fatalities occurred. Reports for minor accidents are produced by the AAIB using details provided by the pilot involved on a standard form, whereas more serious accident reports are compiled by AAIB Field Investigators. The AAIB database categorises reports under the headings of general aviation (fixed wing and helicopters), public transport (fixed wing and helicopters) and sport aviation/balloons.

The category for GA (fixed wing) was selected from the database and a search made for accident reports dating from 1st January 2005 to 31st December 2011 producing a total of 1007 reports. Data regarding the age of the pilot in command, level of license held, flight experience (all four categories), severity of injuries and the main causal and contributory factors as determined by the AAIB were collated for analysis. Accidents were also labelled as either HF or NHF in accordance with HFACS definitions.

On occasion some elements of data are absent from the reports, due in part to the manner in which minor accident reports are collated; for example a pilot may not divulge their age or type experience on an accident report form. In some serious accidents, particularly those involving fire, information may have been lost through destruction of the pilot's log book. Additionally the log book simply may not be up to date or correctly completed. Hence in the results, 'N' does not always equate to the number of accidents in the sample.

Using Civil Aviation Authority (CAA) records on ages of registered UK pilots in 2005, 2006 and 2009, t-tests were performed against the sample pilots to determine any differences in mean age. To eliminate bias from all the UK's commercially active pilots, age data for both sets was restricted to (N)PPL holders, being generally more representative of the GA community. Due to the large numbers within the population, a 5% representative proportion of each age was used in the tests, the resulting mean values being no different to the full population.

Age groups at 10 year intervals were established to determine both the distribution and relative representation of ages in both the sample and the population. These were also used to determine trends in levels of experience and accident type. Additionally they illustrated the representation of age according to injury severity.

As no data for UK GA pilot experience levels is available in the public domain, data from the 2011 GA concerning the respondents details of their total and type experience and currency levels was used to compare with sample data, both statistically and empirically.

For a secondary view on experience and how it relates to accident involvement as a stand-alone factor, an experience grade was established, grade 1 being the least experienced and grade 13 the most experienced. Each category was assigned a suitable experience level interval for each grade; 2000 hours for total, 500 hours for type, every 30 hours for the last 90 days and every 10 hours for the last 28 days.

6.1.6 Data analysis

6.1.6.i Mean age and distribution

The (N)PPL sample data (n = 707) revealed all accident pilots to have a mean age of 55.8 years (SD 11.950), significantly higher than the population mean age in each of the reference years as calculated from CAA data; 2004 (n = 1151): mean age 44.4, SD 12.656, t[1856] = 19.209, $p < 0.05$; 2005 (n = 1021): mean age 45.1, SD 12.913, t[1726] = 17.497, $p < 0.05$; 2008 (n = 1014): mean age 46.6, SD 13.464, t[1719] = 14.546, $p < 0.05$.

Age group distribution for both sample and population is analogous to a standard distribution. For sample pilots however, the overall trend is positively skewed by 10 years (Figure 9); combined figures show 76.4% of the population (63.3% of the sample) to be aged between 31 and 60 and 57.9% of the population (73.5% of the sample) to be aged between 41 and 70.

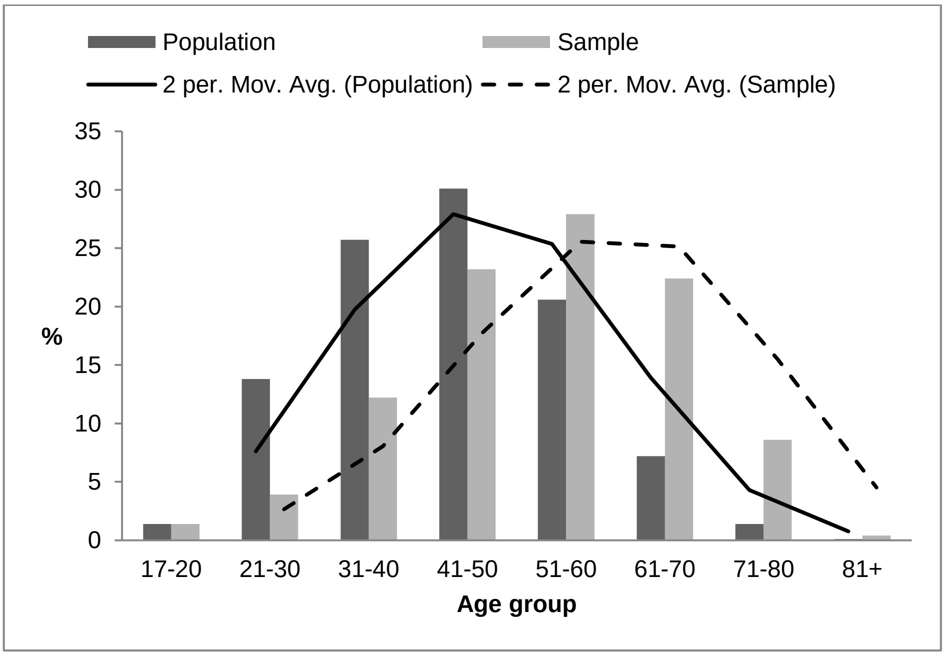

Figure 9: Representation of sample and population pilots in each age group

Accounting for age group size within both the population and the sample, the relative representation of pilots becomes biased towards pilots aged 61 and over (Figure 10).

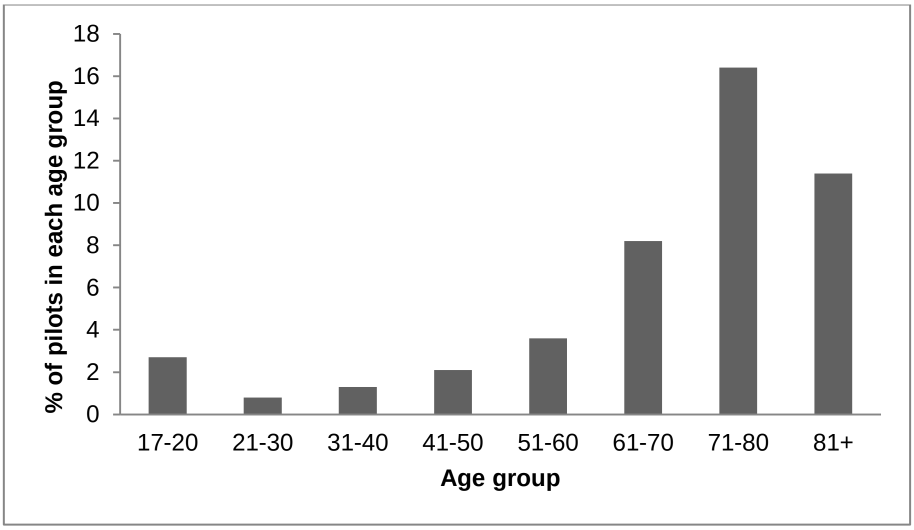

Figure 10: Actual proportion of sample pilots within the population per age group

6.1.6.ii Pilot flight experience

With regard to experience and accident involvement, it was shown that with increased experience comes a strong tendency to reduce risk of accident involvement. Using an experience grade system, those with the least amount of experience (grade 1) in each category were much more prevalent in accidents and for the categories of total, type, last 90 days and last 28 days respectively accounted for 80.1%, 87.6%, 75.7% and 71.9% of accidents. The remaining grades were apportioned as in Figure 11.

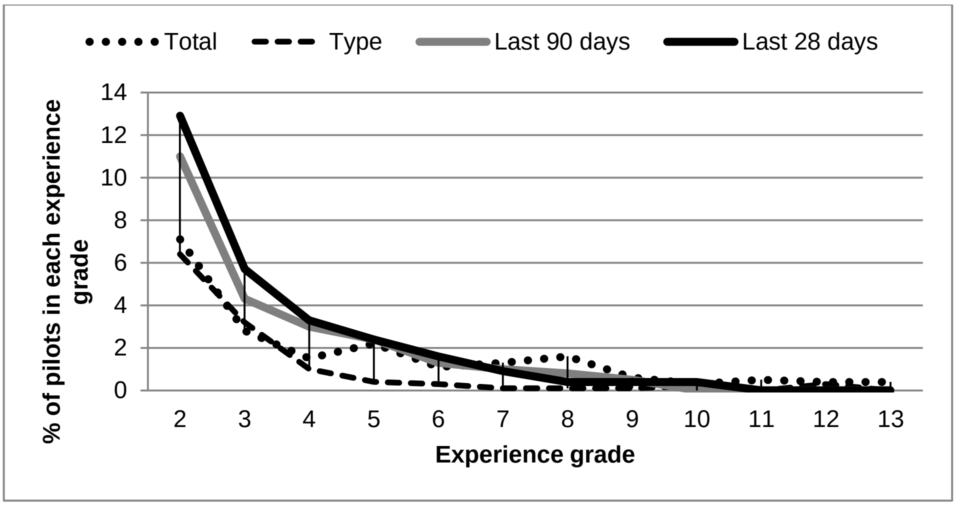

Figure 11: Percentage of pilots in each experience category according to grade

The sample mean for total flight experience was 2064.1 hours (n = 1001, SD 415.912), significantly greater than pilots in the GA survey with 982.6 hours (n = 399, SD 2340.026); t[1398] = 4.898, $p < 0.05$. In both the sample and survey, there was an increase in total experience with increasing age (Figure 12).

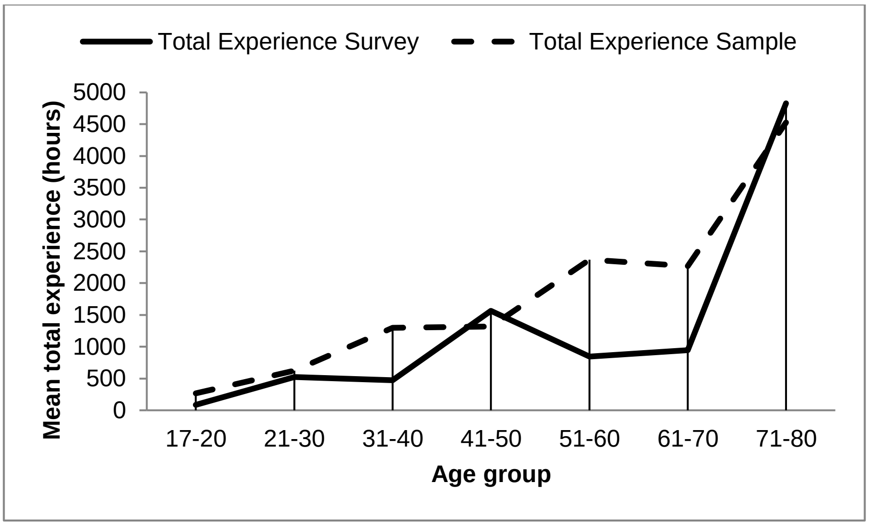

Figure 12: Mean total experience for both sample and survey pilots by age group

The sample mean for type experience was 264.1 hours (n = 991, SD 645.770), not significantly different from pilots in the GA survey with 297.8 hours (n = 321, SD 501.459); t [1310] = 0.781, $p > 0.05$. Increasing age related to an increase in type experience for both sample and survey pilots (Figure 13).

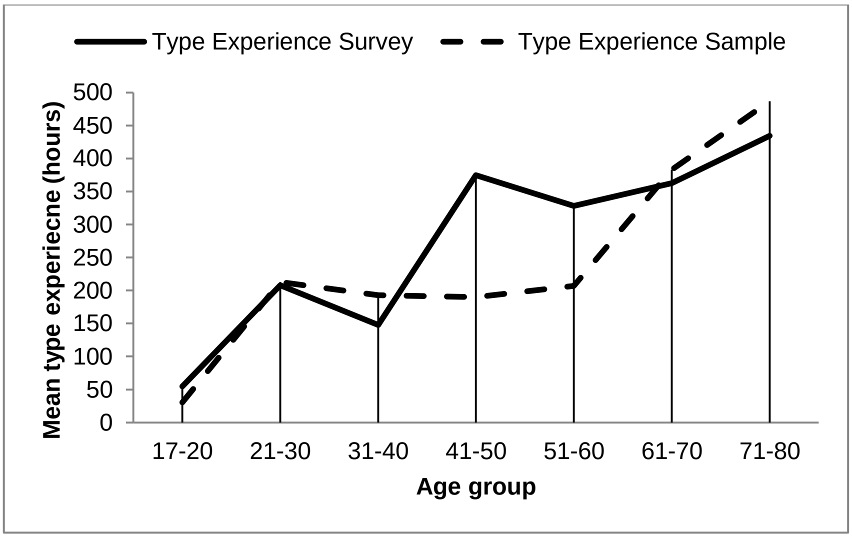

Figure 13: Mean type experience for both sample and survey pilots by age group

Regarding currency, sample pilots had flown a mean of 29.8 hours (n = 986, SD 44.754) in the previous 90 days, more than the 26.9 hours (n = 401, SD 47.114) flown by survey pilots, but not significantly so; t [1385] = 1.071, $p < 0.05$. A tendency for 90 day currency to increase was observed up to the 31 – 40 age group in the sample and up to the 41 – 50 age group in survey pilots. Thereafter currency showed a sharp decline for both sample and survey pilots with increasing age (Figure 14).

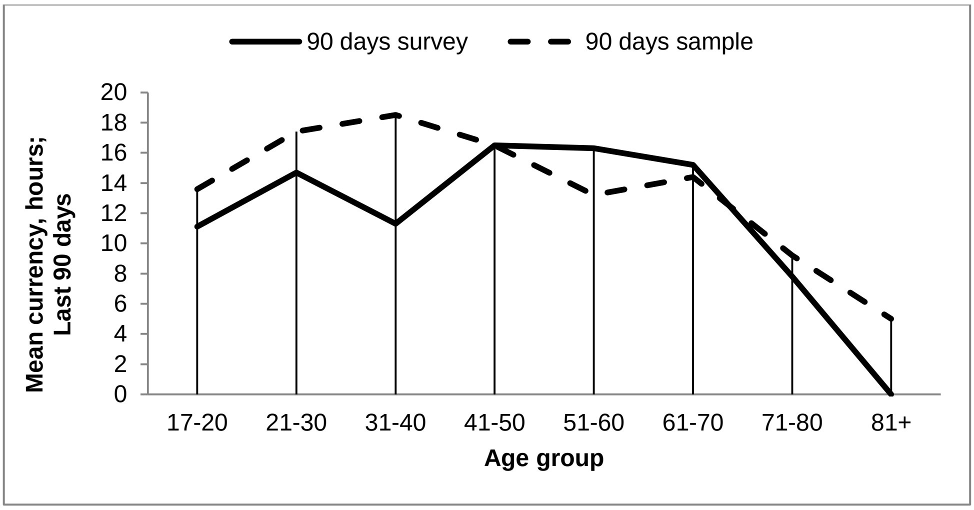

Figure 14: Mean 90 day currency for sample and survey pilots by age group

In the previous 28 days, sample pilots had flown a mean of 10.9 hours (n = 986, SD 15.450), not significantly more than survey pilots who had flown 9.5 hours (n = 396, SD 17.145); t [1380] = 1.483, $p < 0.05$. Reflecting the trend of 90 day currency, increasing experience accompanies increasing age up to the 21 – 30 age group in the sample and the 41 – 50 age group in the survey. Thereafter 28 day currency decreases with increasing age (Figure 15).

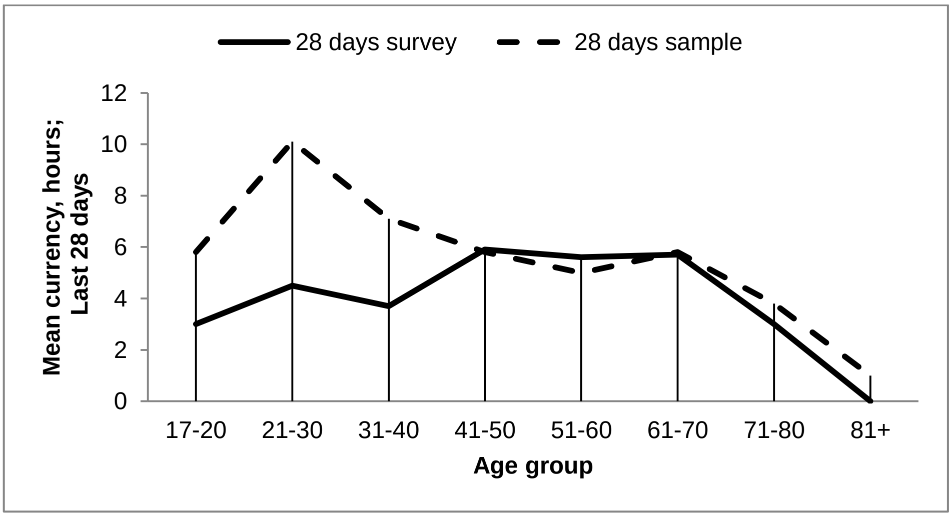

Figure 15: Mean 28 day currency for sample and survey pilots by age

6.1.6.iii Human factors

The data demonstrates no significant difference between the mean age of HF pilots (53.1, n = 633, SD 13.172) and NHF pilots (53.0, n = 356, SD 13.081); t [987] = 0.038, $p < 0.05$. This is supported by the proportion of HF pilots to NHF pilots showing little difference between pilots aged under 53 (HF: 63%, NHF: 37%) and those aged over 53 (HF: 64.9%, NHF: 35.1%).

6.1.6.iv Accident type

For all age groups, LOC was the most prevalent accident type, the highest rate occurring in the 17 – 20 age group (Table 11). Technical failures were the second most common accident type for all age groups (except 81+ where CFIT accounted for 25%) affecting the 21 – 30 age group most of all. Also for all age groups (except 17 – 20 where "other" was more frequent), airmanship was the third predominant accident type, most pervasive for the 31 – 40 age group.

Table 11: Most prevalent accident type by age group

Age group	LOC %	Technical %	Airmanship %
17 – 20	**78.6**	14.3	0
21 – 30	47.5	**37.5**	10.0
31 – 40	41.0	32.8	**22.1**
41 – 50	51.5	31.6	12.6
51 – 60	50.0	30.2	14.0
61 – 70	48.4	30.9	17.5
71 - 80	55.8	26.7	16.3
81+	50.0	0	25.0

6.1.6.v Injuries sustained

The mean age of pilots receiving fatal or serious injuries (53.7, n = 95, SD 14.451) was greater than those receiving minor or no injuries (53.0, n = 903, SD 13.024), but not significantly; t [996] = 0.511, $p < 0.05$. T test results do however show fatal and seriously injured pilots to be significantly older (53.7, n = 95, SD 14.451) than the population in 2005 (45.1, n = 1021, SD 12.913); t [1114] = 6.165, $p > 0.05$.

Considering representation of injuries within each age group, fatal and serious injuries were more apparent in the oldest age group of those aged over 80 followed by the youngest age group (Table 12). Pilots who received the least fatal and serious injuries were in the 41 – 50 age group.

Table 12: Pilot representation of injuries sustained by age group

Age Group	Fatal and Serious %	Minor and None %
17 – 20	14.3	85.7
21 – 30	12.5	87.5
31 – 40	10.7	89.3
41 – 50	5.6	94.6
51 – 60	10.4	89.6
61 – 70	9.0	91.0
71 – 80	14.0	86.0
81+	25.0	75.0

6.1.7 Discussion

6.1.7.i Means and distributions

The data in this study clearly suggests that with increasing age comes an increased likelihood of pilot accident involvement, particularly over the age of 60. Mean age and distribution of age in accident pilots compared to the population provide a compelling argument for this. Referring to Figure 9 and additional to the figures quoted, within the (N)PPL population, those between 17 and 50 accounted for 65.1% of pilots, but just 32.5% of accidents. This indicates younger pilots are less likely to be involved in an accident than older pilots, consideration for group size within the population (Figure 10) further emphasising an increased likelihood of accident involvement over the age of 61.

These results conform to general ideology, 62.1% of participants in a short online survey (n = 95) by the Author, judging pilots over the age of 45 as more likely to cause an accident, 44.2% believing this to be due to poor judgement, slow reactions or poor skills. Whilst it is broadly accepted that as people age certain cognitive and physical processes slow and diminish, it is not necessarily the case that an older person is less fit or competent than someone 20 years younger, because people age at different rates (Merat et al, 2005). Given that accident reports do not mention the pilot’s state of mental or physical health, it would be an unsubstantiated declaration that older people crash simply due to their being in inferior condition compared to their younger peers.

6.1.7.ii Age and flight experience

Support for Bazargan and Guzhva's (2011) conclusion that pilots over the age of 60 are more likely to be involved in accidents caused by pilot error and the general belief that older pilots cause accidents through slow reactions, poor skills and judgment is also absent from the data here, indicating instead that age has a negligible effect on error or human factors. In the UK older drivers are deemed to be more careful and less risky than younger ones and are rewarded with lower insurance premiums. Indeed it has been argued by some (e.g. Li et al, 2003) that aging may bring greater expertise and enhanced safety behaviour, endorsed here in Figure 9, which demonstrates that increasing experience does reduce risk of accident. Figures 4 and 5 confirm that increasing age tends to correlate to increasing experience and thus it can be inferred that, to a point, older pilots are safer.

Conflict arises from the pure age data referred to previously which implies that as much as increased experience may help reduce accident risk, increasing age has an overriding effect. Looking at Figures 14 and 15, however, there is an issue with older pilots not maintaining their levels of currency. Whilst total and type experience have a safety value, currency is important as it is an indication of how practised a pilot is in the operation of an aircraft in recent weeks and is deemed to be necessary to build and maintain decision making expertise, (Jensen, 1997). O'Hare and Chalmers' (1999) asserted concern that flying less than 30 minutes per week is not insufficient to maintain the standards of proficiency needed in a complex and demanding activity such as flying. From Figures 13 and 14, it can be calculated that pilots aged over 70 fly less than 39 minutes per week in the preceding 90 days (8 hours in 90 days) and most fly less than 30 minutes per week in the preceding 28 days, putting them at an increased risk of accidents compared to younger pilots due to a lack of decision making capability and proficiency.

6.1.7.iii Habits and training

Negative traits of increasing age and experience, cannot be ignored, manifesting as bad habits, previous research in commercial aviation, where continuous assessment and on-going training is considered vital for safety, showing that habits tend to remain and are evident in flight test performance years after initial training (Jensen, 1997). Other potential negatives of greater age and experience may also include complacency, over-confidence or a reluctance to believe that the ageing process has affected pilot competence. Indeed, the concept of deterioration error is taught to pilots in the human performance and limitations module of the ATPL theory and is believed to manifest from over-confidence and complacency (Oxford Aviation Services, 2007).

Alternately, Groff and Price (2006) suggest that training and operational differences as opposed to physical or cognitive issues have an influence on the results of age based research, citing motivation for learning to fly produces differences in the ages of pilots who are just beginning to fly; commercial pilot training is much more intense and operations are heavily regulated compared to GA flying and individuals pursuing this field will tend to be younger than those investing in recreational GA. Data from the CAA and the GA survey demonstrated the bulk of (N)PPL pilots to be in the 41 to 60 age group whereas the bulk of commercially qualified pilots lie in the 31 to 50 age group.

6.1.7.iv Accident type

For many accidents in the sample, loss of control (LOC) was cited as a causal factor ranging from directional control on the ground to fatal instances of stalling and/or spinning. Maintaining control of an aircraft is a skill which is most likely to be enhanced through experience, particularly recent flying. The high proportion of young pilots, particularly those in the 17 – 20 age group within the sample who lost control can therefore be ascribed to a lack of skill associated with their age and/or low level of flight experience, given that most of these pilots, even if they are on a commercial flight training programme, will be at the beginning of their flying career as by law they cannot achieve a pilot’s license until the age of 17 (21 for commercial licenses).

Technical failures can happen through poor maintenance, inadequate pre-flight checks or out of pure bad luck, but in general the more flying a pilot does, the greater their risk of exposure to such an event. The fact that the 21 – 30 age group have a greater comparative prevalence in these events than other age groups (Table 11) presents an apparent dilemma of logic. Firstly, why does the youngest age group not appear to be afflicted by technical failures when they are just a few years younger? The answer is simply that they are more overwhelmed by LOC and although they have technical issues, they have many more associated with LOC. Furthermore, relating to the earlier statement concerning their likelihood of still being in training, much of their flying takes place close to their home airfield and any impending technical failures may not have time to take hold, the student pilot being able to quickly land without further incident and thus not being required to report an accident.

From age 21 the relative prominence of technical failures causing an accident steadily reduces, possibly out of a growing level of experience whereby the pilot is better equipped in skill and presence of mind to manage a problem successfully, the same positive change also being potentially associated with increasing age. As has been stated previously, age appears to have a greater influence over accident involvement than experience, so there is no reason to believe there is any difference here and the reduction in technically induced accidents is more down to increased age than increased experience.

Airmanship comprises a mix of skill, common sense, procedural discipline and courtesy. Lapses in this particular proficiency would logically be associated with younger pilots who may lack the common sense, discipline and manners of their older peers, or who have not had the opportunity to build their flying skills. This appears at least in part to be true, the 31 – 40 age group being most susceptible to these lapses. The bias of other causes combined with a higher likelihood of recent training having taken place is a credible rationale for the lack of airmanship accidents occurring to younger age groups. Beyond the age of 40, age appears to have a positive effect on the proportion of accidents being caused by poor airmanship, a large drop being recorded in the 41 – 50 age group and only slightly increasing thereafter.

6.1.7.v Injuries sustained

Fatal and serious injuries by age group would be graphically represented by the bathtub curve, the youngest and oldest age groups showing the greatest proportions. For those over the age of 70, this can perhaps be explained by the comparative frailty of people at this age, even those who have maintained a high level of fitness, the OECD (2001) determining that on the roads, older drivers have a higher fatality rate than younger drivers owing to the natural physical vulnerability of older people, although this could not be absolutely substantiated with evidence in this case.

Referring to 7.6.4, with more than half of all accidents involving those aged over 70 being due to LOC, it’s reasonable to assume that this type of accident results in higher impact forces than others, whether that be from ground collisions with buildings and other objects or from high speed impacts with the ground following a stall. This explanation is a plausible elucidation of the higher proportion of younger pilots receiving serious and fatal injuries, most of their accident being LOC related. Regardless of accident type, or cause, it remains that there is a distinct increase in fatal or serious injury likelihood for those aged 17 – 30 and particularly for those over 70.

6.1.8 Summary of Part 1

This first part of Chapter 6 has shown there to be clear evidence to conclude that accident pilots are significantly older than the general pilot population, qualifying the beliefs of many that older pilots are more likely to cause an accident due to their diminished capabilities. These beliefs, however are not substantiated entirely as there is no evidence in UK GA accident data to suggest that older pilots are more likely to cause an accident through error or human factor related issues.

Whilst increased experience is related to both increased age and reduced accident involvement, lack of currency among older pilots appears to counteract their overall flying experience, making them more susceptible than younger pilots to accident involvement.

Younger pilots are more likely to have an accident associated with loss of control, even accounting for the high level of LOC amongst all age groups, but do not feature in accidents involving poor airmanship.

The highest proportions of all accident types, by age group, occurred in the three youngest groups and for the remaining age groups there is no discernible difference in the proportions involved in particular accident types, other than those already mentioned.

Pilots aged over 80 are the most likely to receive fatal or serious injuries in an accident, those in the 17 – 20 age group being the second most prolific in this category of accident, only surpassing the 71 – 80 age group by a minimal variance.

Whilst it would be difficult and costly to implement new policy to regulate for concerns of age in UK GA, it must be put to the flying clubs, training organisations and pilots themselves, that there is a responsibility in the GA community to be aware that the safety of younger and older pilots is, in different ways, affected by their age. Mutually agreeable steps must be taken to ensure these potentially vulnerable pilots are monitored and supported in their activities. Individual pilots, of all ages, must too bear the responsibility of ensuring they are fit to fly each and every time they climb into a cockpit and be encouraged by their peers, as well as the authorities, to be completely honest in their self-assessment. Ultimately the safety of themselves and their passengers is at stake.

Part 2 of this chapter makes a more detailed examination of the characteristics of human factor accidents and their relationship with pilot experience, making further reference to HFACS as presented earlier in 6.1.4.

6.2 Human factor accidents and their relationship with pilot experience

6.2.1 Introduction

In Part 1, the influence of age and pilot experience on the incidence of accidents was explored, determining their influence, if any, on the likelihood of individuals to be involved in an accident.

Following on from that discussion, it is important to offer detail on one of the main causal factors of UK GA accidents, human factors, the indications for which show an increasing trend from 2005 to 2011. Thus in Part 2 of this chapter, definitions of different aspects of human factors and how they can affect flight safety will be offered along with further information on how the accidents reviewed were separated into either the human factor (HF) or non- human factor (NHF) categories. Discussion will focus on the particulars of the accident pilots and whether any specific attributes of HF accident pilots, such as experience or age, were comparative to NHF accident pilots.

Studies (e.g. Lenné et al, 2008) have shown 70% to 90% of all aviation accidents occur within GA, 85% of those implicating human factors as a contributory causal factor. These statistics are well known, but less well known is the relationship between experience and HF accidents in GA. Does experience reduce the chances of a pilot making HF errors or are errors made randomly by pilots of all experience levels? This chapter explores this relationship to determine trends in the experience levels of pilots who are in command of GA aircraft involved in human factor related accidents in the UK.

6.2.2 The connections between GA and commercial aviation

Although this chapter does not intend to determine which human factors are involved in UK GA accidents, it is still important that a brief overview of the subject is presented and a link to commercial aviation made to emphasize that there is an association with human factors mutual to both sectors of the industry.

Situational awareness is a significant factor in the ability of a crew to cope in difficult situations. Research in commercial aviation has shown that in multi-crew situations the pilot flying is the one most likely to lose SA and commits more of the critical errors leading to accidents than the monitoring pilot (Jentsch, et. al., 1999). This suggests that the workload of flying an aircraft reduces the ability of the pilot to maintain awareness in a problem situation (Jentsch et. al., 1999). In single pilot operations such as GA, in an emergency the pilot must fly the aircraft, perform associated tasks and try to identify the problem, in order to attempt a resolution, but this proves difficult, as it is generally their own errors they have to identify (Deutsch & Pew, 2005).

The most frequent human errors befalling both commercial aviation and GA fall into level 1 of HFACS as presented in Chapter 5; skill based, decision and perceptual. The most prevalent errors are skill based accounting for 45% and 80% of accidents in each field respectively and include poor scan patterns, inadvertent activation or deactivation of switches, forgotten intentions and omitting items from checklists (Shappell & Wiegmann, 2009).

Decision making is a more complicated process than might first be apparent, as discussed in Chapter 4. Wickens and Flach (1988) describe the process as one where the pilot must make choices based on the least negative outcome and stems from the cognitive route of situation assessment, cue seeking, hypothesis formulation and testing and decision formulation. When considering that many decisions in an emergency must be made in a split second and under duress, it is conceivable that some pilots make the wrong choice, given the reduction in performance once stress reaches a given level (Chapter 4, Figure 8).

Perceptual errors often occur in visually impoverished environments where pilots can misjudge distances, altitude and descent rates, as well as misinterpreting visual and vestibular sensory inputs (Shappell & Wiegmann, 2009). Possible reasons for such errors include cognitive limitations, fatigue and poor training (Helmreich & Merritt, 2000).

6.2.3 Pilot experience; the arguments

A general definition of experience would be the observation of, or acquaintance with facts or events resulting in knowledge and/or skill. To gain experience in any task is to enhance understanding and familiarity, the desired goal to be better and more efficient at that task. The presumption is that those with experience are more accomplished in a given task and in an activity such as flying, this in turn makes the individual a safer pilot. For the most part this is probably true, but not everyone is alike and so not everyone will necessarily benefit in the same manner from the rewards of experience.

The various categories of pilot experience have previously been discussed in Chapters 3 and 5, thus further definition is not warranted. However, the conclusions of other research on how experience affects accident vulnerability have not been fully presented and follow here.

During specific periods of a GA pilot's flying career, they become vulnerable to accident involvement (O'Hare & Chalmers, 1999) and at around 100 hours has been presented as a possible weak point (Olsen & Rasmussen, 1989). Jensen (1995) suggested that pilots with between 100 and 300 total flying hours are susceptible to accidents and Booze (1977) found those with 101 to 200 hours recent flying have a ten-fold increased accident risk compared to those who have currency of just 0 to 10 hours. Additionally, the Aircraft Pilots and Owners Association's (AOPA; 2006) suggested pilots with 200 hours total experience are most prone to have an accident.

Conversely, Pratt (2003) found that experienced pilots with more than 1000 hours were involved in three times more fatal accidents than those with less than 100 hours. Furthermore, O'Hare and Chalmers (1999) concluded that pilots within the 100 to 200 or 100 to 300 total time periods are not at increased risk of accidents. Thomson et al (2004) suggested that experience induces overconfidence and that experienced pilots tend to take more risks. Booze (1977) concurred, believing flight experience becomes a risk for high-hour pilots due to overconfidence and a lack of vigilance.

The findings presented here are conflicting and the study in this chapter will seek to confirm which, if any, relate to accidents in UK GA, as well as verify whether or not pilot experience has any correlation to accidents and incidents where human factors are considered to be causal or contributory causes.

6.2.4 Expertise

An alternate method for measuring flight experience is in the form of a pilot's expertise, i.e. their level of license should indicate their level of competence and ability and would suggest that an ATPL qualified GA pilot with 500 hours is probably more proficient than a PPL qualified GA pilot with 700 hours. These assumptions were positively reflected by Taylor et al (2007) who found that expertise can result in better flight performance and even overcome the effects of aging on flight competence. However, as the majority of pilots in this study held only non-professional licenses, they cannot be classed as experts, thus it was considered more rational to use hours gained as the primary method of gauging experience.

6.2.5 Gathering and analysing the data

The methods used to gather and analyse data were the same as those submitted in part 1, but some aspects differ as they were adapted for the specific analysis of HF data, thus relevant elements shall be repeated here both for clarity and continuity.

The 1007 gathered accident reports were independently classified by the author (a qualified private pilot) and two other persons, (one a University Senior Lecturer in Aviaiton, one a Crew Resource Management Instructor specialising in human factors) as either HF or NHF using HFACS as a primary guide. NHF accidents were deemed to be those where the pilot's actions or inactions were not causal or of any major consequence to the accident and as such succumbed only to misfortune. Meetings were convened to discuss their findings and mutually agree on the final classifications.

As alluded to in Chapter 5, HFACS was used as it is an established and accepted format for classifying the main subsets of human error types and assisted in the determination of the causes and contributory factors of accidents as either human factor or non-human factor.

Classification was determined by comparing the probable causes (as determined by the AAIB) to the criteria of each HFACS level, starting at level one (Table 10, p70) and establishing whether or not the actions or inactions of the pilot corresponded to these criteria. Additionally contributory factors such as the human/environment interface, technical and/or ergonomic issues and cockpit task management were simultaneously considered, allowing a more measured determination to be made as to whether the accidents should be classed as human factor events. These were defined as causal if they initiated the chain of events leading to an accident and contributory if they exacerbated a situation that otherwise might not have resulted in an accident had the contribution not been made. It was also determined at what level the HF accidents occurred within the HFACS model hierarchy

Reports of less serious accidents, especially if completed by the accident pilot alone, may only contain a few paragraphs and do not always provide a possible cause. Although in the minority, these reports gave the authors a difficult task in determining the full sequence of events and whether or not the accident could be attributed to human factors, either fully or in part. Many pilots however, gave an honest account of the accident and offered likely causes, even if they considered themselves to be to blame.

During the classification process to ensure appropriate rationale, the works of Hawkins (1987), Edwards (1988) and Reason (1990), were utilised along with studies based around the HFACS framework, e.g. Dambier and Hinkelbein (2006), Li and Harris (2006), Lenné, et al (2008). Also appraised were the works of the HFACS authors and their associates (i.e. Wiegmann et al, 2005; Shappell et al, 2005; Shappell and Wiegmann, 2009) as well as the UK CAA's CAP 719, Fundamental Human Factors Concepts (2002).

6.2.6 Data analysis

Data for the categories of total hours, type experience, the last 90 and last 28 days was collated and the mean values for each calculated. The data was analysed using t-test calculations to determine the significance of variations in the data between HF and NHF accident pilots.

Two classes of data results were formed for clarity; flying experience (total and type) and currency (last 28 and 90 days). To produce a graphical representation of how accident involvement changes with experience, HF and NHF experience levels for both total and type were grouped using appropriate intervals; every 1000 hours for total and every 400 hours for type.

The accidents within the sample ranged from minor incidents where little or no damage occurred and no injuries sustained to serious accidents where substantial damage occurred and injuries from minor to fatal were reported. In the process of analysing the data, the severity of injury according to accident type was also examined at a rudimentary level.

6.2.6.i Findings; Initial numbers and HFACS hierarchy classification

It was found that 63.4% (N = 638) of the sample accidents were deemed to be HF in nature, somewhat lower than the expected values considering previous research. Referring to the HFACS model, it was determined that the majority of HF accidents (73.6%) occurred as level one type; unsafe acts. Skill-based errors accounted for 66.6%, decision and perceptual errors inducing 3.6% and 3.2% respectively. Overall, unsafe acts produced 82.9% of all HF fatalities, 39% being skill-based errors, 24.4% perceptual errors and 19.5% decision errors (Table 13, p98).

This corresponds to Wiegmann and Shappell's (2003) suggestion that 80% of all aviation accidents are linked to unsafe acts by pilots. The findings of other studies (e.g. Wiegmann et al, 2005; Shappell et al, 2005; Lenné, Ashby and Fitzharris, 2008; Dambier and Hinkelbein, 2006) also show skill-based errors to be the most prominent in GA and commercial accidents, decision and perceptual errors following as important issues with slightly varying results.

Table 13: Summary of accident classification according to HFACS

HFACS Level	Fatal	Serious	Minor	None	Total	%
Level 1: Unsafe acts						
Violations	0	0	0	1	1	**0.2**
Perceptual errors	12	1	3	4	20	**3.2**
Skill-based errors	18	12	41	356	427	**66.6**
Decision errors	9	1	2	11	23	**3.6**
Level 2: Preconditions for unsafe acts						
Technological environment	0	0	1	3	4	**0.7**
Physical environment	1	1	12	79	93	**14.5**
Crew Resource Management	0	2	3	58	63	**9.9**
Physical/mental limitations	0	0	0	1	1	**0.2**
Adverse physiological state	6	0	0	0	6	**1.1**

The physical environment (HFACS level 2; preconditions for unsafe acts) produced the second highest overall proportion of accidents at 17.4%, 4.9% of these proving fatal, accounting for just 1.3% of all HF fatalities. Collectively, 79% (75.6% skill-based errors) of level 1 accidents resulted in no injuries, whereas no injuries were reported in 83% of level 2 accidents.

6.2.6.ii Total and type experience

Mean values for each experience category were shown to be significantly greater in NHF accidents than HF accidents in all cases; total experience (HF 1748.5 hrs, SD 3950.3 Versus NHF 2614.3 hrs, SD 4467.865): t [990] = 3.163, $p < 0.05$, type experience (HF 214.4 hrs, SD 528.636 Versus NHF 354.8 hrs, SD 812.856): t [980] = 3.270, $p < 0.05$;

Notably, a small number of pilots had more than 10 000 total hours, but less than 50 hours on the accident aircraft type; 2.5% of HF pilots and 2.2% of NHF pilots. Exploratory analysis revealed the difference between both total and type experience levels not to be significant.

Concerning pilots with less than 10 000 total hours, statistically, the difference in experience between HF (1129.1 hrs, SD 1695.064) and NHF pilots (1717.8 hrs, SD 2179.870) was significant; t [550] = 3.565, $p < 0.05$. In comparison, for pilots with more than 50 hours on type, the difference between HF (349.6 hrs, SD 555.277) and NHF pilots (429.2 hrs, SD 631.299) was not significant; t [550] = 1.565, $p < 0.05$.

Taking the mean of each experience category as a cut-off point, 80.5% of all accidents (*n = 806)* involved pilots with 2064 hours or less total experience, 65.5% of these being HF accident pilots (mean 444.1 hrs, SD 431.948). Regarding type experience, 77.4% of all accidents (*n* = 767) involved pilots with 264 or less hours, 67.5% of these being HF accident pilots (mean 65.5 hrs, SD 64.367). When compared to the corresponding NHF values (total: 667.1 hrs, SD 520.991, type: 76.7 hrs, SD 67.019), both were significantly less for HF accident pilots; (total) t [798] = 6.439, $p < 0.05$, (type) t [759] = 2.209, $p < 0.05$.

6.2.6.iii Currency

As for total and type experience, HF accident pilots were shown to have significantly less currency than NHF accident pilots; Last 90 days (HF 24.7 hrs, SD 39.243 Versus NHF 38.4 hrs, SD 51.601): t [975] = 4.664, $p < 0.05$, Last 28 days (HF 9.5 hrs, SD 13.909 Versus NHF 13.4 hrs, SD 17.662): t [875] = 3.872, $p < 0.05$.

Taking 1 hour per week as a measure of good flying currency, it was found that a greater proportion of HF pilots than NHF pilots had flown less than that within the previous 28 and 90 days (Table 14). Conversely a greater proportion of NHF than HF pilots had flown more than two hours or more per week in the previous 28 and 90 days.

Table 14: Percentage of pilots maintaining between 1 and 2 hours per week flying currency (N: HF = 638; NHF = 369)

Currency category	Hours flown	Last 28 Days	Last 90 Days
HF pilots (%)	< 1 hour	50.6	55.9
NHF pilots (%)	< 1 hour	40.5	42.3
HF pilots (%)	> 2 hours	32.4	22.8
NHF pilots (%)	> 2 hours	45.3	39.4

6.2.6.iv Experience grouping

Having grouped and graphically presented total hour's data into 1000 hour intervals and type hour's data into 400 hour intervals, two observations were immediately noted; for both HF and NHF pilots, as experience increases, accident involvement decreases. Pilots with lower levels of both total and type experience tend to be HF pilots, although this is less pronounced on type (Figures 16 and 17).

The first two groups of each category were omitted from the graphical displays for scaling purposes but HF pilots were more heavily represented in the first 1000 hours total (73.7%) and first 400 hours type (88.7%) than NHF (59.7% total, 76.4% type). The reverse was true of the second groups; HF: total 9.7%, type 5.2%, NHF: total 14.7%, type 13.1%.

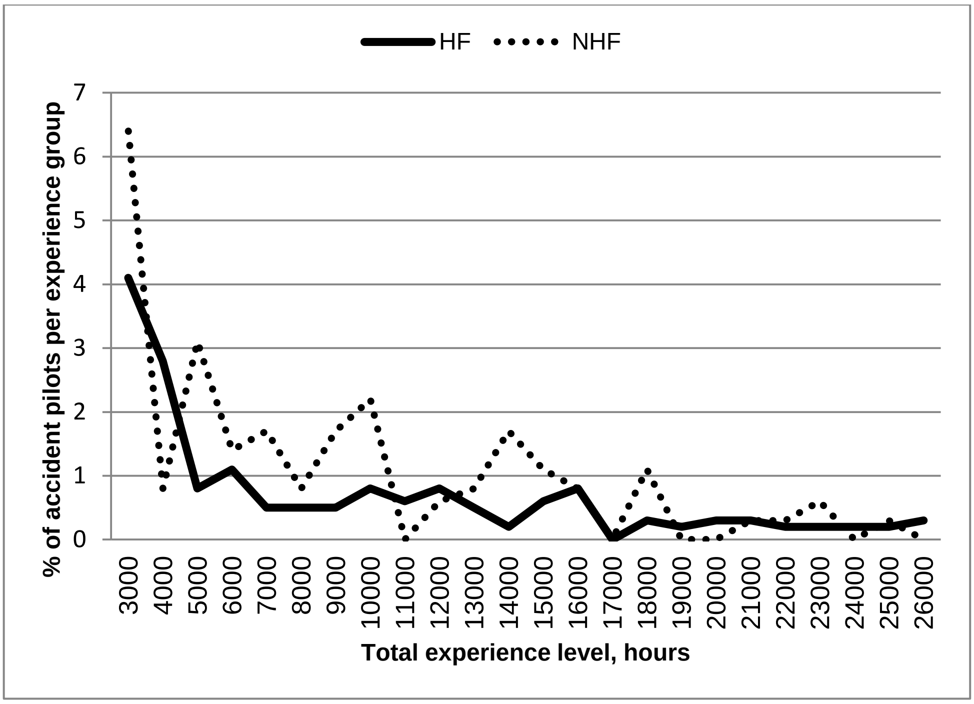

Figure 16: Total experience by 1000 hour interval (N, HF = 632; NHF = 360)

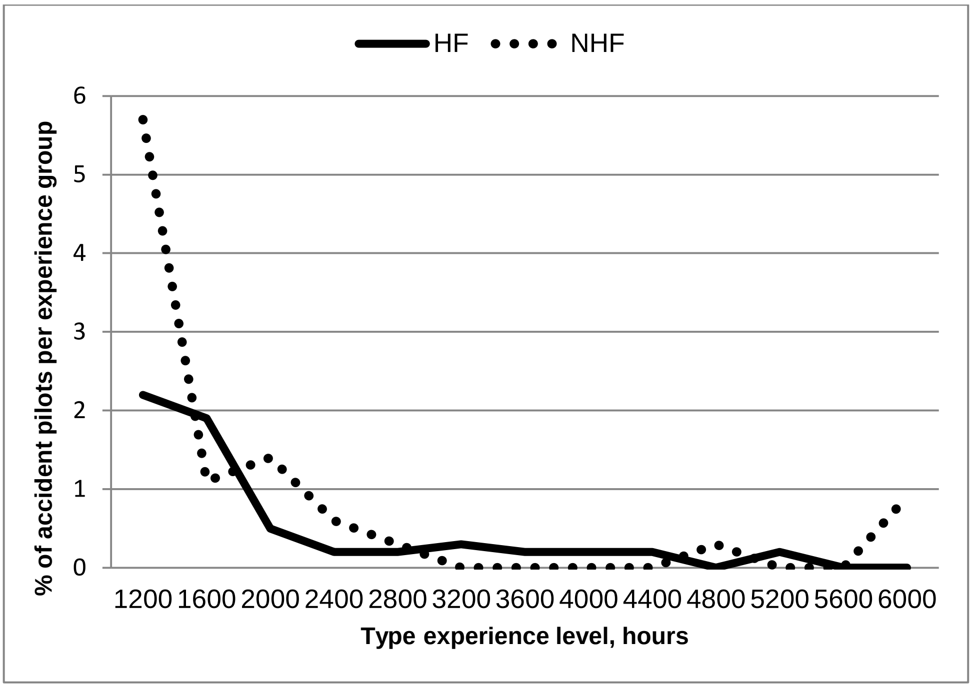

Figure 17: Type experience by 400 hour interval (N, HF = 630; NHF = 352)

6.2.6.v Injuries sustained

The data shows that the majority of accidents resulted in no injuries (79.6%), this figure being representative of both HF and NHF accidents; 79.6% and 79.5% respectively. The proportion of fatal accidents was higher for HF accidents at 7.3% compared to 3.6% of NHF accidents whereas NHF accidents resulted in slightly more minor and serious injuries than HF.

6.2.7 Discussion

6.2.7.i Flying Experience

The significance of differences in experience between HF and NHF pilots show us that its influence on accidents involving human factors is compelling. It demonstrates how valuable experience can be in not only maintaining skills, but also other attributes important in flying such as decision making, procedures and situational awareness.

Although representing a small proportion of the sample, pilots with more than 10 000 total hours but less than 50 hours on type highlighted an important point despite the lack of significance in differences; regardless of total experience gained, any pilot can be vulnerable to accidents following transition to another type. As with currency, accident reports do not state when the pilot last flew the accident aircraft type and even if currency is good, recent flights may have been on a different type. Either way, these pilots clearly have much more experience on other aircraft and as such have a relative lack of familiarity with the accident aircraft's performance capabilities, handling and cockpit layout, these elements arguably being more important than raw flying skills. Interestingly, HF pilots were more representative in this group than NHF pilots, although only slightly. Nonetheless a greater proportion of pilots with large disparity in their total and type experience levels were exposed to human factors resulting in an accident.

The significant differences in mean values equate to NHF accident pilots having 49.5% more total and 65.5% more type experience than HF accident pilots. For any task this is a substantial advantage for performance and efficiency and in flying is the difference between being involved in an accident through chance or misfortune and making errors that exacerbate a situation leading to an accident. For many of the pilots, it was not their mistake that caused the accident, but their apparent lack of flying or type experience preventing them from successfully managing it which resulted in the accident. For others, of course, it was their apparent lack of the same that led them to make an error directly leading to the accident.

6.2.7.ii Currency

Flying requires skill which is most effectively maintained through practise. As a large proportion of GA is recreational, many pilots only fly occasionally. The figures for currency in Table 14 demonstrate that approximately half of HF pilots had flown less than one hour per week. Accident reports, however does not disclose the date of the pilot's last flight, so it cannot be inferred that it was the previous day or week and the pilot may have most recently flown 27 or 89 days ago. Thus it is not unreasonable to presume that some pilots may have been lacking in very recent practise.

The difference in levels of currency equate to and 1.1 (90 days) 1.0 (28 days) hours per week more recent flying by NHF pilots than HF, considerable amounts given that one hour per week is generally accepted as sufficient in itself to minimise degradation of skills. As Table 14 indicated, NHF pilots were much more current in their flying overall than HF pilots and in the same vain, as type experience is important for aircraft familiarity, it underpins the value in flying on a regular basis to keep skills sharp, support the recall of procedures and practise good airmanship. Further supporting this concept is the fact that NHF pilots had 48.3% more currency than HF pilots, O'Hare and Chalmers' (1999) asserting concern that flying less than 30 minutes per week is not insufficient to maintain the standards of proficiency needed in a complex and demanding activity such as flying.

6.2.7.iii Distribution of experience

The arguments concerning vulnerable periods of experience referred to previously are extreme in their diversity, but the bias leans towards the 100 to 300 hour period being the most susceptible to accidents. The evidence in this investigation agrees that pilots early on in their flying career are more likely to be involved in an accident, as would probably be expected. What is added to the argument here is that the type of accident is influenced by experience, those with lower hours more likely to induce a human factors accident and those with greater experience more likely to be involved in an accident through chance or misfortune.

The reasons behind the relationship between experience and accidents are not clearly understood. One suggestion may be that at around the 100 to 300 hour period, a pilot may feel ready to take on a faster, more powerful aircraft or they wish to broaden their experience and become more adventurous in their flying. Both situations harbour unknowns, unfamiliar surroundings and new challenges, increasing the risks involved. Even if the pilot receives excellent instruction on the operation and handling of a new aircraft, their experience effectively reduces back to zero and they need to relearn some of the basic fundamentals of flying a plane, particularly if the pilot has converted from a two seat, fixed undercarriage aircraft with fixed pitch propeller to a four or six seat, more powerful aircraft with retractable undercarriage and variable pitch propeller. In its review of GA fatal accidents from 1985 to 1994 (CAP 667, 1997), the CAA found that 10% of the accidents involved more complex, faster aircraft which require faster thought processes and reactions to keep up with them.

In a similar vein, this period of flight experience may produce a desire in pilots to broaden their skills base and become more adventurous in their flying. This could mean flying further than before, possibly to an unfamiliar airfield and most likely venturing into territory outside the known local area. Any undertaking where the individual is presented with unknowns, unfamiliar surroundings and new challenges puts a person under increased pressure and adds to the risk involved, particularly in flying.

It has been suggested by some that an increase in experience brings an increase in risk taking as skill levels increase (Clarke et al, 2006) and an accompanying sense of growing confidence is felt by the individual. Balance is imperative, however if the individual is to refrain from becoming over confident and losing the ability to be objective about their ability to undertake new, more adventurous activities.

6.2.7.iv Highly experienced pilots

There were a number of very experienced pilots who fell foul of human factors and had an accident. As discussed previously, a number of these pilots were lacking in experience on the accident aircraft type which would likely provide a share of the explanation. Other cases could certainly be explained by exposure, pilots who have flown thousands of hours increasing their risk of an accident purely through the adage that if you fly a GA aircraft for long enough, an accident is bound to happen at some point, whether that be through a human related mistake or misfortune, but there are alternative possible explanations.

The overconfidence, lack of vigilance and increased risk taking alluded to by Booze (1977) and Thomson et al (2004) concerning experienced pilots, supported by Clarke et al (2006) will likely have played some part in a proportion of these accidents. Correctly balancing experience and character is imperative if the individual is to refrain from becoming over confident and losing the ability to be objective about their ability to perform certain tasks. Intrinsically linked to becoming more adventurous, confidence is a vital tool in accomplishing new tasks safely through making definitive decisions and actions. Pilots with over 100 hours may also feel a sense of pride at their achievement.

As well as confidence this could induce a perception that their skills are better than is actually the case, an attitude that has often contributed to serious accidents (Bramson, 1990).

Another notion possibly connected to this new confidence level in a pilot is that of so called ‘get-home-it is.’ Both these conditions are associated with continued flight into bad weather. Aside from over confidence, believing oneself to be more skilled than is actually so or being too proud to ask for help, a causal factor that crops up again and again in this situation is poor pre-flight planning (Pratt, 2003). Failure to either check the forecast or make a sensible decision about whether to fly knowing the forecast is a serious error of judgement and a lack of due care.

6.2.8 Summary of Part 2

There are myriad issues that may cause a pilot to make an error, but do not appear in AAIB reports; personal circumstance, peer pressure, pride, ignorance, lack of knowledge, fear or basic skill levels are all potential advocates of human factor accidents, but lack of experience is tangible and has been demonstrated here to be an essential component in the cause of UK GA human factor accidents. Based on the findings presented here, the following conclusions were drawn:

- Experience is an important factor in GA flight safety, this study demonstrating that pilots with lower levels of total and type experience are more likely to be involved in accidents where human factors are cited as an initial or contributory causal factor.
- Pilots with many total hours flying time experience remain susceptible to HF accident involvement if their experience on a particular aircraft type is low, regardless of their license level.
- Lack of recent flying experience is also a precursor to accident vulnerability, pilots with lower currency levels being more likely to be involved in an HF category accident. Those most at risk have less than one hour per week’s flying time logged within the preceding 90 days.

Further to the findings, there would be prudence in consideration being made by the authorities to introducing simple flight competence assessments at set intervals within a pilot’s flying career, particularly in the first few hundred hours. At the very least, pilots at all levels of experience should be actively encouraged to fly periodically with a qualified instructor to ensure that their skills have not degraded and maintain standards of safety within UK GA.

The third and final part of this chapter will explore the topic of accidents stemming from the pilots exhibiting traits of detrimental airmanship.

6.3 Accidents as a result of detrimental airmanship

6.3.1 Introduction

Parts 1 and 2 of this chapter discussed the influences of age and experience on both their role in UK GA accidents and relationship with human factors

This third part focuses on a cause of accidents that is perhaps one of the most difficult to eradicate, due to it stemming from combinations of the training a pilot has received, the skills they developed both during and after that training, their levels of safety awareness and professionalism when undertaking a flight and also the attitude, character and personality of the individual; airmanship.

6.3.2 Airmanship defined

There is an expectation that all pilots, whatever aircraft they fly and in whatever context, will follow the code of good airmanship. It is an often used term to broadly describe good practise; pre-flight checks, good lookout, courtesy to other pilots, respect for regulations and so on. As will have been alluded to in Chapter 5, detrimental airmanship encompasses tangible pilot errors as well as cases of bad practise and destructive attitudes. It is well known in aviation that human factors are present in 60% to 80% of all accidents, but not all of them are caused by the pilot. As for LOC, meteorology and technical failures, it is often the actions of the pilot in a given emergency that can make the difference between a safe landing and an accident taking place. Skill, decision making, complacency, arrogance, knowledge, resignation and myriad other traits of an individual will determine whether or not they resolve a situation through good airmanship, or indeed whether one is initiated or exacerbated due to detrimental airmanship.

Although it could be argued that most of the accidents within the sample contain some element of detrimental airmanship as a contributory factor, it was determined to be the major cause in just 15.3% of them. It is intended here to discuss both the contributory and causal elements of detrimental airmanship in UK GA accidents using the data to support the theory, focusing to the most extent on fatal accidents.

6.3.3 Fatal mid-air collisions and potential causes

There were 154 accidents categorised as having been caused by detrimental airmanship, 11 of which proved to be fatal. Included in this number are a total of five mid-air collisions, involving ten aircraft, the occupants of four of which survived with no injuries. Although each collision was reported as one accident, for the purposes of this thesis, the data for each pilot was treated separately. With the exception of one, all these collisions took place during the cruise phase of flight.

In each collision, it was concluded that none of the pilots saw each other prior to impact, with the exception of one where a glider pilot tried to take avoiding action, but was unable to avert a collision; this pilot parachuted to safety. In each case it was confirmed that the visibility had been good.

The easiest assumption to make in mid-air collisions is that the pilots were not maintaining a sufficient lookout to be able to have seen the other aircraft and were not adhering to the ‘see-and-avoid’ principle; the pilot looking outside the cockpit and gaining an awareness of what is happening in their surroundings (CAA, 2010). One accident report (AAIB, 2006, p42) highlighted the importance of the lookout in saying:

“Maintaining an effective lookout for aircraft and other hazards is a prime task for a pilot”

There are however several factors that can diminish a pilot’s ability to make visual contact with other aircraft flying nearby, potentially on a collision course and being able to compensate for these will enhance the see-and-avoid action.

The first is the physical limitations of the eye in that it can take up to two seconds for the eye to refocus when changing from, for example, looking at the instruments to looking outside for conflicting traffic (CAA, 2010). Focusing is also problematic in certain meteorological conditions, such as haze and pilots can suffer from ‘empty-field myopia’ where they stare, but see nothing (CAA, 2010). Additionally, the eye relies on motion to attract its attention and the brain can ignore that occurring in the peripheral vision, leading to a tunnel vision effect, which can be compounded by the fact that aircraft on a collision course, whether from straight ahead or the side, appear to be motionless (CAA, 2010).

Assuming a modest closing speed of 200kt (230 mph; the typical cruising speed of a GA aircraft is approximately 100kt, but complex single and twin engine aircraft may cruise at more than 200kt), at one mile distance each pilot will have 15.6 seconds to both see the oncoming traffic and recognise it as a threat, assess the situation and take avoiding action. At this distance, even large aircraft can be difficult to see, smaller aircraft being even harder to detect and may even appear initially to be an imperfection on the wind screen (Leibowitz, 1988). In so being, it is probable that the time quoted here is an absolute maximum and is likely to be much less.

The second factor concerns the obstruction in pilot vision provided by wind screen pillars and other aircraft structural components such as wings. Investigations by the AAIB into relative position of the aircraft at impact and likely pilot eye position reveal that in three of the collisions, this was a reasonable assumption to make. Supporting the concept of visual limits of the human eye as outlined above, the AAIB remarked that:

"There are limitations in the human visual system that serve to make collision avoidance difficult by visual means alone……small targets may be hidden behind (aircraft structures)" (AAIB, 2006, p42)

A third element concerns the clarity with which aircraft appear against a given background; grey cloud, blue sky, brown/green fields, etc. Referred to as visual conspicuity, the AAIB (2009) cited two reports by the RAF Institute of Aviation Medicine, both concluding that powerful forward-facing lights and the use of black paint on aircraft have statistically significant advantages in making aircraft visible compared to aircraft without lights and those painted other colours, specifically grey/green camouflage, dark sea grey and red, white and blue (Chappelow & Belyavin, 1992). A third study also cited by the AAIB (2009) concurred with these findings, stating that a black aircraft is more conspicuous than a white one and that reflective tape on the wings can also help (Head, 2002).

A factor that cannot be ruled out in any mid-air collision, particularly where the occupants have been fatally injured, is the attention being paid by the pilot and/or their passenger to the outside environment just prior to impact. Maintaining a good lookout is imperative in any visually conducted flight if safety is to be preserved, but other tasks must also be performed in unison with the lookout, also for the sake of safety; en-route checks (fuel and instruments), navigation and radio calls. Additionally, it must be remembered that statistics from the 2011 survey revealed 93.5% of pilots partake in GA for pleasure and thus amongst the piloting tasks, there will be an element of 'enjoying the view' and (where carried) conversing with passengers. Thus it is impossible for a pilot to maintain a 100% lookout and given the figures calculated above, it can be seen that any action by the pilot other than lookout that takes more than a few seconds has the potential to bring two aircraft within close proximity of each other, without either pilot being aware.

6.3.3.i Contributory causes

The four above-mentioned potential causes of mid-air collisions are quite generic in that an element of each probably plays a part in most, if not all such events. The accidents in the sample each also had specific factors that were deemed likely contributory factors by the AAIB.

The pilot of one aircraft was found to have two types of drug in his system, one consistent with a non-prescription decongestant and the other with motion sickness or gastrointestinal relief; respectively Ephedrine (or Pseudoephedrine – the two are pathologically indistinguishable) and Scopolamine (AAIB, 2006). The pilot had declared a medical condition to the CAA, the medication for which is acceptable for issue of a medical certificate, however neither of the two drugs named are acceptable for use by a person acting a sole pilot of an aircraft (AAIB, 2006). It is proposed here that the drugs were purchased under a brand name and the pilot would have not been aware of their illegality regarding flying. Even research into allowable drugs in the UK does not render any answers, the CAA website not providing a list of drugs that are not acceptable for use whilst flying. Considering the uses stated for each of the drugs, it is difficult to envisage the pilot would have had any reason to believe they would affect his ability to fly his aircraft. Moreover, there was no evidence to prove the presence of these drugs had any effect on the pilot's ability to fly. It is recommended therefore, that upon gaining or renewing any medical certificate, all pilots are provided with a list of drugs and their associated brand names that are considered unacceptable for use whilst flying in order that they can refrain from aviation whilst self-medicating with over-the-counter drugs for minor ailments such as blocked sinuses or gastrointestinal complaints, as was seemingly the case here.

A factor in one collision was the participation in a properly organised aerial race. As this is an event that carries inherently higher risks than regular flying and is outside the boundaries of what would be considered normal GA activity, (unlike aerobatics, for example, which is relatively popular among UK GA pilots, 7.9% of the survey saying they partake in it regularly) it shall not be discussed further in this thesis, other than to state that any of the four generic factors could also be applied to this accident.

In two of the collisions, three of the aircraft involved were RAF training aircraft. One of these involved the aforementioned glider pilot who parachuted to safety post impact. The RAF aircraft was performing aerobatic manoeuvres at the time of the collision and two main factors call into question the levels of airmanship being demonstrated by the commander, a highly experienced RAF Instructor.

Firstly, the chosen location for the performance of aerobatics was not ideal, being an area of high density traffic. At the time of the collision, five other aircraft were observed on radar within 3.5nm of the point of impact, further radar analysis revealing that 118 aircraft passed through the area between 12:00 and 13:30 (Appendix E), the collision having taken place at 13:17 (AAIB, 2010).

Secondly, the commander suffered from a medical condition that restricted his head movement, thus restricting his capacity for performing a good lookout, which during aerobatic manoeuvres is of much greater importance than in normal flight. The passenger was an inexperienced cadet and it would have been unreasonable to expect him to have made up for the commander's inability to perform a proper lookout, due to his lack of experience.

Assuming the commander had established communications with ATC and was thus likely to have been aware of traffic in the vicinity and combined with his restricted head movement, it is surprising that he elected to continue with aerobatic manoeuvres and is highlighted as a lapse in good airmanship practise, which proved to be fatal.

In the second mid-air collision involving RAF aircraft, again additional to the generic factors presented earlier, the airmanship of these pilots again is questionable, having elected to fly simultaneously in airspace which, due to the local topography and nature of the airspace, was somewhat restricted in size (AAIB, 2010). Considering this environment, it was noted by the AAIB that no procedures had been put in place by either pilot to separate the aircraft during flight, resulting in the deaths not only of themselves, but also of their passengers, cadets respectively aged 13 and 14.

It is possible to suggest that having performed these kind of flights in the same area a number of times, that complacency played a part in these military trained aircraft commanders' lack of airmanship, although this can in no way be substantiated.

6.3.3.ii Mid-air collision recommendations

To make recommendations to be implemented by the RAF is beyond the remit of this thesis, but these accidents still serve an educational purpose to other GA pilots in the UK, in that the airspace within the landmass of this highly populated, relatively small country is restricted due to the physical amount of land available. The popularity of GA is such that daily traffic movements, particularly at peak times such as weekends and holidays, are likely to be numerous and it should be instilled into UK GA pilots that the lookout is not a routine task to be performed occasionally, but is an on-going process requiring the utmost diligence to ensure that every region of the visible sky is thoroughly examined using proper search techniques.

It is thus also suggested that proper search techniques, which are sympathetic to the limitations of the human eye and consider visual obstructions such as window struts and imperfections, are taught specifically to all UK GA students and that it be incorporated into the Human Performance and Limitations syllabus, beyond the biological definitions and explanations.

Pilots should fly with the assumption that there is an aircraft flying towards them and be prepared to execute an appropriate manoeuvre to escape a possible collision. Passengers, if carried should be encouraged to assist and be briefed on proper techniques in the pre-flight brief which they should have received prior to departure, if the pilot is deemed to be performing within the realms of good airmanship.

Proper use of radios should be encouraged, pilots being requested to make considered and accurate position reports, particularly when tuning at a navigational waypoint. In parallel, use of transponders will assist ATC to maintain an overview of an area, although the final responsibility for clearance from other aircraft remains with the aircraft commander. Even on a basic service, pilots should also be required to declare where and when they wish to perform aerobatics and ATC correspondingly be authorised to refuse permission for such activities if they consider it to be a threat to other aircraft in the vicinity, even if the airspace is uncontrolled.

Although many pilots abide by these common sense rules already, by enforcing them, the few who do not may give further consideration to their performance and have a greater respect for the dangers that accompany poor airmanship whilst in the cruise phase of flight.

6.3.4 Other collision accidents

The only non-fatal collision to take place in the cruise occurred between two aircraft during a formation flying training sortie (AAIB, 2006). In the same manner as the racing, formation flying is not common practise in GA and thus the circumstances of this accident fall outside the remit of this thesis. Suffice to say, however that the cause was related to a lack of communication between the two pilots, a form of airmanship crucial in such circumstances.

There were 63 collisions within the sample that did not occur during the cruise, 34 (54%) taking place during the taxi; surprising given it is regarded as a generally safe phase in the flight cycle, the speeds involved being comparatively slow (most students are taught to taxi at a fast walking pace). All of the collisions involved contact with buildings, parked aircraft, or obstacles in the ground such as fences or signs. Common causes corresponding to detrimental airmanship were: poor judgment (32.4%); distraction (23.5%); poor lookout/SA (20.6%). Two pilots continued their taxi, despite being blinded by sun glare and one pilot taxied along an access road, not the designated taxiway and struck a fence.

The cases of poor judgment could have been resolved by requesting help from a marshall or ATC for distance guidance (it can be difficult to judge where the tips of wings are, but best practise when in doubt would be to ask for help).

Good airmanship practise would suggest that whilst taxiing, other tasks should not be carried out, other than those prescribed as necessary (checking the compass moves in the correct sense during a natural turn for example). It was interesting to note that two of these accidents were commanded by highly experienced pilots with students on board, respectively having an ATPL with 20,393 hours total time (AAIB, 2006) and a CPL with 13,050 hours total time (AAIB, 2009). The first was distracted by asking the student if she was alright due to feeling nauseous, the second by writing down the 'chocks off' time; both would have been better performed when the aircraft was stationary, considering the first incident occurred approaching fuel pumps and the second in the built up area of the aerodrome.

6.3.4.i Approach and landing

Three out of the ten accidents to occur during the approach and landing phases, resulted in serious injuries to at least one party, all of which will briefly be described below.

A low sun producing troublesome glare prompted the first of these pilots to fly deliberately low in order that he might follow the row of approach lighting, stating that the visibility was also better at a lower altitude (AAIB, 2007). A go-around was considered but the pilot believed he saw the start of the runway and elected to continue, moments later realising that he was too low and applying full power to abort the landing. Unfortunately this action was too late to prevent collision with a 30ft high lighting gantry, half a mile from the actual runway threshold. Good airmanship practise should have dictated that the pilot performed the go-around at the first sign of potential danger which would have been from the outset of the approach as he realised visibility into the sun was unacceptable.

Performing a manoeuvre that might otherwise be described as good airmanship, the pilot of the second serious accident was making a precautionary over flight of a potential landing site to determine its suitability, but whilst concentrating on his instruments, failed to notice a high rate of descent develop and power cables ahead, with which the aircraft ultimately collided (AAIB, 2008). It is unusual that a pilot flying low to the ground should be concentrating on instruments, when in fact he should have been visually checking that he was clear of all obstacles. Again, best practise in this situation is to first fly over the landing site at a height that is likely to be above obstacles such as power cables to check for their very presence. This is then followed by a lower pass, if it is established that no such obstacles pose a threat. Good airmanship would dictate that an appropriate configuration be adopted for the aircraft and that three circuits be made at progressively lower heights whilst keeping workload to a minimum (Thom, 1994).

The third was appreciably contributed to by the fact the pilot at fault did not have the ATC tower frequency tuned in and thus was unaware of another aircraft (a helicopter) being present on the runway (AAIB, 2011). The type of aircraft being flown dictated that communication with the tower be vital as being a tail dragging bi-plane meant that forward visibility was limited. Good airmanship should have resulted in the pilot performing a go-around manoeuvre as he would not, in any case, have received permission to land.

An aircraft of similar design also crashed on landing, this time killing both the pilot and the passenger due to an approach that was flown too low. In a level attitude compared to a normal approach, the pilot was unable to see a crop spraying vehicle in the runway undershoot and collided with it (AAIB, 2009). In this case, the pilot would not have required permission to land as the airfield only had an air to ground (A/G) facility and not full ATC. Of note was the fact that despite being an experienced pilot (2500 hours total time), he had zero hours experience on the aircraft type (AAIB, 2009). Had the pilot applied the principles of good airmanship, without a clear view of the runway, in an unusual approach attitude and with no experience on the aircraft type, a go-around manoeuvre should have been executed. The AAIB conclusion supports this in saying *"(the aircraft's) occupants were unable to ensure that the flight path ahead was clear of obstacles."* (AAIB, 2009, p44). Figure 18 shows the aircraft and the crop sprayer moments before impact and demonstrates how the pilot would have had difficulty in seeing anything ahead at all.

Figure 18: Pre-impact position of aircraft relative to collision 'target' on approach: Source, AAIB, 2009

6.3.4.ii Experience levels

As a group, pilots in collisions contributed to by detrimental airmanship were not inexperienced having a mean of 3846.2 total hours (SD 6286.296) and 304.3 hours on type (SD 698.916). Nor were they lacking in currency having flown a mean of 32.9 hours in the last 90 days (SD 48.867) and 12.5 hours in the last 28 days (SD 16.927).

The range of experience for total hours was from 25,131 to seven total hours, 44.4% having more than 1000 hours; 5000 to zero hours on type, 28.6% having more than 200 hours; 250 to zero in the last 90 days, 9.8% having 90 hours or more; 84 to zero in the last 28 days, 11.5% having 28 hours or more.

6.3.5 Complacency an issue?

With experience ostensibly not proving to be a major contributory factor in collisions, it must be proposed that some level of complacency existed in the pilots involved. This is not likely to have been in the sense of arrogance, but more a lack of expectation. As has been demonstrated in this section, it is easy for the human eye to miss other aircraft in the cruise. Added to aircraft structures obscuring views and other distractions it is easy to consider that these pilots did perform lookouts, but that they were not sufficiently thorough, the likelihood of a mid-air collision happening negating the need for the lookout to consistently be as thorough as suggested here. A similar form of contentment must convince pilots on approach to land that, even if they are lower than normal, there is not likely to be anything for them to collide with on the approach path to a runway. Had they not felt content with that consideration, it is proposed that they would most likely have performed a go-around.

A high level of diligence should be maintained in all phases of flight, including the seemingly innocuous task of taxiing where the slow speeds might eliminate thoughts of danger. Particularly during the approach and landing phases, pilots should heighten their levels of awareness and concede that the approach to an aerodrome will likely have objects with which a collision will occur if they do not heed to the principles of airmanship when low on approach and either return to a normal flight path or initiate a go-around.

6.3.6 Going around on landing

The go-around is a manoeuvre made when a pilot is not satisfied with the approach and is deemed to be best practise in terms of airmanship, compared to attempting a landing that is likely to be uncomfortable at best. However, if not performed correctly, the results can be equally undesirable and good airmanship is vital at this crucial time.

Eight accidents resulted from flawed go-around manoeuvres. On three occasions pilots did not adopt a correct pitch up attitude to assume a climb, resulting in a collision with obstacles including trees, a fence and a hedge. Contributing to these accidents was the restricted view each aircraft presented to the pilots, all being of the tail dragger type. Their restricted view should have been enough to alert them to the necessity for a go-around in the first place, but does not explain why they did not adopt the correct procedure, colloquially referred to as 'power up, pitch up, clean up' referring respectively to increasing power, raising the nose to adopt a climb attitude and at appropriate times, retracting flaps and landing gear.

Two pilots continued their approaches and tried to force-land the aircraft, realising too late that they needed to abort and go-around; one collided with a boundary fence, the other a tree having also failed to prevent the aircraft from drifting to the side of the runway.

A further two pilots did not effectively manage the aircraft configuration, one being distracted by the process of retracting the flaps and colliding with a tree, the other forgetting to retract the final stage of flap (used to increase drag on landing sufficiently to slow the aircraft down).

The final accident involved a collision with trees on approach to land at a private airstrip, the cause for which could not be fully established, but the pilot was fatally injured, (AAIB, 2011). Evidence suggests the pilot made a late go-around decision in potentially adverse weather (wind) conditions whilst possibly distracted by a heart condition and possibly suffering the side effects of having taken tramadol at some point prior to the flight (a pain killing drug with drowsiness as a known side effect; drugs.com, 2013). These latter contributory causes constitute poor airmanship alone as flying with a known condition and using a drug known to affect concentration in the form of drowsiness are not conducive to safe flying.

The pilot was flying on a NPPL license, only necessitating that the pilot make a medical declaration, supported by his GP and take responsibility for only flying when fit to do so (CAA, 2013). Additionally the pilot was the owner of the aircraft in question flying into his own private airstrip (AAIB, 2011). This raises issues concerning the monitoring of pilots who own their own aircraft, particularly those who fly from private airstrips.

6.3.7 Experience levels, causes and recommendations

The eight pilots involved in the go-around accidents were also not lacking in experience, having mean total hours of 2287.1 (SD 3660.511), 109 hours on type (SD118.404), 20.6 hours in the last 90 days (SD23.287) and 9 hours in the last 28 days (SD 9.024). None of these pilots had less than 274 hours total time and all had flown at least 1 hour in the previous month, suggesting that this is not an issue of experience. There is also no clear evidence to suggest that skill-based errors were to blame, although this cannot be ruled out. It is suggested that a combination of skill, lack of practise and procedural errors resulted in the go-around manoeuvres not being successful.

Similar to Practise Forced Landings (PFL), the go-around may be a flight task that is taught and practised during training, but not necessarily considered once a pilot starts flying without an Instructor. In the 2011 survey, 9.7% of pilots stated they had never performed a go-around, or only performed one in their flying career. Of concern is the mean total experience of these pilots; 383 hours for those who had never gone around and 254.7 hours for those who had only done it once. More disturbing were the pilots with 466, 550, 2000 and 3004 hours who stated they had never performed a go-around which suggests they either consider every approach they make to be satisfactory, or they have forced some landings without considering aborting.

An additional 44.6% of the survey pilots confirmed they had gone around a ‘few’ times, this group having a mean total experience of 692.4 hours. Again of concern is the 37.2% of these pilots who have 500 or more total hours (including 25 who have between 1000 and 10,000 hours) meaning that the manoeuvre in question has been performed and/or practised very infrequently during their flying career. To put this in context, the author recalls making several go-arounds in one day when approaching an unfamiliar aerodrome in a slight to moderate crosswind. Best practise in terms of airmanship would be to abort any landing that does not conform to the expected norms of an approach and to do so at an early stage; the closer to the ground on commencing a go-around, the greater the risk of not completing it successfully.

Thus it is recommended that the go-around manoeuvre not only be specifically tested, but also included in the post licensure monitoring scheme proposed in Chapter 10. Furthermore, it is suggested that the mechanics behind the manoeuvre be taught and examined in the PPL theory modules under Principles of Flight, in the same manner as stalling.

6.3.8 Additional airmanship accidents

Due to the nature of this category, there were many different contributory causes, some of which could be broadly sub-categorised and are presented in Table 15

Table 15: Experience levels and 'N' for other detrimental airmanship accidents

Description	N	Mean Experience			
		Total	Type	Last 90	Last 28
Non-compliance/completion of checklists	9	2780.8	1124.2	17.4	7.3
Distracted from flying the aircraft	12	1656.1	537	24.8	9.8
Cockpit ergonomics – using the wrong lever	8	2676.4	274.6	44.3	16.8
Fuel mismanagement – starvation	13	2253.8	174.9	27.4	11.6

6.3.8.i Aircraft performance

One further accident type contributed to by poor airmanship, resulting in 14 events, three of which were fatal, is performance. This relates to the known performance limitations of the aircraft versus the size, surface and surroundings of the runway to be used. In all cases, the pilots did not appreciate or consider these factors, leading to either the aircraft overrunning the end of the runway, or being forced into the air without sufficient speed and consequently stalling or colliding with obstacles that otherwise would have been cleared in a properly executed takeoff.

None of the pilots in question were inexperienced, total flying hours ranging from 118 to 10500, although two pilots only had 4 and 8 hours respectively on type, the former being one of the fatalities. These levels of experience again suggest that some form of complacency existed in these pilots at the time, thus they did not feel the need to perform calculations on aircraft performance or its weight and balance. For some the problem was exacerbated and arguably caused by the lack of take-off flap setting (usually one or two stages of flap to increase the available lift for a given speed, thus allowing for a shorter take-off run).

Although taught as part of the PPL syllabus, weight and balance and performance calculations are not necessarily part of every pilot's routine, particularly if the pilot is accustomed to a long runway with few notable obstacles to overcome after take-off. It is recommended here that clubs and schools are encouraged to refuse hire of an aircraft to individuals until they have performed, submitted and had approved both weight and balance and performance calculations pertinent to the aircraft they will be flying and the passengers and/or cargo they will be carrying. This should have the possibility of being enforceable at aerodromes where the runway is less than an established length, has notable obstacles to clear at either end of any runway or has characteristics such as a prominent slope or others that may prove detrimental to an aircraft's performance.

6.3.9 Summary of Part 3

This part of chapter 6 has highlighted the importance of pilots acting in a considered and professional manner following completion of their training. Whilst the majority do take the privilege of being able to fly an aircraft very seriously, even for these individuals, it is easy to formulate bad habits, or to forget the complete substance of the principles of good airmanship. Again, this serves to underpin the need for better post licensure support and monitoring, combined with enhanced training both on the ground and in the air to maintain levels of both skill and knowledge that combine to make for a safer pilot.

The following chapter looks at the main causal and contributory factors in UK GA accidents, including those influencing the most serious ones and discusses which phase of flight these occur in; loss of control, controlled flight into terrain, technical failures.

Chapter 7: Main Causes of UK GA Accidents

The previous chapter discussed sample accidents with respect to human influences and the associated contributors; age, experience, human factors and detrimental airmanship.

This chapter focuses on the most common and serious causes of GA accidents in the UK, covering incidence of loss of control (LOC), controlled flight into terrain (CFIT) and technical failures. Additionally, this chapter will look at accidents according to the phase of flight in which they occur.

In terms of LOC, the discussion proposes that the approach to training be adapted to be proactive rather than reactive, given that the data shows many of the airborne LOC accidents occur following a stall at relatively low altitude, where time to recognise the LOC condition and recover from it is minimal.

Although less prevalent, CFIT will be highlighted as an accident type with a high mortality rate, borne out of an apparent lack of appreciation for the prevailing meteorological conditions, combined with a deficiency in appropriate skills and/or qualifications.

Technical failures are introduced as principally benign incidents, dominated by failures of the engine and landing gear. Discussion will highlight how pilot technical knowledge is key to many engine failure incidents being potentially prevented in the first place.

Finally accident occurrence according to phase of flight will be presented. Each phase will be defined and data from the sample used to determine the most prolific accident phase looking specifically at the main categories of accident occurring in each phase and whether or not pilot experience is a factor.

7.1 Loss of Control

7.1.1 Initial data examination

Combining CAA data (CAA, 1997; 2006) with the sample data reveals that from 1985 to 2011 there were 456 fatal GA accidents in the UK killing more than 650 people. Amalgamation of the available data shows 39.2% were the result of loss of control (LOC). In the USA, National Transportation Safety Board figures from 2007 to 2009 indicate 40.9% of all fatal GA accidents (N = 611) were also attributed to LOC (NTSB, 2011). The Aircraft Owners and Pilots Association’s Air Safety Institute data from 1996 to 2009 reveal 24.8% of all fatal GA accidents in the USA took place in the manoeuvring phase of flight, 59.2% of all manoeuvring accidents involving LOC.

In both countries, stalling/spinning are a major factor in LOC accidents, 80% occurring below 1000ft in the USA (AOPA, 2003), 87.7% below 2000ft in the UK (based on an assumption that most GA activity takes place at or above 2000ft, thus those in any phase of flight other than the Cruise are below 2000ft). This particular phenomenon accounted for 11.4% of all LOC accidents in the UK from 2005 to 2011.

In the sample data alone, just less than half (49.7%) of the reviewed accidents involved some element of LOC, 58.6% (29.1% of the sample) of which occurred in the air, the rest whilst still on the ground. These figures compare favourably to the findings of Gratton and Bromfield (2009) who determined that 33% of all GA accidents from 1980 to 2006 were airborne LOC. As seen in the previous chapter, some cases of LOC are pilot induced. Still a major issue in GA accidents, statistics shows it to be an increasing phenomenon in both the UK and the USA, AOPA's Nall reports from 1997 to 2011 showing the proportion of fatal accidents from manoeuvring LOC to have risen from 19.3% to 38.7%, peaking in 2010 at 66.7% (Figure 19) (AOPA, 1998 – 2012). Many of the LOC accidents in the sample stem from a lack of skill combined with either a lack of knowledge or poor decision making.

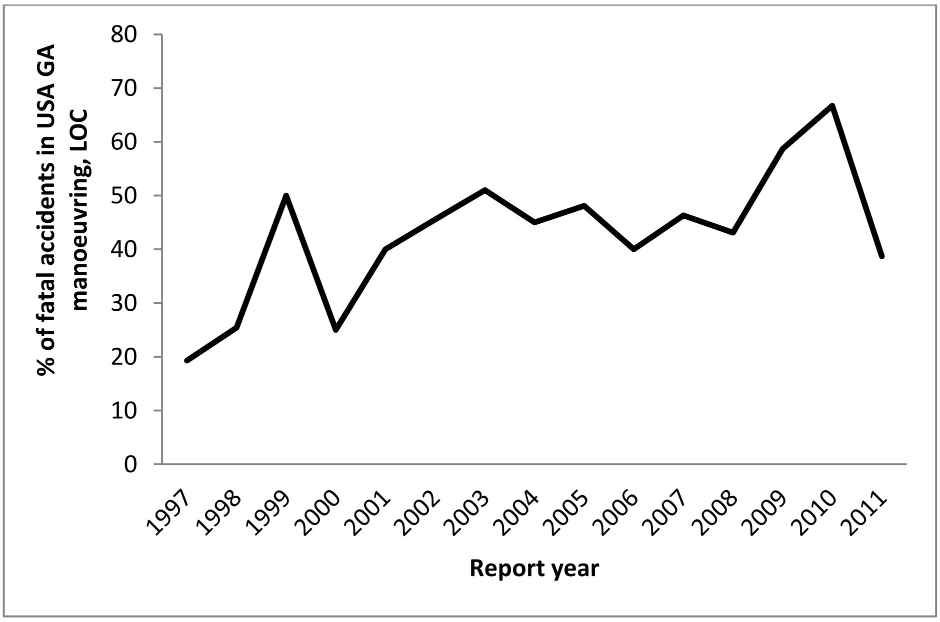

Figure 19: Percentage of fatal accidents resulting from LOC in the USA; Source: AOPA (1998 - 2012)

7.1.2 LOC as an aviation phenomenon

Losing control of an aircraft is an easy thing to do; they are sensitive to control inputs and to meteorological elements such as turbulence and wind. Pilots are therefore trained to maintain control and to understand the aerodynamic and meteorological forces that can have a destabilising influence on an aircraft. Some aircraft are more susceptible than others to different kinds of control loss; tail dragging aircraft are renowned for 'ground looping' if too much rudder or differential braking is used and for 'nosing over' if regular braking is excessive; high wing aircraft tend to be naturally less stable in the air for aerodynamic reasons and will enter a spin more readily than a low wing aircraft, however that instability means they are also easier to recover from any such manoeuvre.

The ease with which control of an aircraft can be lost is not confined to GA, many major commercial aviation accidents citing LOC as a major contributory factor, some of the most notorious identified in Table 16. These accidents occurred despite the training and experience of the pilots, who were operating in a multi-crew situation.

The various contributory causes of these LOC accidents are not exclusive to commercial aviation; fatigue, bad weather, systems failures, and human factors are all possibilities in GA. In the same manner that commercial pilots receive revised and improved training following the lessons learned in each of these and other accidents, GA pilots should also be given the opportunity to develop skills to combat conditions they may encounter during their flying career through training that is periodically enhanced and reviewed in the light of accident investigations.

Table 16: Commercial aviation LOC accidents

Flight details	Accident information	Source
Air France 447, 2009	Stalled and crashed into the sea during a storm	BEA, 2012
Air France 358, 2005	Overran runway at Pearson International Airport during heavy rain storm	TSB, 2007
Colgan Air 3407, 2009	Stalled on approach to land, Buffalo New York	NTSB, 2010
Delta Airlines 191, 1985	Crashed short of the runway on approach to Dallas Fort Worth due to a microburst from a thunderstorm	NTSB, 1986
Eastern Airlines 401, 1972	Crashed into the Florida Everglades when the autopilot was inadvertently disconnected; pilot were distracted with a minor problem and did not notice	NTSB, 1973
Flash Airlines 604, 2004	Crashed into the Red Sea after take-off at night due to pilot disorientation	Egyptian Ministry of Civil Aviation, 2005
Air Florida 90, 1982	Stalled and hit a bridge due to crew failure to properly de-ice their aircraft or to effect a recovery manoeuvre	NTSB, 1982
United Airlines 232, 1989	Loss of hydraulic power led to a virtually uncontrollable aircraft which crashed on landing at Sioux City, Iowa	NTSB, 1990
Turkish Airlines 1951, 2009	Crashed on approach to Amsterdam Schiphol following a stall caused by a faulty autopilot	The Dutch Safety Board, 2010

7.1.3 Experience as a causal factor

The initial compulsion with LOC accidents would be to say that experience is a factor. Indeed, statistical analysis shows that LOC accident pilots have significantly less total and type experience than other accident pilots; respectively: 1535.9 hrs (SD 3786.213) versus 2064 hrs (SD 4154.912) total, 168.2 hrs (SD 363.571) versus 264.1hrs (SD 645.770) Type; $t\ (1496) = 2.385$, $p < 0.05$, $t\ (1485) = 3.071$, $p < 0.05$. Contrastingly, LOC pilots had significantly more total experience than those in the GA survey from 2011; respectively: 1535.9 hrs (SD 3786.213) versus 988.3 hrs (SD 2344.778); $t\ (893) = 2.524$, $p < 0.05$. It was shown, however that in terms of experience on type, the LOC pilots had significantly less experience than their survey counterparts; respectively: 168.2 hrs (SD 363.571) versus 304.5 hrs (SD 509.041); $t\ (802) = 4.419$, $p < 0.05$.

Regardless of total experience, the number of hours flying a pilot has in a particular type of aircraft is arguably more important as it reflects how well the pilot knows specifics of the aircraft such as performance, handling and cockpit layout. Considering this, it is important to note that compared to both other accident pilots and the UK GA population, LOC pilots had significantly less experience on the accident aircraft type, which may provide at least a partial explanation as to how they managed to lose control of their aircraft.

A factor previously established as important in Chapter 6 is experience gained within the last 90 and 28 days. Statistical analysis of the sample data shows the LOC accident pilots to have significantly less currency than other accident pilots; respectively: 23.9 hrs (SD 40.210) versus 29.8 hrs (SD 44.754) in the last 90 days; $t\ (1473) = 2.445$, $p < 0.05$; 8.7 hrs (SD 13.182) versus 10.9 hrs (SD 15.450) in the last 28 days; $t\ (1473) = 2.655$, $p < 0.05$. Comparison with the survey data revealed that although the LOC pilot has less currency than the UK GA population, the difference was not statistically significant; Survey mean, last 90 days 26.9 hrs (SD 47.114), $t\ (888) = 1.014$, $p < 0.05$; survey mean, last 28 days 9.5 hrs (SD 17.145), $t\ (888) = 0.798$, $p < 0.05$.

Although not always statistically significant compared to the known population and other accident pilots, the data does confirm that LOC pilots tend to be less experienced in terms of flight hours, but that does not necessarily mean they are less skilled. Definitive proof that experience is a key factor in LOC accidents would only be gained by placing more experienced pilots in the same scenarios the LOC pilots were in at the time of their accidents and observe whether or not the outcomes were the same. To achieve this would necessitate use of a Full Flight Simulator (FFS) with fully programmable software to accurately recreate the exact conditions experienced by the LOC pilots. This would be an expensive and timely exercise and as such has not yet been attempted, thus until such evidence is attainable and available, it has to be concluded that experience is a factor in LOC accidents.

7.1.4 LOC in visual and meteorological conditions

A brief clarification is required before discussion of this topic as there is often misuse of the terms involved. Visual Flight Rules (VFR) and Visual Meteorological Conditions (VMC) are often used in the wrong sense, perhaps due to them having similar implication, but are legally different. Pilots flying under VFR are flying in accordance with the regulations, pilots flying in VMC are flying in conditions where VFR flight can be performed, but may not necessarily be flying under VFR; they may be flying under Instrument Flight Rules (IFR). Flying in Instrument Meteorological Conditions (IMC) requires that the pilot is appropriately qualified with either an IMC rating or an Instrument Rating (IR), but may not necessarily be flying under IFR (which requires the pilot to hold a valid IR). In this thesis, reference will be made to VMC for visual conditions, as even if pilots are flying under IFR, they still have the ability to visually confirm their aircraft's attitude, altitude and location. Similarly IMC will be referred to as these conditions do not allow visual reference outside the cockpit and it is inferred that any pilot flying as such is duly qualified (additional ratings are not always cited in AAIB reports).

An anomaly derived from the sample data is that pilots who lost control whilst airborne flying in VMC had more than five times more flying experience and a third more type experience than those who lost control in IMC; 1286.3 (N = 40) versus 241 (N = 4) total hours; 109.4 (N = 40) versus 81.8 (N = 4) hours on type. The same pattern was noted for currency, IMC LOC pilots having 2.5 (N = 3) and 10.5 (N = 2) hours recorded as means for the last 28 and last 90 days respectively, compared to 8.1 (N = 38) and 20.2 (N = 39) hours for the same respective categories for VMC LOC pilots. The very low N value precluded the possibility of meaningful statistical analysis, but the differences in all four categories of experience are notable.

Although it is expected that those with less experience, even if duly qualified, would be more likely to encounter difficulties in IMC, it is not understood why much more experienced pilots lost control in the more familiar and less task demanding environment of VMC. Flying visually requires a pilot to regularly scan the instruments to ensure heading, height and speed are being maintained, the greater proportion of time being spent looking outside for visual cues in terms of navigation, aircraft attitude and other traffic. When flying by sole use of instruments, pilots maintain a continuous scan of all the instruments without reference to external cues, usually because they are not available. This requires a lot of concentration as the pilot has to assimilate information from just the instruments and translate it into a visualisation of the aircraft in several dimensions; pitch, roll, yaw, speed and geographical location.

Due to the nature of this kind of flying, it is suggested here that pilots flying in IMC, whether qualified or not maintain a better SA than those who are flying in VMC and whose attention to the state of the aircraft is possibly minimised by the use of external references; there is no mandatory requirement for PPL pilots to be taught instrument flying, but they are permitted to undergo 5 hours of basic instrument appreciation in a flight simulation training device (FSTD) (CAA, 2013). In at least two fatal accidents, the aircraft were observed to enter tight turns in close proximity to the airfield, the accident reports suggesting the pilot was attempting to maintain visual contact with the runway in order to line up for landing. It is possible to intimate that both pilots were distracted from the precarious state of the aircraft (a tight turn, low to the ground) by the temptation to fly the aircraft directly to the runway as opposed to using the instrument scan combined with external cues to execute a properly formatted approach pattern; downwind, base leg and final approach. In IMC conditions, these pilots would have made full use of the instruments and thus noticed and indeed prevented any excessive manoeuvres.

The suggestion is that pilots losing control in VMC do so because their attention is biased towards external cues that instil confidence in the accuracy of their flying and thus their instrument scan is correspondingly weakened. External cues can be misleading; cloud shape and position can produce a false horizon illusion persuading pilots they are in a turn when in fact they are not, sun glare can alter perceptions of distance, as can haze, thus they have a reduced situational awareness. It is further suggested that basic skills are inadequate to deal with LOC. Whilst LOC accident flights in VMC tend to have been under the command of pilots with a good level of currency, the CAA suggest that the lack of skills mentioned are due to either poor initial training or a lack of refresher training (CAA, 1997) a subject which will be discussed in Chapter 10.

The question therefore remains that if pilots flying in IMC have a better SA due to the focus placed on aircraft movements through close observation of the instruments, why did four such flights result in an accident, three of which were fatal? The first fact of note is that none of the pilots in question were qualified for IMC flight or instrument flying and had received no relevant training beyond that they will have received as part of their PPL.

The second notable issue derived from the accident reports is that three of the four pilots involved owned the aircraft, thus it could be inferred that the pilots were more audacious in their operation of the flights on the day in question, given that they would not have to report to anyone prior to departure. This claim however cannot be substantiated and the evidence in the reports does not suggest that any of the pilots were purposefully reckless.

The best evidence suggests that one pilot was simply spatially disorientated, the radar track demonstrating an erratic pattern with large changes in heading, before a right turn through 140° over a period of 40s before rapidly descending and turning through a further 150° before impact killing both occupants (AAIB, 2006).

For a second pilot, the presence of conditions conducive to carburettor icing may have increased workload in poor visibility, for which the pilot was not rated. This additional problem precluded the possibility of reaching an airfield with better weather and may have induced the fatal LOC event in an attempt to execute a forced landing (AAIB, 2008).

The third case resulted in the deaths of three family members; the father being the pilot, the daughter being the co-pilot and the mother as a rear-seat passenger (AAIB, 2008). Evidence from the technical inspection revealed a pre-impact vacuum pump failure, which would have led to erroneous indications from the attitude indicator, also known as the artificial horizon (a gyroscopic instrument reliant on airflow produced by the vacuum pump to maintain rigidity and thus accuracy; Oxford Aviation Services, 2007). Again the pilot was not qualified to be flying in the conditions presented at the time, but is a likely example of a relatively well qualified pilot struggling with a major malfunction in difficult circumstances. Moreover, the presence of alcohol in the systems of both the pilot and co-pilot will have exacerbated the issue. Post mortems found the pilot to be almost five times over the prescribed blood alcohol limit of 20mg/100ml and the co-pilot more than twice the limit (AAIB, 2008).

The final case of LOC in IMC was non-fatal, the pilot stating that after inadvertently flying into IMC, he became distracted by the aircraft autopilot and his GPS system, allowing the aircraft to fall into a LOC situation from which he could not recover provoking him to use the on-board Ballistic Recovery System (BRS – a parachute for the aircraft) (AAIB, 2011).

These four accidents, although in the minority of categorisation, resulted in the deaths of six people and cannot be dismissed because of their minimal representation. Although pilots receive a basic appreciation of instrument flying, the depth of training received may be dependent on the Instructor, school policy and the individual student. Thus it is recommended that to reduce LOC in IMC incidents, it is no longer presumed that pilots will not encounter such conditions as they are not permitted to fly in them according to the privileges of their license and it is instead assumed that all pilots will encounter such conditions.

Training for a PPL is usually undertaken in good weather and combined with privileges of the license forbidding flight in conditions below set minima, the PPL pilot is rarely exposed to adverse weather and as such cannot accurately assess the prevailing conditions, or be able to draw on experience to relate them to his or her own skills (CAA, 1997). Accordingly, the five hours instrument appreciation should at least be doubled to provide PPL pilots with a solid comprehension of the skills needed if and when poor visibility is encountered. Furthermore, enhanced training on instrument flying will aid in prevention of LOC in IMC and VMC, a topic that is to be discussed both later in this chapter and in Chapter 8.

7.1.5 Stalling and Spinning

The most referred to loss of control types are those of stalling and spinning, which account for the majority of not only LOC deaths (17 out of 23; 73.9%), but also of 30.9% of all UK GA fatalities and 5.7% of all accidents from the sample. This compares to the USA where the Air Safety Foundation (ASF) of AOPA determined that 10% of all accidents and 13.7% of all fatal accidents are reported as of the stall/spin variety (AOPA, 2003). They further concluded that 28% of stall/spin accident are fatal, concurring with the sample data where 29.8% of all stall/spin accidents were fatal.

A stall occurs when the wing no longer produces sufficient lift to overcome the weight of the aircraft. There is belief among some pilots that airspeed and angle of attack (relative position of the aircraft nose to the horizon) are the crucial elements in maintaining lift (AOPA, 2003), airspeed forming part of the lift equation (Equation 1):

Equation 1: The Lift equation

$$\boxed{L = \tfrac{1}{2}\,\rho v^2 C_L Max S}$$

The other elements of lift are air density (ρ), Coefficient of lift (C_L Max) and the surface area of the wing (S). The coefficient of lift is a term used by aerodynamicists to model how the complexities of wing shape, incline to the airflow and some flow conditions affect lift (NASA, N.D), but is beyond the scope of this thesis and as such no further explanation is required.

Although these are important, the overriding component is the critical angle of attack, which is the angle between the wing and the relative airflow. In a powered descent, the aircraft may be travelling at an airspeed above the calculated stall speed, but due to the upward relative airflow arising from the aircraft's descent (which may also be induced by a rapid nose down manoeuvre) the effective angle of attack is increased and if it exceeds the critical angle, the wing will still stall. Again, aerodynamics fall outside the bounds of this thesis, but some further explanation will be given in Chapter 9.

It could be inferred from AOPA's statement that a lack of knowledge of this phenomenon may play a part in stall/spin accidents, leading to onset of the startle effect, pilots not expecting a stall to occur in their present state. The startle effect can be described as an instinctive reaction that negatively affects information processing and may be a major contributory factor in poor pilot performance during critical events (Martin, Murray and Bates, 2012). This phenomenon was cited in the final report on the Air France accident in June 2009 when the aircraft entered an unrecovered stall, stating that neither pilot formally identified the stall as they never knew they were stalling and consequently did not initiate recovery procedures and furthermore that there was poor management of the startle effect (BEA, 2012).

The main topic of concern with stalling/spinning is not the event itself, it is the reaction time of the pilot to both recognise and recover from it, the resultant height loss depending on those reactions. AOPA cited a NASA study which demonstrated that in controlled conditions, the height lost by a typical GA aircraft in a spin to be around 1100ft (1100ft for a Grumman AA-5 and 1160ft for a Piper PA-28). This height loss in a real situation is likely to be greater, as the pilot is likely to take more time to recognise the condition and the startle effect may then impede judgment and increase recovery time. At low altitude, this can have severe consequences, the sample data showing that 41.2% of all stall/spin fatal accidents occurred in the phases of flight closest to the ground; approach, climb and go-around.

Stall conditions, if recognised and dealt with in a timely manner, are not difficult to rectify and can be recovered in less than a few hundred feet. The NASA experiment referred to measured height loss from a spin; an aggravated stall where one wing continues to make more lift than the other due to yaw (side to side movement in the horizontal plane), causing roll (the wings tilting around the nose-to-tail axis of the aircraft) which in turn exacerbates the yaw and a spiral descent of the aircraft develops (Thom, 1994). Because of this motion, spins are more difficult to correct, thus the differences in loss of height found by NASA compared to the stall losses quoted earlier.

7.1.5.i Stall prevention over stall recovery

Despite the evident history of this problem, emphasis during flight training remains on recovery from the stall. The process involves the student forcing the aircraft into a stalled condition and recovering when directed by their instructor. The student is fully prepared for the task, has received recent instruction in the procedure and is at a height sufficient for safe recovery. This exercise holds great merit for student pilots and should never be dismissed, but they are predominantly being taught to react to a prepared situation, little emphasis being on identifying the threatening conditions that can lead to it. Much more constructive, palpable instruction for GA pilots on predicting, preparing for and preventing stalls and other LOC conditions would give pilots greater protection when in flight and is a suggested modification to GA training that would ultimately save lives. Chin and Lau (2004) observed that many accidents occur prior to landing or just after take-off, not only because of the slow speeds and low altitude, but also because pilots fail to recognise an impending stall

7.1.6 Movement of the Air

Within the sample there were many references both by pilots and the AAIB to probable causes of LOC involving turbulence, wake turbulence, down-draughts, windshear, tail winds, cross winds, gusts of wind, wash from propellers, sink and other such disturbances in the atmosphere. Rather than collate them into numerous separate categories and given that several terms were used to describe the same phenomena, it was deemed more logical to assemble them into one common group; air movement.

Several triggers for air movement are possible in aviation, some being natural and others man made or influenced and the most prominent ones warrant explanation.

Atmospheric turbulence can be caused by two main processes. The first is convection; whereby heat rises and displaces cold air which, being denser and heavier than warm air sinks. The rising heat is generated by the sun warming surfaces on the ground. As not all surfaces absorb and release heat in the same manner, the rising air is not uniform, thus over a city, for example, the air above is in constant vertical motion, giving rise to the turbulence reported by some pilots.

Wind is essentially created through a complex process of the Earth's rotation mixed with the heating of the surface as described above, leading to areas of low pressure and high pressure; wind is the resultant flow of air equalising these areas of pressure gradient. Flows of air are rarely smooth and constant and can cause considerable turbulence, particularly to a light aircraft. Where winds travel at different speeds and/or in different directions (the reasons for which lies outside the scope of this thesis) they can cause windshear, where a pilot may encounter a shift in the direction and speed of wind (the wind velocity; W/V) and either gain or lose lift, again causing potentially severe turbulence; loss of lift close to the ground, on approach to land or immediately after take-off is particularly dangerous.

It is this type of wind that is most undesirable close to the ground and has caused some of the worst commercial aviation disasters, such as Delta Airlines 191 in August 1985 when a severe form of windshear known as a microburst (a fast downward moving column of air that bounces off the ground in all directions causing critically large shifts in airspeed) resulted in the aircraft landing short of the runway and veering off into water tanks, killing 134 persons on board and one on the ground (NTSB, 1986). Following on from that and other notorious windshear accidents, commercial aviation now has technology, such as low level windshear alerting systems (LLWAS), to provide pilots with advanced warning of windshear conditions. In GA, no such system exists and pilots must rely on the information given to them by radio operators at aerodromes, by other pilots who may report such occurrences after landing or their own judgment through use of windsocks.

A third form of turbulence can be caused even on calm days; wake turbulence. As an aircraft moves through the air, it displaces it and causes a disturbance in its wake, much like the disturbance felt by a pedestrian stood at the side of a road as a lorry passes. Moreover, the pressure differentials caused between the upper and lower surfaces of the wing bleed off at the tips of the wing and upon meeting, twist together to form a rotating horizontal column of air. Should another aircraft enter one or both of these vortices, it can cause a rapid rotation of the aircraft as well as deplete the lift produced by its own wings.

With light aircraft, the level of wake turbulence produced is minimal and will normally dissipate before another aircraft lands/takes off behind. However, at aerodromes where larger aircraft also operate, GA pilots must be aware of the potential hazards of wake turbulence and ATC at controlled aerodromes should provide sufficient gaps between larger aircraft and smaller following aircraft to allow any vortices to dissipate.

Similar to wake turbulence, disturbed airflow produced by stationary fixtures, such as buildings and geographical obstacles can also be of concern. Research by the Hong Kong Observatory (HKO) found that buildings close to the runway can induce airflow disruptions and associated turbulence (HKO, 2003). This type of turbulence may also be caused by obstacles such as nearby forests, mountains and even passing vehicles (cited by one accident pilot as a major contributory cause).

Wind flowing in directions other than along the runway induce a cross wind component that must be accounted for and managed accordingly by turning the aircraft into wind and effectively flying sideways until touchdown when the pilot aligns the aircraft with the runway using rudder. Although not mandatory, due to the processes involved in producing lift, it is preferable to land and take-off into wind. Where this is not possible, or a pilot chooses not to, a tail wind component must be considered. On longer runways this may not be an issue, but at smaller aerodromes, a tail wind on landing can increase a light aircraft's ground speed to the extent that it cannot be brought to a full stop before the end of the runway, resulting in runway overrun, which at best will result in no damage to aircraft or persons, but at worst could potentially be fatal.

Loss of height caused by all of these conditions can be described in many ways by pilots who have suffered an accident because of them; sink, an air pocket, down draught, or high rate of descent (ROD). These could also be confused with the effects of windshear, but without specific evidence of the reason, it is impossible to determine exactly what these pilots encountered.

Some crosswind conditions were exacerbated by aerodynamically induced propeller wash; the slipstream produced by the propellers twists around the fuselage of the aircraft and hits the vertical stabiliser, thus inducing a yawing motion which can add to cross wind effects in some circumstances, requiring more corrective action than might normally be expected.

Closer review of the sample data revealed eight possible sub categories under the main heading of 'air movement' as listed in Figure 20, which also gives the proportion in each subcategory. As can be seen, one third of the accidents cited either gusts of wind, or the simple generic presence of ‘wind’, more than a quarter involved a crosswind component and a fifth resulted from windshear or some variant of increased rate of descent.

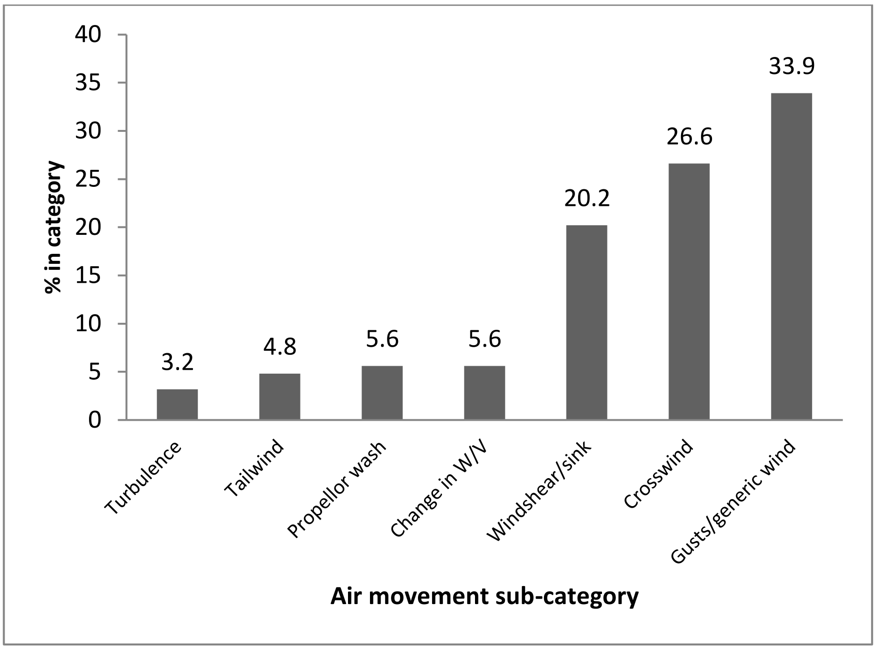

Figure 20: Proportion of each sub-category within air movement

None of these conditions should cause a light aircraft to crash on their own, assuming the pilot is properly prepared, trained and if flying within the limits of both their own skills and the structural envelope of the aircraft.

7.1.7 Experience as a factor

With the exception of type experience, there was no significant difference calculated between categories of experience for accident pilots versus survey pilots (Table 17). The suggestion from this is that air movement can cause any pilot to lose control, data from the sample supporting this notion in that the most experienced pilot was an ATPL holder with 24,395 hours total time, 40 hours on type and respectively 25 and 15 hours in the last 90 and 28 days. The next five most experienced air movement accident pilots had a mean total experience exceeding 12,500 hours, more than 600 hours on type and respectively 170 and 60 hours in the last 90 and 28 days. All six were affected by basic issues of crosswinds, gusts and propeller wash.

Table17: T-test results; air movement accident pilot versus survey pilot experience ($p < 0.05$)

Category	Data sets	Sample	Survey
Total	Hours	1468.1	990.9
	SD	3372.698	2342.378
	t value (df 521)	**1.770**	
	Hours	194.8	305.1
Type	SD	384.010	508.335
	t value (df 430)	**2.172**	
	Hours	30.1	26.9
Last 90 days	SD	53.204	47.114
	t value (df 522)	**0.637**	
	Hours	10.4	9.5
Last 28 days	SD	16.519	17.145
	t value (df 517)	**0.501**	

The category where a significant difference was calculated was in type experience, sample pilots having less such experience, corroborating the findings from Chapter 6. This could imply that some pilots may not have understood the characteristics of the aircraft's handling well enough to anticipate the effects of wind on it. Sorting the data with reference to type experience in ascending order shows the 11 least experienced pilots on type to have a mean of 3171.6 hrs total time (lowest, 105 hours; highest, 12,500 hours), but only a mean of 5.1 hours on type. This compares to the next 20 who have a mean of 238.4 hours total experience, but 14.8 hours mean on type. This reinforces the point that total experience is not a good indicator of a pilot's likelihood to have a wind-based accident.

There is room here to propose that at least some of these pilots were probably operating outside the limits of their own skill base and/or the aircrafts structural limits. This then introduces the concept of pilots not knowing their own limits or those of their aircraft, an issue which needs to be addressed in order that pilots make better decisions about whether or not to go flying on a particular day. Consideration should therefore be made, not only in how to measure a pilot's limits, but also to adopt guidelines whereby pilots are recommended not to fly in certain conditions, given their 'skill rating' and that should they chose to fly do so at their own risk, forfeit all insurances and accept liability for any damage to aircraft.

7.1.8 Landing

The issue of LOC during this crucial manoeuvre needs specific attention. For the purposes in this thesis it is considered that there are three main stages of the landing phase; approach, touchdown (including roundout and flare) and the roll out. More specifically, this section will examine the touchdown stage, as the data showed there to be 175 accidents at this point, 28 of which were dealt with in the previous section on air movement, 45 involving various contributory factors such as management of flight controls, lack of type experience, the adopted approach profile and stalling just prior to touchdown. The remaining 102 accidents involved a bounce, resulting from a harder than normal touchdown.

A small bounce in GA flying is to be expected on occasion, landing being arguably the most demanding task required of a pilot (Ebbatson, Harris & Jarvis, 2007) with positive control needed in three aspects; vertical speed (rate of descent), horizontal position relative to the runway centreline and forward speed. To merit an accident report to be filed, the bounces in the data resulted in either aircraft damage or injury to occupants, having been sufficient to remove positive control from the pilot.

In many cases, as the accident resulted in only minor damage to aircraft and in 94.1% no injuries to occupants, the details of possible causation are often little more than the fact that a bounced landing took place. Despite this, the potential dangers of bouncing and losing control on landing are serious and thus this phenomenon should not be dismissed simply as a minor mishap.

Due to accidents of this nature being reported by the pilot, some of the causes given could be translated into categories of a different accident type; for example flaring too high or too soon would result in a stall and the subsequent bounce, but as a stall is in no way referred to, it was deemed more logical to categorise it according to the pilot's statement in which a bounce has been cited. Common causal factors included poor technique, improper approach speed and the flare, being the most prolific cited in 37.3% of all bounce accidents.

The flare is where the aircraft's rate of descent is cushioned by raising the nose to lessen the impact forces as the wheels touch down. Asked to gauge the level of difficulty of the roundout and flare in the 2011 survey, pilots scored it as a mean of 3.4 out of 10, where 1 was not difficult and 10 extremely difficult. This compared to a mean of 2.7 for the approach. The survey also asked pilots to use the same scale to grade the difficulty of both the approach and the roundout and flare when wind is a factor (the type and strength of wind was not stipulated). The result showed an increase in difficulty for both manoeuvres by a factor of 1.4 to 4.7 for roundout and flare and 3.8 for the approach. Figure 21 shows the mean difference in difficulty between wind and no wind for both, the majority of pilots determining that landing in wind is only slightly more difficult. As can be seen, some pilots find wind to be a positive influence on their ability to perform both the approach and the roundout and flare.

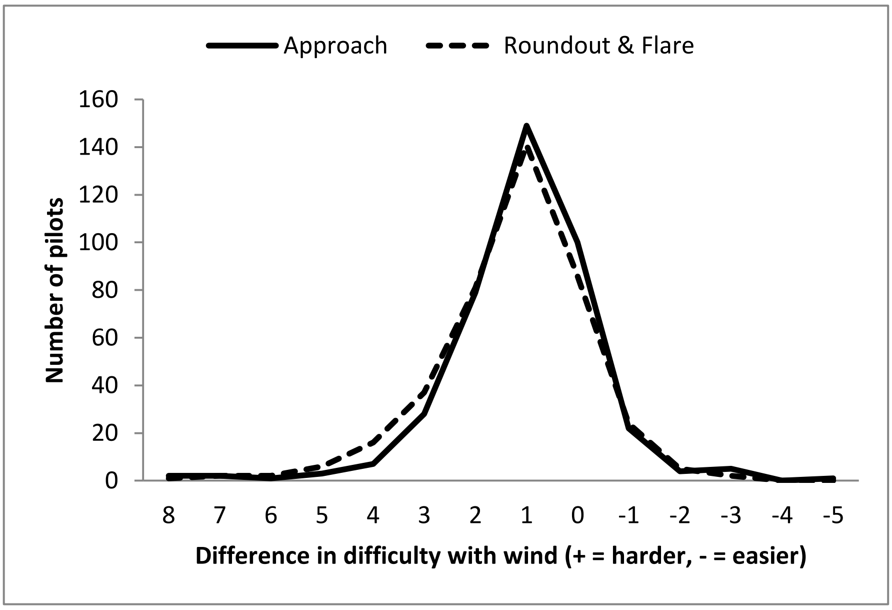

Figure 21: Difference in difficulty between the approach and roundout/flare manoeuvres with and without wind

Perhaps not surprisingly, students rated both manoeuvres, with and without wind as being greater in difficulty than (N)PPL, CPL and ATPL holders. However, more interestingly, ATPL holders considered both manoeuvres to be more difficult, with and without wind, than (N)PPL and CPL holders (Table 18).

Table 18: Difficulty rating as given by pilots in the 2011 survey for approach and roundout/flare, 1 being not difficult, 10 being extremely difficult, including increase factor

License level	Approach	Approach + wind	*Increase factor*	R/O & Flare	R/O & Flare + wind	*Increase factor*
Student	4.1	5.4	*1.3*	4.9	6.1	*1.2*
(N)PPL	2.7	3.7	*1.4*	3.4	4.7	*1.4*
CPL	2.0	2.8	*1.4*	2.3	3.4	*1.5*
ATPL	3.3	4.3	*1.3*	3.6	4.9	*1.4*

Reasons for ATPL holders considering these manoeuvres as more difficult than other lesser license holders are not know, but it is proposed they have a greater appreciation for the complexities involved in these sectors of the landing phase and how critical they are and thus give them greater deference in terms of skill required and thus their relative difficulty.

This data indicates that few qualified pilots in the survey rated either of these landing sectors higher than five out of ten for difficulty (7.2% approach, 18.6% approach in wind, 16.4% roundout/flare, 33.5% roundout/flare in wind) yet represented 61.8% of all bounced landings and nearly half of those caused by a poor flare (47.6%).

The causes of landing accidents in the sample are a subjective topic, some pilots citing external factors such as wind, others admitting to poor technique. Where one submits an early flare as the cause, another will describe a stall onto the runway, or deduce that the bounce resulted from a high ROD. This makes it difficult to positively identify specific areas where safety improvements could be made in this phase of flight. Given, however that relatively few pilots consider either the approach or the touchdown manoeuvres to be overly difficult, it is proposed that complacency is a feature of these accidents and that clubs, instructors and authorities take positive steps to raise awareness of the potential dangers surrounding LOC on landing.

7.1.9 Level of license

In stall/spin accidents, as a proportion of the pilot population, AOPA found the majority of pilots in the United States to be licensed to PPL or CPL level, students and ATPL holders being least likely to be involved in this type of accident (AOPA, 2003). As a proportion of the sample, (N)PPL and CPL pilots were also found to be the most represented in stall/spin accidents, being 6.5% and 6.1% respectively, students accounting for 3.8% of their group and ATPLs, 1.1%.

With respect to the ATPL holders, it is reasonable to assume that their knowledge and experience provide them with a barrier to stall spin accidents, hence their low representation in the data. Reasons for students being less represented than (N)PPL or CPL holders are less clear, but it was considered that due to the nature of their activities, mean currency levels would be greater than for (N)PPL pilots. This however was proven not to be the case for either the category of last 90 days or the last 28 days, the means being calculated for all accident pilots and LOC pilot only (Table 19).

Table 19: Mean currency for pilots in all accidents and LOC accidents versus survey means

	Full Sample (hours)		LOC only (Hours)	
	Last 90 days	Last 28 days	Last 90 days	Last 28 days
Student	12.6	5.8	12.3	5.8
Survey student	8.5	2.9		
(N)PPL	14.5	5.5	13.8	5.1
Survey (N)PPL	15.3	5.4		

There was also no discernible difference between the mean values in the same categories for pilots in the 2011 survey, in some cases means for accident pilot currency actually being higher than for survey pilots.

The potential source of this phenomenon, it is therefore suggested, lies in the freshness of the knowledge and instruction received by the students and thus the ability to recall procedures not only quicker, but also with greater accuracy than (N)PPL pilots who may struggle to do so, having not practised stall recovery, emergency landings or other procedures in recent weeks, months or possibly years. In the time between formulating an intention and carrying it out, the intention must be stored in the prospective memory (Reason, 1990), being where the mind stores planned actions, releasing them only at the appropriate time, such as when a pilot needs to perform a specific task or manoeuvre related to safety (McDaniel and Einstein, 2007); recovering from a stall, for example. This is known to be one of the more vulnerable parts of the memory system, failure of which is among the most common form of human fallibility (Reason and Mycielska, 1982). Should this be the case (and it is accepted that this theory is formulated on the basis of some supposition) it supports the notion for refresher training for GA pilots, particularly those at (N)PPL level.

The higher rate of representation for CPL holders above that of students and ATPL holders is not one concerning either currency or lack of knowledge, given that 43.9% of all CPL holders involved in LOC accidents were instructing at the time of the accident (47.8% for all accidents). This compares to just 31.3% of ATPL LOC pilots (33% for all accidents), leading to a possible deduction that these accidents were contributed to by the student pilot and were not necessarily directly associated to the aircraft Commander; the CPL pilot. This however suggests that Instructor competence is an issue, whereas the more likely explanation is that Instructors prefer to let their students fly as much as possible, the risk being that they make an error of judgment which, due to startle, is not immediately corrected by the Instructor. With a high proportion of these accidents (87.3%) occurring below the 2000ft level (as defined previously) or on the ground, it is reasonable to assume that little time remained following the onset of LOC in which the Instructor could effect a proper recovery, given that even at a taxi speed of 10kt, an aircraft travels 5.1 metres in one second.

7.1.10 Summary of Part 1

This section has highlighted the main issues concerning LOC in UK GA, demonstrating that as the single biggest accident factor, experience, training and awareness all have contributions to make to some of the major causes. Whilst good training and maintenance of skills through regular flying is valuable, pilots of all experience and license levels remain vulnerable to LOC accidents if they do not retain an awareness and acceptance of their own capabilities in testing conditions. It is further suggested that steps are taken to make pilots less eager to fly in conditions that may be less than ideal through giving flying clubs more powers to inspect log books and refuse hire of aircraft if conditions are deemed to be below that suited to the pilots perceived skills set and license privileges.

Part 2 of this chapter will focus on the often fatal incidence of controlled flight into terrain (CFIT).

7.2 Controlled Flight into Terrain and Meteorological Influence

7.2.1 General meteorological influences

Meteorological conditions are rarely a direct cause of aviation accidents, more often the resulting actions, decisions and skills of the pilots being to blame. Even sophisticated modern technology cannot prevent an accident if a pilot misinterprets information, makes an erroneous decision, or lacks the skills necessary to effectively use the technology at hand.

There are several ways meteorology can adversely affect the safety of an aircraft, particularly rudimentary machines such as those mostly flown within GA; wind, precipitation, visibility, temperature, air density (high airports), icing and turbulence. For the most part, aircraft will be affected in the air, but as briefly suggested in the previous chapter, they can also be afflicted by certain conditions on the ground. Many meteorological events have already been discussed in Chapter 7.1 concerning LOC accidents; wind, inadvertent flight into IMC, carburettor icing, pilot skills, training and levels of SA all being major influences.

Where meteorology is most influential is when pilots, whether qualified or not, fly in or into conditions of reduced visibility. In UK GA, unintentional flight from VMC into IMC is an occurrence that can have three potential outcomes; safe return to VMC, LOC or CFIT. The latter two predominantly result in fatalities, CAA figures showing CFIT to have represented 20.5% of fatal GA accidents from 1985 to 1994 (CAA, 1997). Discussion in this chapter will centre on the reasons for pilots flying from VMC to IMC and briefly explore the qualifications required to be allowed to penetrate adverse conditions safely. Moreover, enhancing the brief description presented in Chapter 5, CFIT will further be defined and possible reasons for pilots flying into terrain explored, beyond those already offered.

7.2.2 Sample data; the incidence of CFIT

Although only 15 CFIT accidents were recorded in the sample, seven were fatal and two resulted in serious injury to the occupants. Compared to the CAA figures cited earlier, this suggests that CFIT is a reducing trend in terms of accidents, here only representing 12.7% of all fatal accidents. Nonetheless the high ratio of fatal to non-fatal CFIT accidents is alarming, nearly half ending fatally, nine people being killed.

None of the pilots involved could be deemed as inexperienced, the scope of total experience levels recorded ranging from 110 to 4268 hours and on type from 70 to 1500 hours. Levels of currency were marginal for four pilots and one had no recorded information to allow a determination. The small number involved in CFIT precluded conclusive statistical analysis, but exploratory evaluation determined that in all categories of experience, there was no statistical significance between that of the CFIT pilots and both the survey or other accident pilots.

Of the four pilots with minimal currency, one specifically demonstrated the concerns raised in this thesis about aircraft owners assuming complete autonomy regarding their ability to fly. The pilot took off from Spanhoe, a very small unlicensed airfield lying within the Military Air Traffic Zone (MATZ) for RAF Wittering, where it is highly unlikely he will have been challenged about his currency or license privileges. He had not flown at all in the previous 28 days, only logging two hours in the previous 90 days. The intended route was only 6 nautical miles (nm), but very low cloud, mist and fog was approaching from that direction and despite being aware of this the pilot still took off (AAIB, 2009). It was noted in the accident report that the pilot had in previous years enhanced his license with an IMC rating, but this had expired in 1997, 11 years prior to the accident and had not logged an instrument flight since 2004. Ultimately the reasons why the pilot entered into fog and crashed could not be established with any certainty, but it is suggested here that his lack of currency, expired IMC rating with lack of recent instrument flying and possibly his age (85) were significant contributors.

This accident serves to highlight the issues of maintaining currency and flying within one's abilities and license privileges. It also emphasises the dangers of poor decision making and complacency; in this case, despite the approaching weather, the pilot still decided to go, likely with the thought that the shortness of the route minimised the possibility of anything untoward happening. Furthermore, it establishes the difficulties in monitoring those who are not required to verify the particulars of their license and associated privileges to any person prior to flying; aircraft (co-) owners. Similarly, it demonstrates that for those who are club members, such safeguards should not only be in place, but used diligently to ensure that those flying are doing so in as safe an environment as possible. It is recommended here that action be taken to ensure all reasonable steps are taken by all clubs and schools to enforce minimum currency requirements and to physically inspect member licenses and log books, prior to any aircraft hire being authorised.

7.2.3 Areas of concern

Close examination of the information from each of the 15 CFIT reports reveals there to be three broad areas of concern; a lack of appreciation for the weather; a lack of ability or willingness to maintain minimum safe altitudes (MSA), navigational track and/or standard operating procedures (SOP); flying outside the privileges of the license and associated ratings.

In all cases, had more consideration been made to the actual and forecast weather, even if the pilot continued with departure, their SA would have been enhanced and perhaps decisions to turn back or divert could have been made sooner, before difficulties were encountered. Indeed it is suggested here that given the circumstances prior to some of the accidents, a greater appreciation for the weather should have precluded departure from the outset.

In four of the accidents, pilots deviated from their intended plan or SOPs, two of these taking place not only in less than acceptable weather conditions, but also at night. It is not known whether lack of skill, distraction, complacency or poor decision making were contributory factors leading to these actions, but it is likely that one, or a combination of these were influential in each accident. These situations support the notion that enhanced instrument flight training be incorporated into the PPL syllabus, if for no other reason than to allow pilots to accurately follow a planned track if they inadvertently stray into IMC. Currently, pilots are restricted to maintaining visual contact with the ground, leading in two cases to the pilots descending below the MSA to establish this protocol, resulting in the CFIT accident. Had they sufficient skills to remain in IMC until such time as a descent was safer and more appropriate, they may have returned to visual conditions and been able to divert or carry out a precautionary landing.

Of course the argument stands that they should not have entered IMC in the first place, some possibly stating that enhanced instrument training might encourage some to fly when the weather is marginal and thus lead to more accidents. However, combined with the suggested enforcements, there is little reason to believe that by giving a pilot improved awareness of instrument flying skills, it will result in anything other than an improvement in GA safety.

The third area of concern, pilots flying outside the privileges of their license, should be relatively easy to address for the most part by following through with the enforcements proposed above. However, maintaining supervision of owners may prove more difficult; even where they fly from licensed airfields, they could perceive such authority as invasive and unnecessary. It is thought though, that the majority of pilots, whether owners or not, do take safety seriously and thus would not take any such enforcements as anything other than a positive step forward to improving UK GA safety. Those who take offense at such moves could, however still be persuaded to enrol on such a scheme if the CAA were able to deliver a mandate requiring that all pilots receive a competence check flight at least annually, where the assigned Instructor would check the pilot's log book for flight authorisation notifications from designated persons at their home aerodrome. For the minority who possess their own aircraft and/or airstrip, concessions could be made to allow for retrospective notifications to be made. Further details of this proposed scheme will be discussed in chapter 10.

7.2.4 Summary of Part 2

This section has concentrated on the meteorologically influenced phenomenon of CFIT and explored some of the potential issues surrounding its pervasiveness in fatal accidents. Sample accident data was used to identify main areas of concern and provide possible solutions to improving safety in UK GA with specific reference to this accident category.

Part 3 will repeat this exploratory review for technical accidents.

7.3 Technical Failures in UK GA Accidents

7.3.1 The nature of technical failures

Technical failures are the least common accident cause, most being able to be contained and managed in flight. In the commercial aviation industry, reliability of modern aircraft (particularly those designed and built from the 1980s onward) precludes the incidence of frequent serious failures and their designs are such that minor failures are not sufficient to cause anything more than inconvenience in the form of precautionary delays and diversions.

GA aircraft, specifically those within the boundaries of the definition of GA for this thesis (as expressed in chapter 3) do not generally demonstrate the same level of reliability as commercial aircraft, using less sophisticated engineering techniques and fewer advanced technologies in their manufacture and operation; for example the piston engines used are more akin to those found in a car and most instruments are analogue or mechanical in nature, although modern ‘glass cockpits’ are more and more being retrofitted to older aircraft, particularly those used for commercial pilot training. Whilst new designs and models are continually being developed with improved technologies and engineering, their expense relative to the financial constraints within GA mean the propensity of GA aircraft flying are of the older, less reliable type. It is however the ability of the pilots to cope with any failures that is of greater importance in them being able to manage situations and prevent accidents occurring; thus the area of human factors is much more prolific in the research resources applied to it.

7.3.2 GA accident rates compared to commercial operations

As stated, catastrophic technical failures in commercial aviation are comparatively rare and usually result in nothing more than a nuisance. Even serious incidents such as those afflicting Qantas Flight 32 can be successfully managed. In this case, an engine suffered an uncontained failure, resulting in a loss of fuel and some hydraulic and electrical power failures due to damage incurred by debris from the exploding engine (ATSB, 2013). The numerous backup systems and the training received by the pilots and cabin crew resulted in a safe emergency landing with no injuries reported.

GA however presents a greater number of technical failures per flight hour; Using statistics from Boeing (2012), the approximate frequency of fatal system/component failure accidents in worldwide commercial operations is one per 142.9 million flight hours. Using the same calculation principles presented in Chapter 5, the UK GA frequency of fatal technical accidents is one per 1.27 million flight hours, approximately 112 times worse than for commercial operations.

Possible reasons for these accidents will be addressed here and in particular, the two main categories of technical failure (engine failure and landing gear failure) will be discussed in greater detail. Discussion will include how Pilot response to technical failure is a key factor, GA pilots in the UK not being subject to continuous assessment and competence checks like commercial pilots, but are instead trusted to review and practise emergency procedures (with an Instructor) at their own convenience. The implications of this regulatory loophole will be evaluated in terms of risk to UK GA safety.

7.3.3. Engine failure

7.3.3.i The problem with carburettor icing

Of the 13 fatal accidents recorded as being due to a technical problem, ten (76.9%) were cited as direct engine failures, all of which involved some form of starvation of fuel to the engine or carburettor icing. In total, more than a third (34.9%) of the 149 engine failures were determined to have likely been caused by icing in the carburettor, but as ice would have melted by the time any inspection took place, it was impossible for the AAIB to confirm such conclusions. Such inspections however can rule out any other mechanical defects, if the engine is proven to run normally at that time.

Carburettor icing is a phenomenon that can occur even on warm days, particularly when humidity is high, temperatures within the low pressure area of the venturi in the carburettor capable of dropping by as much as 22°C, as heat is absorbed through vaporisation of the fuel (Oxford Aviation Services, 2007). To some pilots, the indicators for carburettor icing might appear to suggest fuel starvation, as the symptoms are similar; a drop in RPM and associated rough running of the engine, including vibration. This confusion may have led to some of the engine failures reported and hence explain why the system appeared to be fully functional upon inspection. The difference between the two problems is that with correct diagnosis and management, carburettor icing is curable through the application of bleed heat from the engine, selected via the carburettor heat control. Heat must be applied for a sufficiently long time to melt all the ice. As the melted ice is blown through the system, pilots should initially expect the problem to temporarily worsen and recognise this as a process of de-icing the carburettor. The heat should not be removed until the engine returns to normal.

Application of carburettor heat in non-icing conditions is normally accompanied by a drop in RPM as the less dense hot air is released into the system, but in a loss of power situation, if a pilot does not anticipate the increased rough running, they may be panicked into assuming they have taken an incorrect action and seek to rectify that by closing the heat control. Thus the indications of a rough running engine may cause confusion to some pilots and they may feel pressured into making precautionary or emergency landings (the point in the flight where these accidents took place), based on poor information, gained from a lack of knowledge.

Indeed, if carburettor ice is not cleared an engine will progressively lose power and may eventually stop. A pilot may expect this if they have incorrectly diagnosed carburettor icing as a more serious problem, thus completing their mental model and confirming their decision. Had they maintained the application of heat for a few seconds more, it is likely that the engine would have restored itself to full power and an accident on landing without power in a field would have been avoided.

7.3.3.ii Fuel starvation

Following appropriate application of carburettor heat, if the engine does not return to normal power, it is logical to conclude that another potentially more serious problem is present. In 27 accidents, it was concluded that fuel starvation was the primary cause. The most obvious cause of fuel starvation is an insufficient amount in the tanks, but this was classed as being detrimental airmanship due to the failings on the part of the pilot to check the fuel levels before departure.

The cases of fuel starvation in this section relate to technical conditions and failures. Most were cited as blockages within the system, either in the pump, the filter or at the injector nozzle. Blockages in the fuel system can be caused by a number of different issues, one of which is contamination of the fuel; in some reports this phraseology was used to describe the cause leading to engine failure and thus was established as a separate sub-category.

In the same manner that physically checking fuel levels before departure is imperative, visual inspection of the fuel is also an essential pre-flight check. From fuel drains in the wing tanks and the engine, the pilot can take small samples of fuel and check them for water or debris particles which, if present will likely cause engine problems. However, water and debris can also get into the fuel after checking via condensation and particles from the fuel system itself dislodging. Thus for these engine failures due to fuel starvation, it was deemed appropriate to categorise them as technical accidents, given that AAIB reports do not always state the pre-flight checks that were carried out by the pilot, thus it was impossible to implicitly categorise them all as detrimental airmanship.

Other causes of fuel flow restriction included a poor fuel/air mixture, an inability of the system to deliver fuel due to aircraft manoeuvring and leakage from the aforementioned fuel drains which can, on occasion fail to close after inspection of the fuel is completed.

Of these 27 fuel related accidents, three were fatal, one report citing fuel contamination, a second an obstructed fuel jet, the other a blocked fuel injector nozzle. These serve to highlight the importance of thorough checks before departure, particularly with fuel, considering that in many light aircraft, the gauges inside the aircraft are deemed to be unreliable and should not be counted on for accurate information concerning the levels of fuel in the tank(s).

7.3.4 Pilot responses and actions

In training at (N)PPL level, students are instructed on the procedures to adopt in the event of an engine failure. The engine failure after take-off (EFATO) scenario leaves little time for anything other than setting the aircraft up into the glide, making a short radio distress call and securing systems such as fuel and electrics in preparation for an emergency landing.

In the cruise, pilots have more time to perform tasks due to the height at which they are flying, greater height providing more time. Students are instructed both on the ground and in the air in how to set the aircraft into a glide, choose a suitable landing site and make an appropriate radio call to inform ATC of their predicament, location and intended actions. During this process the student is reminded of the importance of maintaining the best glide speed (that at which the aircraft will not stall, but will travel the furthest horizontal distance per unit of vertical distance).

The practise forced landing (PFL) is generally performed at 2000 – 3000ft, as this is the most common height band within which GA pilots fly. As the process involves complete reduction in power, there is a risk of carburettor icing as described above. To prevent the PFL becoming a real emergency, carburettor heat is applied and the engine is warmed periodically by increasing power for a few seconds. Although an imperative safety requirement, warming the engine can provide students with a false demonstration of the forced landing process as engine warming provides added height and thus time that otherwise would not be available in a real engine failure scenario.

An additional misrepresentation in a PFL is the glide performance of the aircraft. As stated in one accident report where the pilot was caught out by this phenomenon:

“Once the engine has stopped, the drag will increase and the glide angle is steeper than during a practise forced landing when the propeller is still rotating” (AAIB, 2007, p36).

The PFL will never accurately replicate an engine failure scenario, but it will give pilots the skills necessary to carry out the procedures with maximum effect in a real situation. Just as currency helps a pilot maintain basic flying skills, regular performance of PFLs should be part of a GA pilot's flying regime in order to retain these additional vital skills. In one accident that occurred in September 2010 it was stated in the report that:

"The pilot last conducted PFLs during his biennial flight with an Instructor in November 2009…..but was unlikely to have done so during flights without an Instructor" (AAIB, 2011, p56)

In a further report from an accident involving engine failure, the AAIB articulated the thoughts of the pilot involved who commented that:

"….there is little to prepare a pilot for the reality of (an engine failure) and that regular flying, continual education…….all help a pilot to be better prepared" (AAIB, 2011, p63)

Considering these comments, it is surprising to find in the 2011 survey that 10.8% of pilots admitted to not performing PFLs, an additional 23.9% stating they only practise them in the presence of an Instructor (when having a biennial or revalidation check flight). Whilst the final group are at least receiving instruction, they may not fly with an instructor for many months, even years and thus will not have performed PFLs in that time. This equates to more than a third (34.7%) of UK GA pilots who do not regularly practise the essential skill of landing an aircraft without power away from an aerodrome.

Including the three incidence of fuel starvation, engine failures and their resulting forced landings caused nine fatal accidents within the sample. The engine failures themselves were not specifically dangerous; it was the lack of accuracy on the part of the pilot in executing the landing that ultimately caused the fatal injuries. The flight experience among the pilots ranged from a PPL holder with 50 hours (total and type) to an ATPL holder with 13,750 hours, 150 of which were on type, a third pilot having 1138 total hours, 687 being on type. Thus it cannot be surmised that flight experience is necessarily a factor. None of the reports suggested that any of these engine failures exhibited any characteristics worse than other similar events in the sample, with the exception of one where it was likely the pilot was incapacitated to some extent by smoke in the cockpit.

To combat this issue, it is recommended that PFLs be part of the improved post licensure support and monitoring proposed by this thesis and that as a minimum, GA pilots receive a briefing on the topic of engine failures both after take-off and in the cruise on an annual basis.

7.3.5 Landing gear failure

There are two general types of landing gear accident; either the gear collapses on the runway or after landing, or the aircraft is forced to land without the gear locked in the down position. Most aircraft flown in UK GA are of the fixed gear type, as shown in the survey, only 24.4% stating they fly complex single engine aircraft and 8.6% multi-engine aircraft (which tend to be complex); complex types have a retractable landing gear, a variable pitch propeller for more efficient use of engine power and often have more powerful engines than 'regular' GA aircraft.

Following the same process as fuel, where a pilot has inadvertently landed their aircraft without lowering the landing gear, this has been categorised as an airmanship issue. In this category, only gear-up landings involving technical malfunctions have been included.

Depending on the make of aircraft, there are three main systems used to retract and lower landing gear in GA aircraft; electrical, hydraulic and mechanical. Defects with all three types were cited within the sample and included complete failures, partial failures where the gear started to retract/drop but did not complete the cycle and occasions where the gear retracted without being commended to do so by the pilot.

In total there were 42 gear retraction issues, representing 37.8% of all landing gear failure accidents, none resulting in more than minor injuries to persons on board.

Of the 111 landing gear accidents, 49 involved structural failure of the gear or the struts and supporting framework. Causes of structural failure included fatigue cracking, stress corrosion and failure of parts such as the bungee truss and suspension brackets. A further nine failures were structural, but had been induced through poor or lack of proper maintenance. Again, none of these accidents resulted in more than minor injuries to the aircraft occupants.

Although representing 11% of all accidents in the sample, landing gear failures are not seen as a major threat to life and in a technical sense are not able to be managed by pilots as the event tends to happen without warning, except where it is an extension issue on aircraft with retractable gear. Hence these accidents are only presented in this thesis as a representation of the type of accident that can only be prevented through better maintenance and pre-flight checks.

7.3.6 Summary of Part 3

Part 3 has discussed the main accidents types caused by technical failures and has shown that despite their relatively infrequent occurrence, they still have the ability to result in fatalities. It has been shown that perhaps compared to other accidents, where technically induced, it is not the initiating cause that necessarily leads to the accident, but the actions taken by the pilot and their management of them, these being factors in a PPL pilot's training and subsequent support that can be addressed, as presented both here and in Chapter 10.

In part 4, the different phases of flight will be examined and the associated problems for each of those in terms of accidents discussed.

7.4 Accidents in UK GA by Phase of Flight

Historically and worldwide, the phases of landing and take-off have been highlighted as the most likely times for an aviation accident. Thus this section of Chapter 7 statistically compares the sample data with that gathered from the 2011 survey to determine how closely UK GA reflects this statement, looking specifically at the main categories of accident occurring in each phase and whether or not pilot experience is a factor.

7.4.1 Phases defined

The process of flying involves a number of separate phases which link together to form a flight; planning, engine start, taxi, take-off and initial climb, climb, cruise, descent, approach and landing. Each event carries risks which if not properly managed, can lead to accidents. Lenné, Ashby and Fitzharris (2008) in Australia, O'Hare and Chalmers (1999) in New Zealand, Dambier and Hinkelbein (2006) in Germany and Boeing (2012), among others, have calculated the frequency of accidents according to the phase of flight, Boeing concentrating solely on commercial aviation. With the exception of O'Hare and Chalmers, their results indicated that landing is the phase most likely to induce an accident, each with different findings for the successive most prolific accident phases (Figure 22).

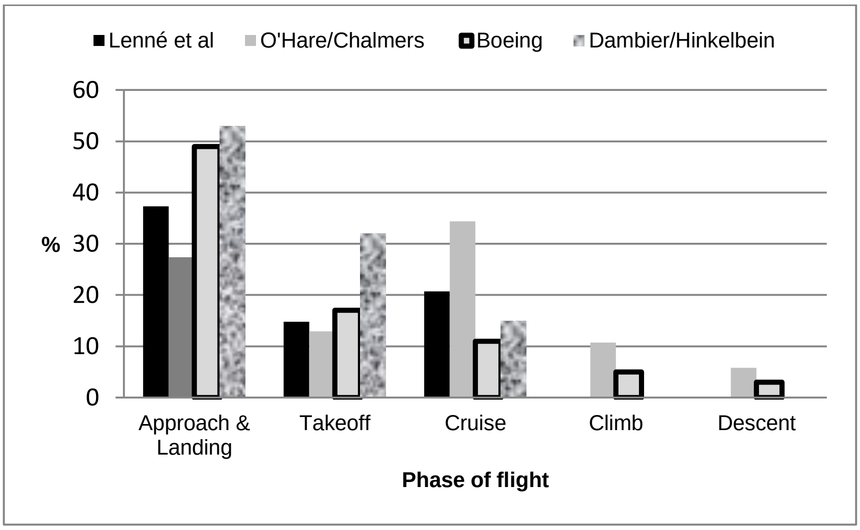

Figure 22: Accidents by phase of flight according to previous research findings

Traditionally take-off and landing have been tagged as critical flight phases due to the inherent dangers associated with manoeuvring an aircraft close to the ground in either a slow, high drag configuration, or under heavy acceleration to very high speeds. They are phases of flight requiring skill, coordination, concentration and practise.

In order that the reader fully comprehend the basic complexities of commanding a light aircraft and thus has a better understanding of the conditions surrounding the accidents presented here, a brief summary of each phase and its sub-parts is given below.

7.4.1.i Planning and pre-start

In GA a flight will be preceded by the pilot making appropriate assessments of the current and expected weather for the intended route and used to devise a flight plan which, where necessary, is presented to Air Traffic Control (ATC) for approval. The plan is then used by the pilot for heading and altitude information and estimated times for the route. A weight and balance calculation is made to confirm that the aircraft will be within the manufacturer's limits for performance for take-off (out of limits the aircraft may not be able to take-off and if it does may be uncontrollable once airborne). A pre-flight check is then performed where the aircraft is inspected by the pilot to ensure that its systems, fuel and structural integrity are satisfactory; these activities are categorised as the planning phase.

7.4.1.ii Engine start

Once planning and the pre-flight inspection are complete, the pilot is then ready to start the aircraft engine. Although different engines require different start up actions (engine priming via an in-cockpit pump or propeller swinging, push button or key ignition etc) the processes in place for safety are generally based on the same principles; the throttle is opened just enough to allow adequate fuel flow, but not enough to allow excess power to be developed by the engine. Brakes are applied and the appropriate controls (they may be operated by the rudder pedals or a lever) covered in anticipation of further application being required after engine start. A good lookout all around the aircraft gives the pilot situational awareness in terms of pedestrians, vehicles or buildings which may be affected by the wash of the propellers as the engine starts and is accompanied by a vocal warning ("CLEAR PROP") to anyone in the vicinity that the engine is about to be started. Once started it is the pilot's responsibility to prevent any movement of the aircraft, visually check the instruments for any failures and adjust the engine RPM to the recommended idle setting.

7.4.1.iii Taxi

Taxiing an aircraft to the runway involves good situational awareness, good control of both steering and speed and an appreciation of the wind direction and strength. Throughout the taxi, the pilot will either be talking to or listening out for communications from ground based ATC and other aircraft operating at and in the vicinity of the airfield.

7.4.1.iiia Situational awareness

The dimensions of a light aircraft, typically 7 – 8m long, 8 – 10m wingspan, requires that the pilot maintain good situational and spatial awareness, especially when taxiing within a parking area or near buildings and other structures such as fences and airport signs and marker boards. It is also a prudent time to check the operation and effectiveness of brakes, which is usually done within the first few meters of movement.

7.4.1.iiib Steering

Steering differs from aircraft to aircraft. Some types have nose wheel steering which is controlled through the rudder pedals. Others use differential braking whereby the left brake is applied to turn left and vice versa. Again this is affected in most cases through the brake pedals which also double as the rudder pedals. In older tail dragging aircraft, steering may be achieved through deflection of the rudder, but can be augmented by differential braking. Sometimes a combination of all three is required, especially if a tight turning circle is required.

7.4.1.iiic Speed

The control of speed is important and is best achieved through careful manipulation of the throttle. The pilot can be distracted whilst taxiing by messages from ATC, the temptation to check the flight plan or to talk to passengers. At the recommended fast walking pace the possibility of distractions leading to an excursion from the taxiway or a collision is reduced. At this speed the wear on tyres and brakes is also minimised and also allows the pilot sufficient time and control to perform taxi checks which confirm that the instruments used in a turn are working in the correct fashion.

7.4.1.iiid Wind

Difficulty in taxiing can arise when the wind speed is such that it impacts on the control of the aircraft. The direction of the wind determines the position at which the controls must be held in order that the effects of the wind are reduced or neutralised. This can lead to a situation where the controls are ‘crossed’ (i.e. yoke to the right, rudder pedals to the left and vice versa) and feel very unnatural, especially to an inexperienced pilot. As the aircraft is turned in the taxi, the position at which the controls are held changes accordingly. Thus good coordination is required to maintain overall control of the aircraft.

7.4.1.iiie Pre take off checks

Either during the taxi or upon arrival at the holding point just short of the runway entrance, the pilot must perform a number of pre take-off checks, mostly concerning the performance of the engine. These are performed at both high and low power settings and include checks on magnetos, carburettor heat and a review of engine temperatures and pressures. Also included are safety checks such as the security of harnesses and hatches (doors).

7.4.2 Getting into the air

7.4.2.i Take off roll

In much the same way as taxiing, the take-off roll requires good situational awareness, good control of steering and speed and an appreciation of the wind direction and strength.

Normal practice requires that the take-off be made into wind in order to maximise airflow over the wings to produce the required lift as early as possible thus minimising the length of the take-off run. On occasions when the wind is not blowing directly in the direction of the runway, a cross wind component will be in effect and the pilot must take account of this during the ground run and subsequent rotation and initial climb. Both feet operate the rudder pedals to maintain directional control down the runway and the left hand operates the ailerons and elevator via the yoke to counteract effects of the cross wind, such as lift bias on the into wind wing. These processes require changes in the level of input, due to the nature of wind (which does not blow with constant strength from a constant direction all of the time) from subtle to large positive control movements. At the same time, the pilot, having applied full power for take-off, keeps the right hand on the throttle in readiness to abort the take-off if necessary at which point the feet would change from rudder pedals to toe brakes.

As well as physical control of the aircraft, the pilot must also monitor its performance and ascertain whether the take-off will be successful. This requires the pilot to keep an eye on the aircraft’s speed and engine instruments as well as retaining situational awareness in terms of the aircraft’s position on the runway and any potential hazards such as other aircraft or vehicles entering the runway. If they have any doubts concerning the likelihood of a successful take-off, they must abort the procedure by reducing power to idle and apply the brakes with sufficient force to stop the aircraft before the end of the runway, but wherever possible without locking the wheels and causing unnecessary wear and stress on the tyres and braking system.

7.4.2.ii Rotation and initial climb

At the appropriate speed, the pilot 'rotates' the nose of the aircraft up and lifts it into the air and into the initial climb. Still maintaining control and situational awareness as in the take-off roll, the pilot must ensure that the rotation is smooth and at just the right speed allowing the aircraft to leave the ground in good time, but not so steeply as to enter a stall. Once in the air the pilot must achieve and maintain the aircraft's best rate of climb by adjusting the attitude of the nose. In the initial climb, the pilot must continue to be prepared to abort the take-off if necessary by either landing back onto the runway if enough remains, or by visually noting potential areas ahead for an emergency landing. At this point, after take-off checks are also performed to ensure that the wheels are not free rotating (which causes un-desired drag) any flaps used for take-off are retracted at the appropriate time, the engine is still performing as expected and the landing light switched off.

7.4.2.iii Climb

Once settled in the climb, the pilot's workload reduces as the effects of crosswinds and threats of ground hazards are removed. It is necessary however, to maintain vigilance for other aircraft in the air and to monitor the aircraft's speed and engine performance. It is usually during this phase of flight that the pilot will contact any en-route ATC and commence navigation. There also remains the threat of having to perform an emergency landing due to mechanical or other failures. This is a crucial issue during the early climb as with the aircraft still at low level, the pilot has very little time to complete the processes involved in an emergency landing including looking for a suitable site to land.

7.4.3 The cruise

Three main processes are key to a safe cruise and are taught to student pilots as "aviate, navigate, communicate." To 'aviate' requires that the pilot flies the aircraft. This involves making regular checks of the fuel, radios, engine, directional indicator (DI or compass) and the altimeter – known as a FREDA check. Also considered important in the 'aviate' process is maintaining a good lookout, not only for other aircraft, but also for potential hazards such as bad weather.

The 'navigate' process is exactly that and is secondary to flying the aircraft, but still important to prevent getting lost or flying into restricted or controlled airspace without permission. It also helps the pilot maintain geographical awareness and in areas of high ground will reduce the risk of collision with such topography.

Much GA flying in the UK may be achieved without use of a radio, however it is prudent and recommended to make use of the radio at all times and this comes within the ‘communicate’ process. Where use of the radio is required, communication with ATC is mandatory. Where it is not, ATC may be contacted to receive such information as changes in atmospheric pressure (important to maintain accurate altitude information) and the presence of other aircraft in the area and their whereabouts. Also in the event of any emergency they are immediately available for assistance. Furthermore, where radio communication is not required or possible, a pilot may make ‘blind’ calls which are transmissions made giving information such as the location, altitude and intentions of the pilot with the objective of making anyone listening aware of their presence.

During the cruise, the processes mentioned here allow the pilot to gather information about the flight and make appropriate decisions such as whether to continue, divert or turn around and continues the level of vigilance required to prevent an accident or to carry out a successful landing in the event of an emergency.

7.4.4 Getting back down

7.4.4.i Descent

The three processes of the cruise continue in the descent, but in a low power state, the pilot must be aware of engine issues such as carburettor icing (an engine can be susceptible to carburettor icing in any weather at any power setting, but particularly at low power settings in moist air) and lack of response or failure. A lookout for other aircraft below must also be maintained which in some low-wing aircraft may mean making manoeuvres to allow a view of the airspace below. The presence of other aircraft will also increase as the pilot approaches the vicinity of the destination airfield. Again, radio communications may not necessarily be required, but contact with ATC (or the radio operator at small airfields) will give the pilot information on air pressure, wind strength and direction, the arrivals process in operation at the airfield and other aircraft approaching or departing.

7.4.4.ii Approach and landing

The definition of where and when the approach begins, for the purposes of this thesis will be considered as the point at which the pilot gains visual contact with the airfield. At this point preparations will be made for the subsequent landing including checks from a written list, settling the aircraft at the appropriate altitude and mentally planning the pattern to be flown, revising speeds and use of flaps and maintaining contact with ATC.

After flying a set pattern around the airfield, the pilot lines the aircraft up with the runway. This is final approach. In a similar manner to the take-off roll, the pilot coordinates the controls to counter any crosswind effects, turbulence and maintain the correct speed. Selection of landing flap, if not already done so, is made at this point. At a suitable height above the runway, the pilot flattens the aircraft's descent (called the round out) and sets the aircraft into the flare manoeuvre, where the airspeed is allowed to bleed off and the nose gently raised to present the main wheels to the runway (a different technique is used for different aircraft, particularly in tail dragger types).

Once the wheels have touched down, the nose is lowered, power removed and the brakes applied. During the roll out, the coordination of controls for crosswind effects and control of the aircraft continues until the aircraft is at a slow and manageable speed. Only at this point can the aircraft be taxied off the runway, parked and shut down.

7.4.5 Aborted landing

At any stage during the landing process, the pilot can decide to abort and re-position for another attempt. This manoeuvre is commonly referred to as the 'go-around.' Made early in the approach, the decision to go-around presents less risks than if made late at low level. It can however be performed relatively safely even after the aircraft has touched down, if the pilot applies all the appropriate procedures correctly. Risks include the failure of the engine with the sudden application of power, collision with the ground if made too late, stalling due to over-rotation in the climb out or failure to correctly re-configure the aircraft for a climb (retracting the flaps too soon can cause a stall due to the loss of extra aerodynamic lift that flaps provide and failing to retract them causes unwanted extra drag which can prevent the aircraft from climbing away at a safe rate for obstacle clearance or also induce a stall).

A go-around can be initiated for several reasons. One of the most common is the pilots discomfort with the approach; the aircraft may be too high, too low, too fast, misaligned with the runway due to wind or being buffeted by turbulence. Other reasons include traffic on the runway, faster traffic behind (usually at larger airports where ATC issue an instruction to yield the runway to a commercial aircraft further out on the approach) or a rapid change in meteorological conditions (wind, visibility etc.).

7.4.6 Accident categories and other information

The same four main categories of accident were used as previously within this thesis; detrimental airmanship, loss of control (LOC), technical failures and controlled flight into terrain (CFIT). The following definitions serve as reminders, each having previously discussed in more detail in earlier chapters.

Airmanship was deemed to include human and pilot errors covering not only the basic categories of error as defined by human factors specialists (skills, decision making, procedural errors, violations and supervisory errors – see Wiegmann and Shappell, 2000), but also omissions of prudent actions such as planning, lookout, and simple common sense.

Loss of control was deemed to be when the aircraft moved in any plain without being positively controlled by the pilot or any other person. Inducements included wind, flight into bad weather, pilot preparedness and runway condition, resulting in a range of events from rolling forward on start up to full spins in the cruise.

Technical failures concerned all aspects of the aircraft; engine, structure, electrics, fuel and hydraulics and landing gear.

Controlled flight into terrain is where an aircraft under positive control by the pilot impacts with either land or water.

Pilot experience categories referred to are the same as those cited in previous Chapters of the thesis, namely: total flight experience, experience on the accident aircraft type and hours flown in the preceding 90 and 28 days. These are used internationally in both general and commercial aviation accident investigation to determine a pilot's experience following an accident.

As commercial pilots operate within GA either for recreation or in a professional capacity such as instructing, this chapter focuses on type experience as a frame of reference, being the only category relating directly to the aircraft involved. However, where other experience types are deemed to be beneficial, they are used alongside type experience to gain a better understanding of the situation.

As explained in Chapter 6.2.4 (p95), an alternate method for measuring flight experience is pilot expertise, i.e. their level of license; Airline Transport Pilot's License (ATPL), Commercial Pilot's License (CPL) or Private Pilot's License (PPL). Taylor et al (2007) found that expertise can result in better flight performance. However, as the majority of pilots in this study cannot be classed as experts, thus it was considered more rational to use hours gained as the primary method of gauging experience.

The accidents examined all occurred between January 2005 and December 2011. Through discussion on the most common accident type in each of the most accident prolific phases and comparison of data gathered from the UK GA population with that gathered from accident reports, it is sought to ascertain whether or not a pilot's flight experience is a major contributor to accident involvement on a phase by phase basis.

7.4.7 The 2011 GA survey

Referring to the 2011 survey, discussed in Chapter 3, the results, more specifically those pertaining to pilot experience were used to determine if there were any differences between the accident pilots and the population. Where these differences occurred, they were statistically analysed to determine the significance of any such anomalies using two-tailed t-tests.

7.4.8 Phase of flight determination

Using the same accident reports as previously in the thesis, determinations were made as to which phase of flight each accident occurred in; start-up/stationary ground tasks, taxi, take-off (including initial climb to 100 feet and abort attempts), climb, cruise, descent, landing (including approach and rollout) and the go-around (rejected landing). Other information gathered from the reports comprised of pilot experience, pilot age, license held, injuries sustained (none, minor, serious and fatal) and contributory causes. Not all the information was used directly in the analysis, but it provided an overview of each event making classification of causes easier. In some cases pieces of information were absent from the report, type experience or age for example, due to the fact that some reports are compiled using information provided by the pilot, who may not have provided full details, or the AAIB were not able to trace them. This was not considered to be detrimental to the analysis.

7.4.9 Accident type and causal factor classification

During the phase determination process, each accident report was examined to establish the main causal factor or probable cause as suggested by the AAIB. The unique nature of individual accidents produced an extensive and diverse list of causes requiring that they be merged into the more useable and meaningful categories described previously; airmanship, LOC, technical failures and CFIT. Where no discernible cause was identified in the report, these accidents were classed as 'other'.

7.4.10 Accident frequency according to phase of flight

Landing contained the highest frequency of accidents with 53.3% occurring during this phase, cruise and take-off phases inducing 14.1% and 13.4% respectively. Taxiing produced a notable 7.2% of accidents, the climb 4.6% and going around 4.2%. Collectively, descent and ground activities accounted for 3.2% of all accidents.

7.4.11 Causal factors

More than 100 individual accident causes were identified in the top four accident phases alone. Collating the data into main accident type categories reveals that LOC accounted for 49.7% accidents, 30.8% were attributable to technical failures, 15.7% to airmanship and 1.4% CFIT. 2.4% of accidents could not be classified due to unknown causes.

An overview of all phases shows that despite LOC being the predominant accident type, it was not the most prevalent in all cases, the climb and cruise phases being more susceptible to technical problem, airmanship being more influential during taxi which supports the discussion in the previous chapter on that subject (Figure 23).

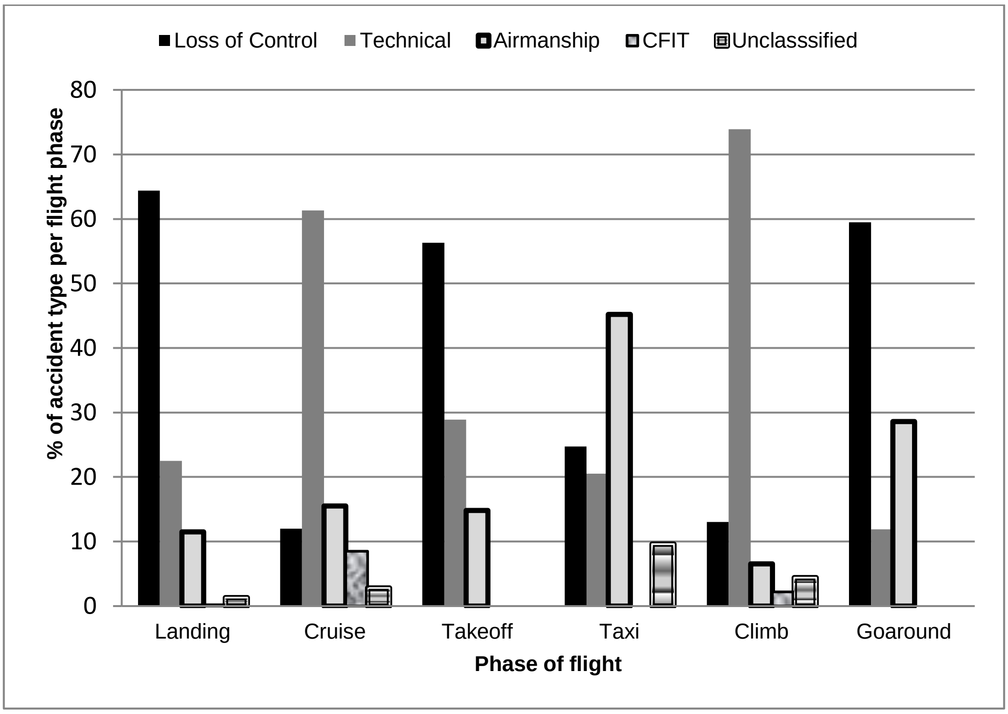

Figure 23: Main accident type/causal factors in each phase of flight

7.4.12 Individual phases

7.4.12.i Landing

Overall 26 individual landing accident causes were identified among the 537 events, integration of which identified LOC as the main accident type relating to 64.4% events. Technical problems accounted for 22.5% and airmanship 11.5%. CFIT was recorded in 0.2% and 1.3% were not classified. 54.2% of accidents occurred at touchdown, 31.3% during the rollout and 14.5% on approach. The mean type experience of all landing accident pilots was 241.7 hours (SD 598.231), not significantly less than survey pilots (294.3 hrs, SD 501.459); $t[849] = 1.333$, $p < 0.05$.

7.4.12.ia Loss of Control

Of the 346 loss of control accidents on landing, 29.8% entailed a bounce on touchdown, 36.9% of which were instigated by a poorly executed flare. Movement of the air (cross winds, tail winds, gusts, windshear, and turbulence) caused 23.7%, runway overruns 11%, inappropriate control inputs (flight controls management) 9.8% and unstable approach profiles 6.9%. Stalling induced 6.1% of events and runway condition 5.5%. Lack of pilot experience was directly cited in 2.6% of accidents, specifically recent flying and type experience, whilst mechanical failure of the controls caused 0.6% a further 4.1% not being classified.

Pilots in LOC landing accidents were calculated to have significantly less type experience (168.6 hrs, SD 330.963) than survey pilots (294.3 hrs, SD 501.459); $t[663] = 3.854$, $p <0.05$, as were pilots suffering a bouncing accident (95.8 hrs, SD 190.504); $t[422] = 3.936$, $p <0.05$.

7.4.12.ib Technical problems

Technical difficulties were dominated by landing gear failures accounting for 78.5% of 121 accidents, 41.1% involving structural failure. Failure to extend the gear through mechanical, hydraulic or other problems caused 22.1% of landing gear accidents, un-commanded retractions on the ground due to the same issues resulting in 9.5%. Mechanical problems other than extension failures produced 12.6%, a further 7.4% citing poor maintenance as the primary causal factor. Technical problems caused by the condition of the runway induced 6.3% of accidents, all of which were nose gear failures. Only one landing gear accident was not classified (tyre separation due to under inflation).

Engine difficulties caused 17.4% of technical accidents, 47.6% of which were caused by (suspected) carburettor icing. Overall 76.2% resulted in total engine failure, 14.3% in rough running engines and

4.8% each of fire and fuel starvation. Pilots suffering engine failure were substantially, but not significantly less experienced in both type (90.6 hrs, SD 158.734) and total hours (1258.7 hrs, SD 3063.248) than other pilots (type: 327.9 hrs, SD 770.019; total: 2965.2 hrs, SD 4820.654); type: t[116] = 1.298, $P < 0.05$; total: t[119] = 1.521, $p < 0.05$.

Overall there was no significant difference between the type experience of pilots encountering technical problems leading to an accident (291.7 hrs, SD 716.041) than those that did not (227.4 hrs, SD 560.135); t[528] = 1.030, $p < 0.05$

7.4.12.ic Airmanship

Omitting to lower the landing gear (or accidently retracting it) factored in 68.3% of 60 airmanship accidents, 58.3% of these pilots having more than 100 hours type experience and all of them more than 100 hours total experience. The main category cited as a reason for failing to lower the gear was distraction, accounting for 26.8% of these accidents. Cockpit ergonomics were attributed to 19.5%, whilst incomplete or insufficient pre-landing checks factored in 17.1%. Other causes included complacency, poor communication and workload.

The other main cause of multiple accidents was the pilots' propensity to approach the runway too low, 15% resulting in collision with power cables, boundary fences and trees. Another 16.7% of accidents cited individual, non-classified causes such as misidentifying the runway, landing without clearance and poor fuel management resulting in starvation.

Failure to lower the landing gear was found to be an issue for pilots with substantially and significantly greater type experience levels (623.2 hrs, SD 1236.351) than pilots of all other landing accidents (214.3hrs, SD 512.374); t[519] = 4.086, $p < 0.05$. Pilots who flew too low on approach were also substantially and significantly more experienced (932.8 hrs, SD 1629.636) than those who did not (493.7 hrs, SD 1112.818); t[532] = 3.268, $p < 0.05$.

7.4.12.ii Cruise

In the cruise (n = 142), 13 individual accident causes and conditions were identified. Technical problems were predominant in 61.3%, airmanship being cited in 14.8%, LOC in 12% and CFIT in 9.2%. 2.8% were not classified. Mean type experience of cruise accident pilots was 236.2 hrs, SD 324.270, less than survey pilots, but not significantly; t[457] = 1.265, $p < 0.05$. Their total experience however (2102.9 hrs, SD 3412.03) was significantly greater than survey pilots (982.6 hrs, SD 2340.026); t[538] = 4.298, $p < 0.05$.

7.4.12.iia Technical problems

The most frequent individual technical cause of accidents in the cruise was engine failure in 87.4% of events, 26.3% of which were due to carburettor icing and 13.2% fuel starvation (pipe blockage, vapour lock, pump failure and lack of fuel). A further 10.3% of technical accidents followed structural failure, electrical failures and fire, resulting in 6.9%.

Pilots who experienced technical problems in the cruise were not significantly less experienced on type (254.0 hrs, SD 330.953) than survey pilots; t[402] = 0.703, $p < 0.05$. Conversely their total experience was significantly greater (2209.7 hrs, SD 3529.462) than survey pilots; t[484] = 4.002, $p < 0.05$.

Where carburettor icing caused engine failure pilots were less experienced on type (143.6 hrs, SD 243.749) than survey pilots, but had more total experience (1210.3 hrs, SD 1802.419), neither difference being significant; respectively (type) t[338] = 1.304, $p < 0.05$ (total) t[417] = 0.429, $p < 0.05$.

7.4.12.iib Airmanship

Of the 21 accidents citing airmanship as a main factor, 57.1% were mid-air collisions, lack of visual contact between involved parties being the principal cause in 66.7% of these, either through insufficient lookout or restricted cockpit views. Poor communications between pilots was also cited as a likely contributing factor.

Fuel management was the prominent factor in 38.1% of accidents, resulting in fuel starvation and subsequent engine failure followed by forced landings where the accidents took place.

Pilots involved in these accidents were less experienced (177.9 hrs, SD 224.039) than other pilots (247.2 hrs, SD 339.599), but not significantly so; t[136] = 0.919, $p < 0.05$.

7.4.12.iic Aerobatics

Of the 23 accidents occurring during aerobatic manoeuvres (including displays and racing), 34.8% were due to LOC and 26.1% airmanship. A further 26.1% was attributed to technical problems including engine failures, structural failures and control restrictions. 4.4% resulted in CFIT following a departure from the set routine. One aerobatic accident was not classified.

Aerobatic pilot’s overall had less type experience (198.5 hrs, SD 313.371) than other cruise accident pilots (243.7 hrs, SD 327.216) and all other accident pilots (265.6 hrs, SD 651.612) but not significantly so; t[136] = 0.609, $p < 0.05$, t[989] = 0.493, $p < 0.05$ respectively. Total experience of aerobatic pilots however, was significantly greater (4271.1 hrs, SD 4803.378) than other cruise accident pilots (1680.4 hrs, SD 2913.404); t[139] = 3.459, $P < 0.05$.

7.4.12.iii Take-off

On take-off (n = 135), 21 accident causes and conditions were identified showing LOC to be prominent in 56.3% of events, technical problems accounting for 28.9% and airmanship 14.8%. Overall 19.3% involved an aborted take-off. Take-off accident pilots had not significantly less type experience (220 hrs, SD 611.407) than survey pilots; t[453] = 1.357, $p < 0.05$.

7.4.12.iiia Loss of control

Air movement triggered 32.9% of the 76 LOC accidents on take-off and 18.4% resulted from a stall. Management of flight controls and runway condition each instigated 15.8% whilst insufficient performance produced a further 3.9%. 13.2% were not classified.

Collectively, pilots who lost control of their aircraft on take-off had significantly less type experience (106.8 hrs, SD 237.542) than survey pilots; t[394] = 3.163, $p < 0.05$.

Where air movement caused LOC these pilots had less type experience (124.8 hrs, SD 324.204) than survey pilots (294.3 hrs, SD 501.459), but not significantly so; t[344] = 1.667, $p < 0.05$.

Pilots who stalled were less experienced on type (210.6 hrs, SD279.592) than survey pilots, but not significantly so; t[332] = 0.601, $p < 0.05$. They also had fewer total hours (753.5 hrs, SD 800.881), than survey pilots (982.6 hrs, SD 2340.026), but not significantly; t[410] = 0.352, $p < 0.05$.

7.4.12.iiib Technical problems

On take-off, engine failure was the prevailing causal factor in 66.7% of technically induced accidents, 80.8% of those occurring in the initial climb. Multiple reasons were cited including fuel starvation, mechanical difficulties and carburettor icing. Lack of performance and structural failures caused 15.4% each whilst one aircraft suffered a propeller control unit failure. Although pilots in technical accidents were more experienced on type (366.4 hrs, SD 961.771) than other take-off accident pilots (159.9 hrs, SD 377.399), the difference was not statistically significant; t[132] = 1.791, p <0.05.

7.4.12.iiic Airmanship

Of the 20 accidents classified in this category, eight individual causes were identified, 35% being poor aircraft performance induced through bad pre-flight planning, procedural errors and distraction. 20% of attempted take offs resulted in the aircraft overrunning the runway due to the required take-off distance being greater than that available for the aircraft type or configuration.

Statistically, these pilots were more experienced (359 hrs, SD 657.292) than other take-off accident pilots (195.6 hrs, SD 602.759), but not significantly; t[132] = 1.103, $p < 0.05$.

7.4.13 Fatal accidents

Within the sample there were 55 fatal accidents resulting in 91 deaths. The cruise produced 60% of these, 14.5% occurred in the climb, 12.7% during take-off, 7.3% on landing and 5.5% on go-around. In 45.5% the principal accident type was LOC, 25.5% of those occurring during the cruise. Overall pilot type experience was less for fatal accident pilots (200.7 hrs, SD 292.692) than survey pilots, but not significantly so; t[369] = 1.293, $p < 0.05$. Their total experience was however significantly greater (2058.2 hrs, SD 3772.947) than survey pilots; t[450] = 2.888, $p < 0.05$.

In 60% of LOC cases, stalling and/or entering a spin resulted from a variety of issues such as poor piloting technique, incorrect weight distribution and manoeuvring, all in VMC. No significant difference between the type experience of fatal LOC pilots (129.6 hrs, SD 193.534) and survey pilots was found, although it was noted to be considerably less; t[342] = 1.570, $p < 0.05$. Spin/stall pilots also had less type experience (137.9 hrs, SD 222.685) than survey pilots the difference not being significant; t[333] = 1.165, $p <0.05$.

7.4.14 Discussion

7.4.14.i Landing

The emergence of landing as the most prolific accident phase is not unexpected, historically the leading cause of non-fatal commercial and GA accidents. Regarded by many as the most demanding task faced by pilots (Ebbatson, Harris & Jarvis, 2007) landing an aircraft requires attention to detail and a respect for the limitations of the aircraft and the pilot (AOPA, 2008). The variables involved are numerous, each carrying their own risks; speed, height, rate of decent, aircraft configuration, runway centreline positioning and the environment. Poor management of these variables combined with poor judgement and/or limited skills can lead to LOC, recognized as the major cause of accidents as identified in both the sample and by the UK Civil Aviation Authority (CAA, 1997; 2006). This particularly appears to be the case during the flare which has been expressed as one of the hardest elements of landing, notably for students (Bramson, 1982). Good judgment, perception and awareness in the three planes of vertical height, horizontal speed and lateral positioning are central to a successful flare. Recent flying experience and practise have also been shown to be valuable, results from a study by Benbassat and Abramson (2002) revealing that pilots accredit successful execution of a flare to practise in the circuit more than their instructor, natural ability and luck, Booze (1977) also concluding that recent flight experience can be influential in lowering GA accidents overall.

Whereas practise and recent flying may help qualified pilots maintain their landing skills, a group who will not yet benefit from these factors are student pilots. Not only are they lacking in the practise and flight time required to build their landing skills, but they are heavily exposed to this phase of flight by virtue of the fact that much of their flying consists of time in the circuit. Although not a substantial proportion of the sample (7.8%) student contribution to the data may partially account for the significantly lower levels of experience found in pilots of LOC and bounce accidents. However the most likely explanation remains the simplest; landing takes time to refine and lower hour pilots are vulnerable in this phase.

Failures of the landing gear, due to technical faults, are an issue in a sizeable faction of landing accidents. Poor maintenance may have been cited in a number of individual cases, but beyond this it must be noted that many GA aircraft are flown into and out of airfields with varying standards of runway surface by pilots of varying skill and will endure any number of rough landings due to either of these facts. An aircraft which has suffered a heavy landing may not show symptoms of damage that are immediately presented in a transit check or noticeable by the next pilot to fly it. Hence logic here would dictate that pilot experience is perhaps inconsequential to the cause or outcome of these accidents.

Despite being a less common technical problem, managing an engine failure, particularly during the landing phase requires quick thinking and sensible flying to produce a positive outcome. To a degree skill will be important, but as long as the pilot does not over manoeuvre the aircraft and makes prudent decisions, simply the ability to get it on the ground will suffice.

Landing with the gear retracted made up the majority of the airmanship accident category and involved mostly experienced pilots. The likely reason for this is that many pilots do not progress to more complex aircraft (retractable landing gear, variable pitch propeller) until they have gained greater levels of experience, hence there is a probability that any pilot involved in such an accident will be relatively, if not very experienced. However this then begs the question why are these more experienced pilots forgetting the obvious and simple task of lowering the landing gear, considering it is a check-list task?

One explanation is that they simply forgot, forgetting to perform certain tasks at a pre-determined time being one of the most common forms of memory lapse (Reason & Mycielska, 1982), perhaps stemming from habitual actions which, according to James (1980) reduce the conscious attention we pay to things we are doing. Indeed performing familiar routines can lead to the mind drifting from the task in hand leading to the 'time-gap' experience where the previous few minutes cannot be recalled (Reason, 2008). Although these possibilities have validity, they do not answer how the item is missed on the check-list.

More than a quarter of the pilots in these accidents were exposed to a distraction of some description. Reason (2008) states that as a limited resource, human attention can be subject to slips, particularly in familiar surroundings, when it is captured by an external distraction. Hence in the cockpit, whilst running through pre-landing checks, an air traffic control call, question from a passenger or jolt from turbulence requiring intervention may result in the check-list being inadequate or incomplete.

Not forgetting that landing is a high stress activity with a high workload, ergonomics can be important in assisting a pilot to complete associated tasks. In some aircraft, the cockpit design is not conducive to safely executing a landing with levers and switches for different functions not only looking similar, but being positioned in close proximity to each other. This is particularly dangerous when controls for throttle and mixture or, in these cases, landing gear and flaps (for example) are as such and may account for a proportion of the gear up accidents citing ergonomics as a contributory cause.

Although not all causes of landing accidents are covered here, those of the gear up type demonstrate that even experienced pilots can be subject to simple human error.

Overall landing accidents involved pilots who were less experienced than the population, but not so much as to make it significant. The significantly lower type experience values of LOC and bounce landings however illustrate the potential impact of being less practised in landing a specific aircraft type.

7.4.14.ii Cruise

The cruise was dominated by technical failures, most concerning loss of engine power through a variety of causes, more than a quarter being carburettor icing. As in the landing phase, management of the situation is crucial to a positive resolution, time being less of an issue in the cruise allowing the pilot to make restart attempts and better preparations for an emergency landing. The fact that pilots suffering technical failures had less type experience (albeit not statistically significant) than the survey pilots supports the suggestion made earlier in 7.4.14.i that this is a potentially important factor in these accidents. It is reasonable to assume that greater type experience may have furnished the pilots with more confidence and aircraft specific knowledge to be able to successfully resolve a technical problem. The fact that these pilots had significantly more total flying experience than survey pilots further supports this notion in that greater experience brings improved knowledge, but relative unfamiliarity with an aircraft appears to have a negative influence on this knowledge and the ability of the pilot to use it successfully.

Although not significant, the comparative lack of experience in pilots suffering engine failure, combined with the high proportion of suspected carburettor icing involved suggests that their lack of experience perhaps prevented the situation being resolved, the application of carburettor heat being a key element. As discussed previously, icing within the carburettor can take up to 30 seconds to clear with application of hot air from the engine. During this period, the initial response of the engine may be to cough and falter giving the pilot the impression that their actions have made the problem worse. Anxiety and confusion during an engine problem, particularly close to the ground during landing may lead less experienced pilots to abandon the attempted resolution and opt instead to perform a forced landing which may ultimately result in an accident.

Perhaps not unexpectedly, LOC was the biggest precursor to accidents during aerobatics, three quarters of which resulted from unrecovered manoeuvres. Aerobatics are inherently dangerous and require precision flying, quick reactions, a reasonable level of fitness and a thorough understanding of the principles of flight involved. The CAA (2010) recommend that novices do not attempt manoeuvres without proper qualified instruction and it is expected that anyone wishing to perform aerobatics in the UK undertakes proper training and AOPA has made available a recommended syllabus to be followed. The data shows however, that many pilots flying aerobatic manoeuvres were not novice pilots, having significantly more overall flying experience than other cruise accident pilots, just four of the 23 pilots having less than 200 hours, 16 of them with more than 1000 hours. Contrastingly their experience on the accident aircraft type was less, indicating that regardless of total flying experience, familiarity with an aircraft, particularly during aerobatics is elemental to maintaining safety.

Overall cruise accident pilots had less type experience than the population and significantly more total experience giving strength to the theory that in the cruise, extensive flying experience may not be worth as much to a pilot as their familiarity with the aircraft in an emergency situation.

7.4.14.iii Take-off

Similar to landing, take-off is a phase requiring high levels of skill, awareness and coordination. Myriad factors can affect a take-off run such as the weather, runway condition and pilot control and the data gathered identified these as influential elements in LOC being the dominant take-off accident type.

Of the LOC accidents, movement of the air was mentioned in nearly a third of reports as a major causal factor and appeared in three main forms; crosswinds, gusts and aerodynamic yaw from the propeller slipstream effect on the tail-fin (Thom, 1994) – a phenomenon which affects most single engine propeller aircraft. Normally these should not cause an issue on take-off as long as the limits of the aircraft (or the pilot's own skill level) have not been exceeded and proportionate rudder control is used. The significant lack of comparative type experience of these pilots leads to a conclusion that the aircraft was flown in conditions beyond the capability of the aircraft, the pilots' skills or both. Given 12 out of 25 of these pilots had more than 210 total hours, one with 14 800 and another 24 395 hours, this would seem to be an arbitrary comment and it is more likely that their familiarity with the accident aircraft was insufficient to prevent LOC in adverse conditions. It is of course possible the accident flight was the first time the pilot had flown that aircraft type in such conditions and thus their type experience in this instance would be rather more critical.

Stalling after take-off is a condition which will occur if the aircraft fails to gain sufficient speed for safe flight and can happen in numerous ways. For example becoming airborne too early, ground effect will allow the aircraft to lift off, but ultimately the aircraft will stall. Pitching up too much to avoid obstacles prevents the aircraft from accelerating and induces a stall. Even if there is sufficient speed, an aircraft in a steep nose up attitude (high angle of attack) will still stall, aerodynamic laws determining that a stall will occur when the critical angle of attack is exceeded, irrespective of speed (Thom, 1994).

Stall pilots were not only less experienced on type than survey pilots, but their overall flight experience was also less. Despite statistical insignificance, it suggests that stall awareness on take-off is greater among more experienced pilots. Whilst stall recovery training can be beneficial at altitude, there is little that can be done once an aircraft enters a stall at low altitude, thus a more reasonable solution would be to place training emphasis on stall prevention. Whatever the solution, the evidence from this data set indicates that experience is an important factor in take-off accidents, particularly in terms of stall recognition and LOC.

7.4.14.iv Fatal accidents

The cruise saw the highest concentration of fatal accidents, LOC being identified as the biggest individual cause. It has previously been shown (e.g. CAA, 1997; 2006) that the majority of fatal LOC occurs in VMC, a fact repeated in these findings. It is proposed that on encountering bad weather, a pilot has no alternative other than to focus on their flight instruments giving them a level of situational awareness sufficient to prevent LOC. Pilots in VMC however may be distracted by external stimuli such as the view and navigation, reducing their focus on flying the aircraft, potentially leading to a lack of speed or attitude awareness and subsequent LOC.

The comparative lack of type experience, although not significant, when considered with the significantly greater total experience of fatal accident pilots, support the conclusions of the CAA (2006 p.8) who determined that "fatal accidents tend to involve experienced pilots…who were lacking in experience on type." As intimated previously the more familiar a pilot is with an aircraft, the easier it will be to perform tasks and manage a stressful situation, further strengthening the stance that type experience is more valuable than total experience.

7.4.15 General discussion

It is normal to presume that when considering an individual who is very experienced in a particular task, they are highly skilled at that task. This is not always the case, however and negative traits such as complacency and bad habits can dilute the influence of experience. It is therefore not possible to make sweeping statements that experienced pilots are less likely to have accidents as they are better pilots. As has been previously referred to in this thesis (Chapter 6), various studies (e.g. Olsen & Rasmussen, 1989; Jensen, 1997; Booze, 1977; AOPA 2006) have found lower hour pilots to be more at risk of accident from 100 to 300 hours, whilst others (e.g. O'Hare and Chalmers, 1999; Pratt, 2003; Thomson et al., 2004; Clarke et al., 2006) found evidence to the contrary, arguing in general that experience can produce dangerous levels of over confidence.

The results from this study corroborate the latter findings in so much as less than a quarter of all the accident pilots had between 100 and 300 hours total experience whilst nearly a third had 1000 hours or more. In contrast, half had 75 or fewer hours on the accident aircraft type, less than a quarter having more than 250 hours. This substantiates the deductions drawn from the data analysis that although a greater proportion of the accident pilots were in fact experienced pilots; their relative lack of experience on the accident aircraft type was likely to have been a contributing factor to the accident cause.

In addition, the skills of decision making and cockpit management, often omitted from training could be enhanced in the simulator. Training the skill of decision making could also be promoted in flight and in the briefing room. Wiegmann et al (2005) cited Burian, Orasanu and Hitt (2000) who found that in some cases, continued or inadvertent flight into IMC was due to plan continuation errors. Wiegmann et al (2005) also stated that decision errors are a result of poor planning both on the ground and in flight and may be a factor of inexperience in recognising the significance of weather related cues. By impressing upon students the importance of thorough planning and revising those plans as and when necessary, including diversion, returning to the point of departure and precautionary landings and by reviewing their ability to recognise a potentially hazardous meteorological situation before encountering it, accidents involving flight into IMC could be prevented.

7.4.16 Summary of Part 4

This section of chapter 7 has seen how the nature of GA in the UK, with its mixture of professional and private pilots flying many different aircraft, results in an almost infinite blend of flight experiences; some very experienced professional pilots with only a few hours on light aircraft and relatively inexperienced private pilots who have all their flight time on one aircraft type and know it intimately.

The indications from this study are that a pilot's experience on a particular type of aircraft is more valuable than their total hours flying and that even highly experienced pilots are not immune to accidents if they are not familiar with the aircraft they are flying. Subsequently it is suggested that additional to the minimum hours rule in UK GA, existing regulation be strengthened and enhanced to ensure pilots are maintaining a satisfactory level of experience on the aircraft they choose to fly and are possibly restricted to flying a limited number of aircraft types.

There is also prudence in suggesting that training be augmented, particularly in the areas of take-off and landing; theory should be included to discuss the effects of varying weather conditions and actions to be taken in the event of loss of control. Technical failures during the cruise also require additional attention both in the form of theoretical and practical training and competence assessment at practical and reasonable frequencies throughout a GA pilot's flying career.

These small measures are necessary to give GA pilots better awareness and enhanced skills in areas which have shown to be problematic and influential in accidents, the result being an expected reduction in accident frequency and severity.

7.5 Chapter 7 summary

This chapter has shown how the many factors involved in flying in GA can, if not properly acknowledged and appropriately managed, lead to accidents that are either lethal (in the case of LOC and CFIT) or completely preventable, such as forced landings due to engine failure, when in fact the problem was simple carburettor icing.

Taking into consideration the statistics and discussions presented not only here, but also in chapter 6 on how the age, experience, knowledge, skill and professionalism of UK GA pilots can have an influence on their likelihood of having an accidents, the following chapter explores ways in which many accidents in UK (and worldwide) GA can be prevented through enhanced training centred around emergency procedures.

Chapter 8: Enhanced Emergency Procedures Training

In the previous chapter, UK GA accidents involving LOC, CFIT and technical failures were examined, giving a clear indication that elements of both practical and theoretical knowledge were absent, particularly in the event of an emergency situation. Accidents were also reviewed according to phase of flight showing landing to be the most prolific phase for accident occurrence. The reasons for accidents to occur in particular phases were presented and discussed and focus centred on landing, take-off and fatal accidents.

With reference to the sample data, in this chapter, emergency procedures will be discussed in detail and appraised in terms of their effectiveness in example accidents. These accidents will highlight how emergency procedures, if executed proficiently may have prevented them from occurring. This in turn will demonstrate that the pilots either carried out the procedures incorrectly, or did not attempt them at all, possibly because they had not practised them adequately since gaining their license, had forgotten them for the same reason, or had omitted them for other reasons (stress, arrogance, lack of awareness and/or knowledge). These examples will enforce the notion that pilots at GA level need continuous evaluation and practise of their skills, particularly where emergencies are concerned. Pilots may have flown for many months or years without encountering any problems, but without having rehearsed or reviewed emergency situations since they gained their license. When a situation does arise, it will be difficult for them to manage due to the lack of practise. Use will be made of the UK GA survey which demonstrates that whilst some pilots do consider what they might do in the event of an emergency, they do not take the time to actually rehearse any such events.

8.1 Stalling

Within the sample there were 57 cases where an aircraft stalled, or entered a spin; 51 stalls and 6 spins. Of those, 11 stalls and all of the spins proved to be fatal. Spinning is not part of the (N)PPL syllabus due to its inherently dangerous content, but as a spin is a stall that has developed into a more serious manoeuvre, essentially, stall recovery training, which is still part of the syllabus, should be adequate to prevent such accidents. However, stall recovery is taught at high altitude (3000ft and above), but only one stall event took place in the cruise, the rest happening in other phases of flight, most notably 10 during a go-around, 11 in the initial climb and 15 on approach and landing. All six spins took place during the cruise, but clearly the pilots were unable to execute a successful recovery from the initiating stall.

8.1.1 Teaching the stall recovery

As noted in Chapter 7 the current taught procedure for stall recovery requires that the student reduces power to idle and waits for airspeed to bleed off. As lift is slowly depleted, the student pulls back on the control column in order to increase the angle of attack and increase the amount of lift sufficiently to maintain the aircraft at constant altitude. As the angle of attack increases and the airspeed reduces, the signs of the stall begin to appear; the stall warning buzzer, light buffet as the airflow starts to separate from the wings and eventually a wing drop as slight variances in wing aerodynamics cause one wing to stall marginally ahead of the other. This is known as a full stall, which if not recovered or recovered incorrectly can develop into a spin.

At this point the student is taught to recover by centralising the control column, using rudder to correct any yaw, applying full power and then applying back pressure on the control column to pull the aircraft into a climb.

The stall recovery is also taught from the incipient stage, when the aircraft has not yet stalled, but is approaching the stall, indicated by the stall warning buzzer. In the same manner as for the full stall, power is reduced and airspeed is allowed to bleed off. Recovery procedure is the same at this stage, but requires less time and effort to establish the aircraft back into positive flying mode. The incipient stage is also used for stalls when the aircraft is configured to land, both whilst flying straight and in a simulated turn from base leg in the circuit to final approach.

8.1.2 Issues with the current exercise

Whilst the recovery procedure can be very effective, it is taught in a false environment under conditions of expectation on the part of the student; they know the stall is going to happen and they have been briefed before the event on the correct recovery procedure. The stall recovery practise performed in the simulated approach configurations do not recreate the situation in term of either altitude available for recovery, or added distractions such as lookout for other aircraft or radio calls to/from ATC.

Although knowing how to recover from a stall in all situations is a valuable exercise, given the data presented in Chapter 7.1 (p118) and the subsequent discussion in Chapter 7.1.5 (p125), it is argued here that it is insufficient to prevent a stall occurring, recognition of the potential causes and subsequent symptoms of the stall not being fully explored during these manoeuvres.

The medical adage that prevention is better than cure would serve well in this situation and that is where it is proposed that focus be applied for this particular scenario.

8.1.3 Prevention is imperative

If stall/spin accident are to be reduced, it is vital that student pilots are taught how to prevent a stall developing through better knowledge and awareness. Maintaining correct airspeed through proper instrument scanning is a key area and instead of teaching students to reduce power and wait for airspeed to be sufficiently low for a stall to develop, they must be encouraged to monitor airspeed effectively, to the point of subliminal repetition. This could be likened to the repetitiveness of ‘mirror, signal, manoeuvre’ as taught to drivers in the UK, which after a period of time becomes second nature to the driver and they perform the task as a motor programme, without conscious thought. However, for pilots, monitoring speed is a task that needs to be performed with absolute conscious thought, thus it must be impressed upon the student that scanning the instruments is ineffective unless they fully absorb the information presented to them.

Additional to this, practical demonstration of how quickly airspeed can diminish would highlight to students the short space of time within which a stall situation can develop. This could potentially be demonstrated at a rudimentary level on a basic simulation device.

Further practical training should demonstrate a stall at normal attitudes (e.g. a replicated scenario of inappropriately managed power and speed in straight and level flight) as opposed to a falsely induced, unusual high nose attitude, to emphasise the fact that an aircraft can stall at any speed and any attitude.

As shown in Chapter 7, speed is only one factor in a stall and it is the critical angle of attack that dictates the point at which an aircraft stalls, combinations of various aerodynamic flows resulting in the potential for an aircraft to stall at any speed for a given angle of attack. Thus the attitude indicator must be thoroughly appraised during the scan along with the airspeed indicator (ASI).

Aircraft configuration can also cause an aircraft to stall if suitable amounts of power are not applied and the aircraft is not handled appropriately. In the same manner, manoeuvring (such as a banked turn) also affects the stalling characteristics of an aircraft by increasing the stall speed, thus reducing the safe operating envelope of the aircraft. The aerodynamics of this phenomenon will be discussed in Chapter 9, but in a turn the wing loading increases, effectively meaning the wing needs to do more work to maintain the same amount of lift.

These principles are taught as part of the (N)PPL theory subjects in ‘principles of flight’ and prior to training exercises, briefings are given to explain the manoeuvres and the aerodynamics involved. However, for some the theory and practical application may be seen as just a box to be ticked en route to gaining the license. Thus a more defined approach is required and it is suggested that stalling become part of an additional theory module specifically concerning emergency procedures, content for which should include review of accident reports in the same manner that they are used for commercial pilot CRM training. This would go some way to increasing pilot awareness of issues such as stalling and lead to a culture where prevention of such events is prioritised over the expertise required to recover from them.

In the longer term, it would be prudent to introducing this new module as part of a package of mandatory refresher training that will be discussed further in Chapter 10, but suffice to say that this action would help those who will not have reviewed either the theory or the practical exercises; i.e. experienced pilots or those who have at least maintained sufficient currency to avoid license revalidation, but passed their exams and flight test several years ago.

8.1.4 Real life examples

In 2005 a pilot was killed when he stalled his aircraft in a turn at low level (AAIB, 2006). It was believed he was attempting to turn whilst maintaining visual contact with a fixed spot on the ground, in doing so entering a steep turn, increasing the stall speed of the aircraft above that of his current airspeed and thus stalling without adequate height to recover. The pilot was experienced with nearly half of his flying time on the accident aircraft type, being licensed at CPL level with an IR.

In 2006 a 16 year old student with just 15 hours experience was killed when non-standard radio phraseology was used to instruct him to perform an orbit on final approach to allow a faster aircraft behind to land; the aircraft was configured to land with full flap and having apparently failed to apply power, the pilot stalled the aircraft (AAIB, 2007), (a feature of the aircraft type was that it had a 40° flap setting which was removed from the succeeding model in place of a 30° maximum due to the high levels of drag created and associated problems with aborted landings, the earlier configuration degrading the pilot’s ability to maintain airspeed; Bromfield & Gratton, 2009).

Clearly in fatal accidents it is impossible to determine the exact reasons for the manoeuvre, but it cannot be dismissed that the proposals here for refresher training (in the case of the experienced pilot) more specific and intense theory (for the inexperienced student) and the more targeted preventative practical training would have had a positive influence on the outcome of both of these accidents.

In a third fatal accident, the pilot encountered an engine failure shortly after take-off, but stalled during an attempted turn back to the airfield (AAIB, 2010). Flying close to an aerodrome, when in the circuit for example, the temptation to turn towards the runway will likely outweigh the option of landing in a field. From certain positions in the circuit this can safely be achieved, but after take-off the aircraft is in such a position that a tight turn would be required to return to the runway. In this instance the best and only option is to land either ahead or within a reasonable arc either side of straight ahead (e.g. 30° to the right; the required gentle turn to achieve this would not pose a threat). A solid grounding in stall theory and/or refresher training, emphasising the dangers of tight turns without power could have prevented this very experienced pilot from making a basic error of judgement.

Although the elements in each of these accidents are different, the enhanced training suggested would provide a better understanding of the surrounding issues and ultimately better information from which the pilot can make better decisions. Theory, supplemented with accident reviews, would provide both the explanation of the mechanics involved in a stall and heightens the importance of prevention over cure. Practical training would demonstrate the value of conscientious instrument scanning and heightened situational awareness, whilst refresher training would prevent deterioration in these vital skills and knowledge.

8.2 Inadvertent flight in impoverished visual conditions

When a pilot cannot see external cues, the only option is to fly the aircraft by sole reference to the instruments. The reasons why some pilots choose to press on into bad weather or poor visibility is no longer the issue in this discussion, the fact remains that pilots do end up in such situations and current instrument appreciation training at (N)PPL level is insufficient to provide a pilot with the skills necessary to maintain positive control of an aircraft in poor visibility. Indeed, it must be noted that visibility can deteriorate on clear days, particularly at times when the sun is low and shining directly into the eyes of a GA pilot. Should such a day be accompanied with even minimum amounts of haze, this can lead to the equivalent of being in cloud where perhaps the only external visual clues are to be found straight down, beneath the aircraft; not a situation conducive to safe VFR flying, as has been the Author’s experience on more than one occasion.

The current allowance of 5 hours in a basic flight simulation training device does little more than introduce a student to the most basic principles of instrument flying, mostly covering straight and level flight, simple timed turns, some unusual attitudes and partial panel (where some instruments are simulated to fail whilst others remain functional; see table 2, Chapter 3, p35). In some cases, Instructors choose to enhance the instrument flight experience during practical flight training, but this is a choice of the individual and not mandatory.

In order for a student to be proficient at such a critical element of flying, it is suggested that 10 hours be mandated, split between the simulator and the aircraft, to give the student the benefit of instruction in a controlled environment, followed by practise in the more task heavy reality of actual flying. Training should venture further than the flying skills already prescribed by exercise 19 of the flight training syllabus to include instrument navigation, at least at a basic level (sufficient for a (N)PPL holder to fly safely and accurately to a diversion aerodrome).

Assuming they themselves are properly qualified, under the privileges of the aircraft commander's license there is reasoning to permit training flights to enter cloud to allow students to experience the actual conditions they could face following inadvertent flight into poor visibility. This would, however necessitate certain preconditions such as authority from the head of training and ATC communication to ensure the chosen area is safe in terms of other traffic present.

To support the practical flight training, it is proposed that procedures for flight in IMC are both taught and examined at theory level, as part of the emergency procedures module referred to in 8.1.3 (p172) in order to give pilots who find themselves in such situations a structured method of resolution to follow.

The skills of instrument flying are however easily depleted if not used on a regular basis and as (N)PPL pilots are not permitted to fly in anything other than good visibility, their use of instruments will be limited to the aforementioned scan, whereby they use the instruments as an aid to the external visual cues in terms of attitude and as a reference for airspeed. Again it is advocated that refresher training include instrument flying and that this particular skill be accepted by the GA community as a vital tool for unexpected circumstances, such as the aforementioned glare and associated poor visibility from flight into sun.

8.2.1 Real life examples

In 2007 an experienced pilot lost control in IMC, possibly after losing engine power due to carburettor icing (AAIB, 2008). In this case, a reasonable level of instrument training (as suggested) could have seen the pilot retain positive control of the aircraft, despite the engine difficulty and resulted in a more positive conclusion; the pilot was fatally injured.

In 2006, in a second attempt to depart Caernarfon following a previous return due to bad weather, the aircraft impacted with the side of a mountain, seriously injuring the pilot and killing his passenger (AAIB, 2007). Having not climbed to the minimum safe altitude (MSA) for the area, the pilot (who has no memory of the accident) appears to have failed to accurately navigate in the bad weather which was encountered for a second time on a different route to that previously attempted. Again, a better understanding of instrument flying, particularly navigation would have given the pilot the rudimentary skills to maintain track which, if followed, would have avoided the high ground with which the aircraft ultimately impacted.

In both cases, initial training may have been some time ago (the second pilot was not as experienced as the first, but had more than 100 hours), thus refresher training at some point, even of the currently authorised 5 hours instrument appreciation would have likely benefitted them in the respective scenarios.

8.3 Take-off and landing

Although not necessarily considered as emergency procedures, taking off and landing in windy conditions have been shown by the data to be times most likely to induce an accident, thus they should be considered in the same manner as an emergency situation.

It is again suggested that the theory behind wind related accidents be made part of the aforementioned emergency procedures module in order that student pilots be given an opportunity to study the myriad situations that can occur during these two critical flight phases due to wind.

Practical flight training in cross-wind techniques is part of the syllabus, needs to encompass all the varying aspects of wind on take-off and landing, but this is difficult as firstly wind cannot be summoned to perform as required on any given training day and secondly, there is no logic in risking safety for the sake of improving it through practising dangerous manoeuvres such as strong cross-wind conditions. Thus there is an argument here for advocating improved simulation in GA. Simulation allows a student to be presented with the worst of conditions, repeatedly, on demand and in absolute safety. However, as simulation is unlikely to enter the UK GA domain in the foreseeable future, there is no rationale in submitting any further recommendations for these flight phases.

8.4 The go-around

This manoeuvre is an essential element of a pilot's training but is unique in that its use is intended as a preventative measure in term of flight safety, but its incorrect execution can also result in an accident, as has been proven through the sample data.

It is included as part of exercise 13 (Table 2, Chapter 3), but is given no more weighting than other circuit manoeuvres, including cross-wind landings. The sample data has shown that this manoeuvre resulted in more than twice the number of injuries than the full sample; of the 42 events, three were fatal, four resulted in serious injury and 11 minor injuries, representing 42.9% of go-around accidents. This compares to 20.3% in the full sample. Thus it is suggested that the go-around manoeuvre be separated into a separate flight exercise.

Unlike take-off and landing, this exercise can be performed safely in the air, just as stalling and steep turns are. At a safe altitude, away from other traffic the aircraft can be configured for landing, a simulated approach made and a go-around manoeuvre performed. Once proficient in the procedure, go-arounds can be practised at real aerodromes where other considerations such as proximity to the ground and other traffic need to be made.

Late decisions to fly a go-around contributed to at least two of the serious injury accidents. One decided to abort the landing after having touched down, but did not have sufficient runway left to take-off again and overran (AAIB, 2007). In a second accident, , the late decision to go-around resulted in the pilot being forced to make a tight turn to avoid trees at the aerodrome boundary, ultimately inducing a stall (AAIB, 2010). These accidents support the notion that go-around theory should also be covered in the emergency procedures module, thus giving students a greater awareness of the potential reasons for and hazards surrounding a go-around manoeuvre and highlight the importance of making the decision to abort early.

In commercial operations, the go-around is cited as a common event for which pilots are properly trained, thus it is advocated that GA pilots should also receive full and appropriate training for it.

8.5 Single Pilot Resource Management

This is an area that will be discussed in detail in the following chapter but it nonetheless worthy of introducing here. In the same way that CRM has improved safety culture in commercial aviation, teaching GA pilots the benefits of effective resource management is a step that needs to be taken to enhance emergency procedures. It provides a formal framework from which GA pilots can draw to make better decisions, manage workloads better and improve their overall awareness, both in times of emergency and during normal flying operations as a preventative measure. Indeed in the USA, the PPL skills test requires that CRM competencies are evident in all tasks (FAA, 2007).

8.6 Oral examination

In the USA, candidates for the PPL are subject to an oral examination prior to taking their skills test. Given the known issue of rote learning mentioned previously in Chapter 3, it is surprising that a similar test has not been introduced in the UK. An oral examination between the student and the examiner prior to the skills test gives a student the opportunity to prove they have not only learned the material required to pass the theory examinations, but that they have a full understanding of it. This could also include the emergency procedures as prescribed in this chapter.

A 30 minute test, completed more as an informal discussion, would suffice to ensure the student has an understanding of aviation theory at a level to satisfy the examiner. This examination would also encourage those taking the theory modules to strive to understand the theory better and could potentially have the effect of eliminating rote learning altogether.

8.7 Summary

This chapter has presented recommendations for improving flight training specific to emergency situations by augmenting the practical aspects and introducing a theory module relevant to that training. Areas of main concern to be covered are stall prevention, improved instrument appreciation and training for the go-around manoeuvre. The notion is that pilots are given a thorough base of knowledge which can in turn be applied in the air and/or in a simulator. It is estimated that the additional flight training required would amount to no more than an additional seven hours as a minimum (two hours additional simulator instrument appreciation, three hours for in-aircraft instrument appreciation and two hours go-around training) and as such would have a minimum impact of the cost of training, compared to the potential benefits of improved safety and fewer accidents, injuries and deaths.

The following chapter will discuss in detail the introduction and potential benefits of single pilot resource management in UK GA.

Chapter 9: Single Pilot Resource Management in UK GA

The previous chapter discussed the possible alternatives and enhancements that could be adopted in (N)PPL training to better prepare UK GA pilots for the eventualities they may encounter whilst flying, including stall prevention rather than recovery, oral testing to ensure theoretical comprehension and the benefits of simulation to maintain both momentum in training and currency for qualified pilots.

This chapter turns to the principles of Crew Resource Management, used in commercial operations and looks at how it can be adapted for use in the mostly single pilot field of GA. Additionally this chapter introduces a Single Pilot Resource Management (SPRM) tool specifically designed for this thesis to simplify the task of emergency scenario management and prioritise the pilot’s actions in favour of the most vital procedure in any situation; to continue to fly the aircraft. The tool was tested through a simple experiment performed on a Flight and Navigation Procedures Trainer (FNPT), the results for which are presented and discussed here.

9.1 Single Pilot Resource Management

9.1.1 Why GA pilots need resource management

Research has shown that GA in the US and Australia accounts for 70% - 90% of all aviation accidents, 85% of those containing some apportionment of blame to human error (Lenné, Ashby & Fitzharris, 2008). The sample data in this thesis has demonstrated that figures in the UK are similar, having on average 144 GA accidents annually within the data time period. Chapter 3 examined the processes necessary for any individual in the UK wishing to gain their (N)PPL, disclosing that they must pass a basic medical, sit nine theory exams, pass a radio telephony exam and take a flight skills test after accumulating a minimum of 45 hours flight training. With the exception of the medical as long as a (N)PPL holder flies the minimum number of hours to remain current, as laid down in CAP 804 (refer to Chapter 3) , they will never need to be examined or tested on any part of the syllabus again.

Commercial pilots must undergo a check ride, usually in a simulator, once every six months and are required to attend a Crew Resource Management (CRM) course before they fly with passengers with refresher training every two years. CRM teaches crews to use all resources available to them to resolve issues that can and do occur in the air. GA pilots only have themselves to rely on in an emergency and with the rate of accidents so high (on average 3.34 per million flight hours in the UK, according to figures calculated in Chapter 5, compared to commercial aviation's $6.1x10^{-5}$ per million flight hours, [Boeing, 2012]) there is a need to look to the professionals for a potential solution to the problem. SPRM is not a new idea, the US FAA having cited issues with single pilot IFR accidents in the early 1980s (Harris and Morrisette, 1982), but the UK CAA has not embraced the idea, any form of pilot resource management being reserved for flight training at advanced level, where CRM is now mandated. Thus, UK and worldwide GA could benefit from its structured integration to basic training by reducing the number of pilots who find themselves unable to make effective use of the resources available to them when they find themselves in difficult or unexpected situations. In this respect, a study was performed to measure the potential effectiveness of SPRM in GA operations, which will be examined in the second part of this chapter, however further research needs to be undertaken into the viability of such a concept being translated into a proper training module for the PPL syllabus in the UK and whether it would have the desired impact on GA safety.

To compliment enhanced emergency procedures training outlined in the previous chapter and in addition to the summary and basic discussion in Chapter 4, SPRM will now be introduced as a tool to further improve a pilot's ability to successfully manage an emergency situation and to augment their general flying skills by improving situational awareness, subsequently making them a more prepared and proficient task manager. Reference will be made to works already undertaken by other aviation specialists as well as to proposed areas of instruction that could be introduced into the current training syllabus alongside the improvements and additions already highlighted previously. Connection will be made to the commercial sector where CRM is not only heavily advocated, but a requirement for UK pilots and has been credited with improvements in the commercial accident rate over the last few decades. The apparent success of commercial CRM begs the question of why a similar process has not been introduced to GA, which will be investigated in this chapter.

9.1.2 Defining crew/single pilot resource management

The notion of Human Factors being a major factor in accidents was first conceived following investigations between 1879 and 1880, revealing 55% (N = 500) of shipping accidents were found to be directly related to them (Croucher, 2007). As modern airliners have become ever more reliable, a switch has taken place between accidents being mainly caused by mechanical defects, to the greater part being attributed to human error on the part of the pilot. Both in Europe and the United States, the concept of CRM and human factors training was introduced in the late 1970s; by NASA in the USA and KLM in Europe (Helmreich, Merritt and Wilhelm, 1999). Since then it has undergone a number of changes, adapting to the needs of the industry and being updated as new research suggested addendums to the current model. Based on Helmreich, Merritt and Wilhelm's (1999) interpretation, the five evolutions of CRM can be basically categorised as:

1. Individual style and behaviour. Psychological traits; Leadership, interpersonal relations, co-pilot assertiveness, captain's reluctance to accept corrections/input from co-pilot.
2. Cockpit group dynamics and flight operations; team building, briefing strategies, situational awareness, stress management, decision making.
3. Systems in which the crew function; organisation, automation. First assessment of human factors, CRM integrated into technical training and extended outside the cockpit to cabin crew, dispatch, maintenance etc.
4. Training and qualification. Advanced Qualification (and Training) Programme (AQP) introduced so carriers can, on a voluntary basis, adapt training to an individual's needs, skills and their role.
5. Error management rather than prevention – human error is inevitable and when it occurs it needs to be managed.

The UK and Joint Aviation Authorities ' (now EASA) requirements for CRM to be integrated into commercial flight training first appeared in November 1992 with amendments to CAP 360 (Air Operator's Certificates) and subsequent publications of new Aeronautical Information Circulars (AIC) to enhance the subject (CAA, 2006)

The techniques advocated in CRM training cover a wide range of knowledge, skills and attitudes, such as communications, situational awareness, problem solving, decision making and teamwork, as outlined in previous chapters and concerns the cognitive and interpersonal skills required by modern pilots to manage the flight safely and efficiently (CAA, 2006).

These skills would also serve to improve any GA pilot's skills at (N)PPL level, particularly given that for the most part, the majority of these pilots fly as the sole pilot on board. Chapter nine of CAP 737 (CAA, 2006) states that whilst the contents of that Chapter (CRM for single pilots) is intended for public transport operations (commercial aviation), the principles involved are recommended as best practise for GA. CRM elements refined for single pilot operation are; communication, health, workload management, error management, decision making, situational awareness and commercial pressures. With the exception of commercial pressures, all are relevant to single pilot GA operations, though it could be argued that pressures from passengers, whether they be family or friends could be equated to those commercial pilots face from their employers.

Although there is material available on the internet concerning SPRM, there is very little that is useful to UK GA pilots. The US FAA have produced a short document on the subject, about a third of which recalls the true story of a pilot who got into difficulties and the lessons learned from that incident. It then continues to discuss the principles of “I’M SAFE” (Illness, Medication, Stress, Alcohol, Fatigue, Eating)and the Five Ps model (Plan, Plane, Pilot, Passengers, Programming), which are acronymic techniques to help pilots make better decisions (FAA, N.D). A third acronym coupled to SPRM procedures is “DECIDE” (Detect, Estimate, Choose, Identify, Do, Evaluate), a fourth being “GRADE” (Gather information, Review, Analyse, Decide and do, Evaluate; Croucher, 2007). Whilst these various mnemonics may well have their uses and elicit some value in terms of effectiveness, they are not as easy to remember as the most basic form of aviation flight safety procedure; aviate, navigate, communicate.

9.1.3 The effectiveness of C/SPRM

Simple and easy to remember, the notion of ‘aviate, navigate, communicate’ as prescribed to students early in their flight training, should work well in the GA environment, but the sample data suggests it is not called upon in an emergency situation as often as it might be. Naturally there exists no data for when it has been used effectively as these situations did not end in an accident, but similarly in GA there is no data on near misses where an accident nearly occurred. This has been a problem in trying to prove the effectiveness of CRM in commercial operations, as little data exists on good CRM maintaining a flight in a safe mode, as this is what is expected of a pilot and thus is not deemed as extraordinary. When an airliner crashes and human error is cited, a new wave of data is compiled to show that bad or lack of CRM was a contributory factor, thus biasing the known data towards its ineffectiveness. Salas, Wilson and Burke (2006) concluded from their research that the impact of CRM on safety cannot be ascertained. The suggestion here is that whilst the sample data shows the weaknesses in the skills and judgments of a small proportion of GA pilots at one given time, it is accepted that for the greater part, the training and associated system does work. That said to simply accept it without acknowledging the importance of making improvements to make it even better is objectionable.

9.1.4 Acronyms and their usefulness

In aviation the use of acronyms, abbreviations and mnemonics to both aid pilot performance and describe the hundreds of instruments, navigation aids, licenses, organisations and procedures, among other things, is common place. They are used for standard operating procedures in both commercial and GA, an example for GA being the standard en-route check, FREDA; Fuel (pump on, sufficient available, change tanks as appropriate), Radio (tuned to correct frequency, navigation aids selected and identified as appropriate), Engine (temperatures and pressures ok, mixture as required and carburettor ice check), Directional Indicator (synchronised with compass), Altimeter (pressure setting correct for location and time).

Such acronyms are swiftly memorised due to the frequency of use and pose little difficulty to GA pilots. Where they are not so often used, or are only part of training exercises, they can easily be forgotten, some of which may be of use to the pilot in their future flying. For example, in a practised forced landing (PFL), following a simulated engine failure, the student is asked to identify a suitable field in which it may be possible to land. The Five S rule is applied to ensure any field adheres to the requirements of size, shape, surface, slope and surroundings, which in a simulated emergency from 3000ft, with the engine running at idle and occasionally throttled up to prevent carburettor icing, may be a straight forward exercise. In a real engine failure, from 2000ft and whilst trying to remember all the other aspects of their PFL training (speed, wind direction, diagnosing the fault and attempting to restore power, the radio call and all the information it is recommended to give, cabin security checks and finally to isolate the engine and electrics to prevent fire upon landing/impact) it is quite possible that for the reasons of cognitive stress presented in Chapter 4, the pilot not only forgets the meaning of some or all of the 'S' terms, but completely omits to use any of them and simply aims for the nearest field. More dangerous is that in an attempt to fit all these procedures in and to try and find a field that corresponds to all five 'S' terms, the pilot simply forgets to maintain positive control of the aircraft and stalls it.

Certainly standard procedures for an emergency are beneficial and most are available from checklists which each pilot should carry with them on every flight anyway, but at no point is there a reminder to perform the single most important task; to fly the aircraft and maintain it in a positive flight attitude. In GA aircraft checklists, one for the Piper PA-28 and one for the Cessna 152, two of the most popular aircraft in GA, the closest reminder of this is to "maintain/attain best gliding speed" (Pooleys, N.D) which appears only in the section for emergency procedures following an engine failure. There is no reference to what the best gliding speed is.

Checklists also only provide procedures for some emergencies, the aforementioned versions not providing any guidance on procedures in cases of inadvertent flight into bad weather, becoming lost or any other scenarios. It is accepted that not all eventualities can be catered for in such a small document, but it is suggested that the wide range of potential circumstances that GA pilots may find themselves in calls for a more generic acronymic tool to compliment the enhanced training discussed previously and one that is specific in reminding the pilot to focus on flying the aircraft. It is proposed that a tool such as FDACS be implemented ('F' standing for 'fly the aircraft'), the details for which will be discussed in part 2 along with the results of a simulator study which demonstrate its potential effectiveness in improving single pilot performance in an emergency situation.

Consideration should also be made to the number of acronyms a pilot has to remember. Those cited in Chapter 9.1.2 can be added to with “PAVE” (Pilot, Aircraft, enVironment, External pressures) and the Three Ps model (Perceive, Process, Perform), demonstrating the large array of such acronyms that pilots may be encouraged to memorise. Some of these are more specific to planning and preparation and it is argued here that they will only serve to confuse pilots in emergency situations when trying to remember which list of letters to recall and then remember what they all mean.

9.1.5 Training SPRM in the PPL syllabus

Recent directives from EASA, which come into force from September 2013, mean PPL students in Europe will have to sit nine theory examinations (CAA, 2013) rather than the seven previously necessitated and will be required to undergo at least 100 hours of ground school instruction towards those modules (EASA, 2011). This is encouraging in terms of safety enhancement as it may reduce the level of rote learning and encourage students to gain a profound knowledge of the theory, lack of appropriate knowledge having been presented as detrimental to decision making in Chapter 4.

It has already been advocated that the knowledge procured in current training regimes is declarative rather than procedural, which in time limited situations such as an emergency is not the preference (Flin, O’Connor & Crichton, 2008). The solution lies in determining what knowledge is needed to ensure safety when translating CRM to SPRM (Flin and Martin, 2001) so it is suggested here that the transference of CRM content to SPRM training be as portrayed below.

The CRM elements outlined earlier in this chapter could potentially be integrated into the PPL theory modules that already exist. A more effective solution would be to encapsulate them into an entirely new module in which the students much be examined, commercial pressures being retitled peer pressure and adapted accordingly. This would also be more straightforward as the contents would not have to be weaved in around existing material.

It would be naïve to think that all the accidents in the sample could have been prevented had the pilots received formal training in SPRM, but it is reasonable to assume that had they not been prevented, the severity of some may have been reduced. The particular elements relevant to each category of accident are outlined below, but it is considered likely that some part of each element could have been useful to the pilot of every accident. Firstly each element will briefly be defined using the outlines from CAP 737, Chapter nine (CAA, 2006) as a guide, to provide the reader with an understanding of each.

9.1.5.i Communications

With no other crew members to communicate with, liaison with ATC will likely be the only form of communication for a single GA pilot, although if flying with passengers on board it is important they be aware of what is going on and be fully briefed before departure on what to do in the event of an emergency. Communication with ATC should only use standard phraseology and where doubt exists, GA pilots are encouraged to seek clarification. It should be recognised that the correct understanding of communications with ATC may be affected by high workload, fatigue, distractions and pre-conceived ideas.

9.1.5.ii Health

It is vital that GA pilots ensure they are fit to fly and do not make assumptions based on the validity of their medical certificate. At any time during a flight, if a pilot is feeling unwell, they are advised to land at the nearest suitable airfield and to advise ATC of their situation so that any priority clearances can be given and medical assistance arranged, if necessary prior to landing.

9.1.5.iii Workload management

With no opportunity to delegate tasks, there is potential for a single pilot to become overloaded, particularly in an emergency situation. Prioritising tasks, thorough pre-flight planning and self-briefing will assist in preserving mental capacity for decision making. These should include intended route, alternate airfields for diversion, up-to-date weather information and forecasts and serviceability of the aircraft. Contingency plans for the most likely emergency scenarios should be devised before departure in order that they can be executed without too much additional workload should the need arise. Easy access to and knowledge of the whereabouts of procedures and checklists for both normal and abnormal situations will also reduce the workload at such a time as well as help the pilot remain calm, giving them more capacity to make a diagnosis and take actions as necessary.

To prevent the need for planning a route to an alternate airfield in the event of an emergency, best use of ATC should be made, declaring an emergency if necessary, but at the very least, requesting a heading to fly to the chosen airfield, or requesting suggestions for any other nearby airfields. Where time is short (engine failure) focus should remain on flying the aircraft and selection of a suitable emergency landing area, any communications with ATC only containing useful information such as location and the nature of your emergency (students are often instructed that their aircraft type, heading, height, intentions and souls on board be given). Where passengers are being carried they should be encouraged to perform tasks that require no aviation knowledge, such as looking out for other aircraft, assisting with the location of a safe landing area and carrying out safety checks such as the security of hatches and harnesses.

9.1.5.iv Error management

Single pilots need to be alert for indications of latent errors (those already in the system such as design flaws or mechanical errors, which may occur at any time) becoming active. It is recommended that proper, diligent use of SOPs are the best defence from this type of error and that actions taken from SOPs be double checked and confirmed, preferably with visual, aural and physical (i.e. touch) confirmation (see it, touch it, say it). In conjunction with workload management, planning the workload will allow the single pilot to make good decisions in good time and to self-check any resultant actions before implementing them.

9.1.5.v Decision making

The acronyms and mnemonics cited earlier in this Chapter (DECIDE, I'M SAFE, Five Ps) amongst others are designed to assist the decision making process and are centred around the processes of:

- Assessing the situation and information gathering
- Considering and choosing the best option
- Communicating intentions and carrying them out
- Reviewing the situation and actions taken
- Adapting to new information or changing situations

It is recommended that whilst experience can assist in the decision making process, single pilots should be aware that not every situation is exactly the same and adaptations made accordingly, ensuring that all aspects are double checked before implementation. Single pilots should also be aware that the fear and anxiety felt in the event of an emergency situation can provoke a desire to resolve the situation quickly, potentially leading to an incorrect action. Thus pilots should try to remain calm, continue to fly the aircraft, take a few seconds to gather their thoughts and properly assess the situation before making any decisions.

9.1.5.vi Situational awareness

Relating to more than just geographical location, SA also encompasses the aircraft and its systems, the weather, the physical condition of the pilot and any local airspace activity. Monitoring systems and aircraft performance along with a sound technical knowledge will help the pilot stay ahead of the aircraft in terms of anticipated problems.

Weather forecasts can be inaccurate and constant monitoring of meteorological conditions en-route, particularly if some weather is expected after the flight is due to have concluded (it can often encroach faster than anticipated), again combined with good technical knowledge can prevent an aircraft being flown inadvertently into bad weather/poor visibility.

Referring to health, it is easy not to notice the symptoms of conditions such as fatigue and cognitive stress when one is busy flying an aircraft. Single pilots are therefore recommended to reflect regularly on their personal wellbeing to prevent onset of such conditions.

In some areas of the UK, the Southeast for example, air traffic can be busy and being aware of this before departure and en-route will heighten a single pilot’s SA in terms of expected traffic and ultimately reduce the risk of mid-air collisions.

Geographical location is important in any emergency; it is advisable to tell ATC where you are so they can accurately advise search and rescue teams where to find you. Partially this can be assisted through thorough planning before departure, which is the only real opportunity for a pilot to examine their intended route for potential hazards, restrictions and potential alternate destinations. Accurate plotting of winds and expected times at en-route way points will also help a pilot maintain a good mental picture of the aircraft’s location at any given time.

9.1.5.vii Peer pressures

Commercial pressures felt by some airline pilots to get their passengers to their destination on time can influence an aircraft commander to make a bad decision and attempt a take-off or landing in unsuitable conditions. This was felt to be a likely contributory factor in the crash of the Polish Air Force Tupolev TU-154M in Smolensk Russia in 2010 (Interstate Aviation Committee, 2010) where, with a desire not to inconvenience their VIP passengers, including the Polish President, the pilots attempted to land in visibility below the minimum standard considered safe to do so; all on board were killed. In GA operations, such pressure is most likely to come from friends and family who are passengers at the invite of the pilot. Where they have promised their guests a programme of events such as lunch or sightseeing, it is sometimes difficult to cancel when conditions are not acceptable. Perhaps more difficult is to turn around once airborne, not wishing to appear incapable or otherwise inferior compared to their passenger's expectations. The result is flight into inappropriate conditions and a potential accident.

It is important for any GA pilot wishing to entertain associates with a flight to explain in full the possible outcomes of any flight before they have agreed to go along. If passengers are fully briefed on the potential dangers of continuing when intuition, training and knowledge suggest otherwise, there is less likely to be any disagreement if the decision is made either not to go, or to turn around en-route.

These principles can also be applied to the lone pilot who may be self-conflicted over whether or not to continue or commence a flight. If doubt exists, the best option will always be to not go or to turn around, but if there is expectation (a customer is waiting for the delivery of their aircraft, people are expecting the pilot to arrive for lunch, the pilot needs to perform the flight to maintain currency) the associated pressure could result in a bad decision in the same manner as friends might in the example above. It is then that the pilot should evaluate and discuss in their own mind the options and possible outcomes. Better would be to discuss it with a fellow pilot who, without having an interest in the value of the flight being completed, will have more clarity of thinking.

9.1.6 Applying SPRM elements to sample accidents

Of the seven elements defined above, only health can arguably be applied to all the accident categories. Particularly in the case of fatal accidents, but also in those where no injuries were recorded, it is not possible to completely rule out conditions such as fatigue and stress as possible contributory causes as the pilot may not have been aware at the time of being affected by either of these, or by other underlying physical or mental conditions. Of course to suggest that health was applicable in all cases would be nonsensical and impossible to prove, but it is the element that could influence all categories of accident.

Regarding the main categories of accident as determined from the sample data, Airmanship, CFIT, LOC, Meteorology and Technical accidents will now be appraised in terms of how SPRM training, based on the seven described elements, may have either prevented, or reduced the severity of accidents:

- Airmanship: Management of fuel could be improved through both error and workload management and enhanced decision making; collisions, particularly those in mid-air would be reduced with heightened SA, improved communications and better workload management; flying too low on approach demonstrates a lack of SA, poor decision making and could be eliminated through error and workload management

- CFIT: As this type of accident tends to occur in darkness and/or reduced visibility, there is an argument to suggest that all elements of SPRM training might have had a positive effect on the outcome of these accidents, but most useful to the pilot would have been SA, decision making and communication.
- LOC: For LOC in IMC, SA and decision making would have best served the pilot, but these may also have helped in LOC accidents during the landing phase, as would communication and workload management, given that had more cognitive capacity been available, they may have made alternative decisions based upon the information to hand at the time.
- Meteorology: Considering the dual category of LOC and meteorology as well as the small standalone category, SA, decision making, communication and workload management instruction may have been useful to the pilot.
- Technical: Despite a greater proportion of these accidents not being directly attributable to human factors, following many of the failures, improved decision making and SA would have aided the pilots in executing better emergency or precautionary landings. Equally communication and workload management techniques could have further enhanced the pilot's ability to conclude the emergency with a more favourable outcome.

9.1.7 Flight training with regard to SPRM

Introduced early in flight training and mentioned earlier in this chapter, the pilot's most basic safety procedure is to 'aviate, navigate and communicate' in that order. 'Aviate' relates not just to flying the aircraft, but also to airmanship and awareness. 'Navigate' reminds the pilot to maintain a mental picture of their location, whether flying visually in GA, or on instruments at 35,000ft in a commercial airliner. 'Communicate' serves as a reminder that other people within the system need to know what you know.

This tool is used to remind students of their next step in the on-going processes involved in flying visually, particularly when travelling from one airfield to another, where the principals of all three are crucial to arriving at the correct destination safely. In terms of single pilot operations, it is a very useful mantra to have and used judiciously will see the typical UK GA pilot maintain a safe flying record.

Teaching the 'aviate, navigate, communicate' values in association with the SPRM elements discussed earlier in this chapter in practical flight training would further enhance their value by contextualising the theory of SPRM, in the same way that teaching straight and level flight, or climbing and descending demonstrates the practical side of Principles of Flight and Aircraft General Knowledge, two of the PPL theory modules. In view of the issues raised in this thesis previously, appropriate associations have been devised and are as follows:

- **Aviate:**
    - Maintaining good levels of SA to remain ahead of the aircraft, clear of other traffic and induce good decision making from quality information.
    - Managing the workload and being alert for latent errors not only makes the flight less task demanding, but frees up valuable cognitive capacity to retain high levels of SA and decision making.
    - Not succumbing to peer pressure either when flying with friends or flying alone under someone else's expectations. To do so would undermine the previous steps taken and detract from the skills and knowledge amassed during training and subsequent flying experience.
    - A Healthy mind and body is essential to supporting the previous points.
- **Navigate:**
    - Good planning and consideration to all possibilities with associated contingencies is key to managing workload once en-route and runs concurrent with being able to competently aviate.
    - In different ways to aviating, good workload management will allow high levels of locational SA to be maintained and assist in good decision making in both normal and abnormal situations
    - Communications: Effective and correct use of the radio allows ATC to both track and assist the pilot as necessary whilst en-route
- **Communicate:**
    - Additional to communications as stated above, passengers should be regularly updated on current location and intentions. It may also be useful if they are made aware of how to tune in 121.5 (the international distress frequency) to cover all eventualities.
    - Before departure, as part of the planning procedure for 'navigate', all radio frequencies to be used en route should be written down in sequence. Frequencies for alternates and local information should also be readily available. Where a dual radio box is available, subsequent radio frequencies should be entered into the second box in readiness for a

quick change as and when required. All of these procedures will help manage workload more effectively.

- Use of ATC for updates on local pressure settings, traffic and other information will allow good SA to be maintained and assist in decision making as the flight progresses.

9.1.8 Summary of Part 1

With such apparent success of CRM in commercial aviation operations, there can be little reason to dispute that introduction of a specifically adapted version for use by single pilots in (UK) GA will have any other effect. The acceptance that single pilot do not have the same level of resources, cognitive capacity or time to perform all crucial tasks as multi-crew operations is clearly not new and both the FAA and CAA have made small steps in providing basic formulas for SPRM in commercial aviation. To enhance safety within UK GA, the next logical step would be to compose a PPL theory module specific to SPRM alongside those already mandatory for issue of the license. As shown, this theory can then have practical instruction using a well-known and accepted tool in the form of the 'aviate, navigate, communicate' procedure.

Having also demonstrated how the principles of SPRM may have prevented or reduced the severity of the main categories of accident found in the sample data, it is recommended in this thesis that it now be formally integrated in the EASA PPL syllabus with the aim of reducing accident numbers by pushing GA more towards the professional practices of commercial aviation.

In the following part of this chapter, some of the principles laid out here will be examined through a simulator experiment to determine if an SPRM tool can be effective in reducing the likelihood of an accident following an emergency.

9.2 An SPRM Tool for UK GA; FDACS

9.2.1 The fatal consequences of failing to fly the aircraft

In many of the sample accident reports, particularly those associated with loss of control, there is evidence to suggest the pilot forgot to undertake the most important task in aviation; to fly the aircraft in a positive and controlled manner. In cases of engine failure or inadvertent flight into bad weather, pilots can easily become distracted by attempts to find a solution or through disorientation and subsequently can neglect to fly the aircraft, potentially leading to a stall and/or spin. In 2005 a Piper PA-28 crashed into the sea after entering a spiral dive after it is believed the pilot became spatially disorientated from flying into bad weather and consequently lost control of the aircraft; both occupants were killed (AAIB, 2006). In similar circumstances, a Zenair aircraft crashed, killing the pilot after it is believed carburettor icing caused an engine power issue in poor visibility, resulting in loss of control (AAIB, 2008).

Perhaps the worst time to suffer an engine failure is shortly after take-off. The aircraft is low with very little time for the pilot to react, but recovery is relatively simple and often practised during training (the EFATO). The best course of action is determined to be to lower the nose to maintain airspeed and aim to make an emergency landing straight ahead, or within a few degrees either side of the nose. This eliminates the need to turn, which can exacerbate the situation due to the aerodynamic phenomena associated with turning an aircraft (which will be explained later in this chapter, but in short, the aircraft stalls easier in a turn). Depending on the altitude the aircraft has gained and the surroundings of the airfield, this is not always possible and a turn may be necessary to avoid collision with buildings or other obstacles. In a similar vein, if the aircraft has gained a reasonable amount of altitude, the pilot may be tempted to attempt a return to the airfield, usually involving a tight (steeply banked) turn. In 2007 the pilot of a Pulsar aircraft attempted such a return following an EFATO, but the aircraft stalled, the subsequent accident fatally injuring the pilot (AAIB, 2008). A similar accident occurred in 2009 when the pilot of a Taylor monoplane stalled whilst attempting an abbreviated circuit to land back at the airfield and was killed in the subsequent accident (AAIB, 2010).

In all these examples, the pilots, for whatever reason, failed to fly the aircraft. Had they done so, they would likely have survived, most probably without serious injury (94.5% of the accidents analysed for this thesis were non-fatal, 90.5% resulting in no or minor injuries). Although there are procedures to follow in such circumstances and pilots are trained to maintain the aircraft in a positive flight mode first and foremost, there is nothing post licensure in place to remind pilots of this crucial task in the event of an emergency and over time, it is possible that the importance of this is lost among the myriad procedures a pilot is taught. Additionally, human nature would suggest that the immediate reaction of a pilot in such circumstances would be to either return to the airfield and/or attempt to resolve the issue. Instead of the numerous procedures in place to procure resolutions to the numerous problems that may occur, if just one were used, it is reasonable to assume that it would be easier to remember and therefore more likely to be used. Furthermore, if the focus of this procedure were on flying the aircraft, it is also reasonable to assume that fewer accidents of a LOC type would occur.

9.2.2 An introduction to the concepts of FDACS

Devised specifically for this thesis to determine the possibility of reducing accidents through GA pilots not prioritising tasks or subsequently managing them effectively, FDACS is a quick and simple acronym tool designed to assist pilots in times of emergency, use of which encourages them to prioritise flying over other tasks thus preventing accidents or minimising their severity. Accidents are not inevitable at any point until the pilot's focus on flying the aircraft is lost. Although alarming for the occupants, an aircraft will continue to fly without power if it is handled correctly and can be brought in to land (usually in a field) without damage or injury to persons on board. Contrastingly, an aircraft with a working engine that has been allowed to decline into a spiral dive is infinitely more dangerous. Even in visually impoverished conditions such as cloud, it is easier to set a plane down from a controlled unpowered glide than it is from an uncontrolled manoeuvre under power. Relatively innocuous situations such as a minor electrical failure can be successfully managed using FDACS as it reminds the pilot of the most important factor – flying the aircraft. Indeed use of FDACS during regular flight to give the pilot enhanced situational awareness would be encouraged in conjunction with the current en-route checks of fuel, engine, compass (or directional indicator), radios and altimeter setting (FEDRA/FREDA).

Notorious accidents within commercial aviation have shown that distraction from the most fundamental function of a pilot can result in tragedy; Eastern 401 (NTSB, 1973), Avianca 052 (NTSB, 1991), United 173 (NTSB, 1979), American Airlines 965 (Aeronautica Civil, 1996). The implementation of FDACS cannot be achieved successfully unless the pilot has sufficient knowledge of the fundamentals of flight and aircraft systems. This knowledge is being threatened by the practise of memorising answers to questions associated with the CAA PPL ground theory examinations. This is opposed to attaining a level of knowledge adequate enough to fully understand the principles of aerodynamics, engineering and the atmosphere needed to effect safe flight in general aviation. The basic principles of FDACS are presented below:

- **F – Fly the aircraft**; Maintain wings level and a profile to retain aerodynamic lift; with power maintain level flight, without power adopt the best glide speed and attitude as recommended by the manufacturer.
- **D – Diagnose** the problem, but only if altitude allows. If not, skip to ‘C’ . Sound knowledge is required at this point to offer the pilot the best opportunity to make a swift and accurate determination of the problem, or even to establish that they do not know what is wrong allowing them to focus on flying the plane and performing the emergency tasks as directed by FDACS.
- **A – Attempt** to resolve the issue, but only if altitude allows. If not, continue to the next stage of FDACS. Again knowledge needs to be adequate enough to give the pilot the means to act swiftly, confidently and decisively.
- **C – Communicate**; Informing personnel on the ground of your predicament can help in a number of ways. Locating your position, vectoring to airfields, information on weather, advice, prioritising resources for you and alerting emergency services, as well as possibly acting as a calming influence to help the pilot refocus.
- **S – Start** preparing for a precautionary/emergency/forced landing. While most accidents result in no or minor injuries, simple actions such as ensuring harnesses are secure, doors or hatches are unlocked and/or open to expedite egress, loose items are secure to prevent unnecessary injury from projectiles and passengers are properly briefed can increase the likelihood of walking away from any complications on landing. Other actions to secure the aircraft, when appropriate, can prevent further problems on the ground. Isolating electrics and fuel can prevent fires erupting and disabling the engine make it safer for rescuers/emergency personnel to approach the aircraft if vacating it is difficult or not possible.

9.2.3 The experiment

To determine the potential influence of FDACS, a simulator study was designed to observe reactions of pilots in an emergency situation, in this case an engine failure shortly after take-off. Two groups each of five pilots were assembled, all being volunteers recruited in accordance with and approval from the University of Leeds’ Ethics Committee.

The simulator used was a Merlin FNPT 1, internally configured as a Piper PA-28 and programmed to perform as such. The Merlin allows an operator to change conditions of flight such as weather and aircraft performance parameters in real time from a remote station. This provided the opportunity to both set the weather conditions as necessary and simulate the engine failure at the pre-determined point manually. More than 65 individual parameters concerning the flight can be recorded and stored on a memory device for later analysis. For the purposes of this study, the parameters recorded for analysis were indicated airspeed (IAS, in knots), pitch angle (degrees), roll angle (degrees) and vertical speed (m/s). It should be noted that whilst the Merlin records vertical data in metres, the prevalence in aviation is to use feet as the instruments are set up to give the pilot information relating to height in this form; thus all recordings of height data have been converted from metres to feet (per minute for vertical speed).

To further analyse each pilots' procedural routine, flap position was also recorded; use of flap in the correct manner can improve the chances of performing a successful landing in both normal and emergency situations. An FNPT 1 operates under the CAA definition of a Flight Training Device (FTD) as stipulated in CAP 804 (2012) and shown in Table 20.

Table 20: CAA definition of each of the three main levels of simulator used for flight training

Simulator Description	Definition According to CAA, CAP 804, Section 1, Part B
Basic Instrument Training Device (BITD)	Ground-based training device which represents the student pilot's station of a class of aeroplane….providing a training platform for at least the procedural aspects of instrument flight
Flight Training Device (FTD)	Full size replica of a specific aircraft type's instruments, equipment, panels and controls in an open flight deck area or an enclosed aircraft flight deck….to represent the aircraft in ground and flight conditions….It does not require a force cueing motion or visual system
Full Flight Simulator (FFS)	Full size replica of a specific type or make, model and series aircraft flight deck….to represent the aircraft in ground and flight operations, a visual system providing an out-of-the-flight-deck view and a force cueing motion system

The system allows an event marker to be placed among the data to more clearly indicate the start of the failure. Unnecessary data more than 20 seconds prior to this point was deleted to allow greater clarity in graphical representations of the data. Data beyond the point of touchdown was also erased for the same reason. Due to differing climb rates and flying styles, not all engine failures were executed at exactly the same point, however use of the event marker allowed the moment of each failure to be aligned for the purposes of data analysis and comparison.

9.2.4 The volunteers

All volunteers were either second or third year students on the University of Leeds' Aviation Technology Undergraduate course giving the experiment a balance not normally possible; they were all of similar age, had similar levels of experience on the same aircraft as the simulator configuration, were of similar levels of educational background and ability and received training from the same flying school. Thus the results could be analysed without reference to problems of mixed age, ability and experience, making them more robust that might otherwise be possible.

The first group (all third year students) was assigned the role of the control group and provided with a training sheet explaining the background to the study, what was expected of them and a guide to FDACS, which they were asked to read during the week prior to the study. They were also encouraged to make their own personalised notes on FDACS to use during the 'flight', as perhaps they might do with such a tool on a real flight. Furthermore they were briefed on FDACS just prior to entering the simulator and told to expect a problem at some point; they were given no indication as to when it would occur or what it would be, but in line with FDACS were advised to ensure they took considered actions to keep the aircraft in flight. Instruction was given for them to fly in their normal manner, following procedures and radio calls as necessary, but to use the principles of FDACS on encountering the problem, heavy emphasis being placed on the need for them to fly the aircraft. Following their flight they were asked to fill in a questionnaire to gather data on specifics such as their levels of flight experience and any recent flying relevant to the study; in this case referring to the last time they suffered or practised an engine failure in flight (Table 21, p198).

The second group (all second year students) was designated as the experiment group and not given any details concerning the reasons for the study, but simply asked to make the flight as described to the control group. Once settled into the simulator they were advised to expect a problem during the flight, but given no indication of what the problem would be or when it would occur. To encourage normal flight procedures and behaviour, each volunteer in this group was told to fly as they normally would and follow procedures and radio calls according to their training. It was also expressed that they were not being tested or judged and there were no expected right or wrong solutions. Following their flight they were also asked to fill in the same questionnaire as the control group to allow direct comparative analysis.

The study required the volunteers to take off from runway 27L at Heathrow airport in minimum legal visibility (5km) with a wind velocity from 310° at 5 knots and climb straight ahead on the runway heading (270°) to 1000 feet (300m). At this point they were instructed to initiate a right turn to enter a normal circuit pattern, climbing to the circuit height of 1500 feet (450m). Their instructions were to enter the circuit, completing all checks as normal and at a given point to leave the pattern and climb to 3000 feet (900m); further instruction concerning headings and altitude would be given after this point. This provided a realistic scenario whilst minimising the likelihood of the control group predicting when the engine failure might occur. The engine failure was initiated during the turn at 1000 feet.

It was hypothesised that the control group would perform better than the experiment group in terms of maintaining glide speed, controlling the descent profile and maintaining positive overall control of the aircraft until a successful emergency landing. The expectation was not that the experiment group would crash or fly dangerously; it was predicted they would fly less accurately with inconsistent speed and descent profiles and relatively erratic changes in pitch and roll compared to the control group. Although these profiles may not necessarily lead to an accident in the controlled conditions of a laboratory simulator, it was conceded that in a real life situation, the related pressures and psychological impacts would likely have negative impacts on the pilot's performance and consequent control of the aircraft, leading to an increased potential for an accident to take place, compared to the simulator. Thus it must be assumed that, however well or badly the volunteer pilots cope with the situation and fly the aircraft, it is likely to be worse in a real situation and thus gives greater credence to the results, demonstrating the need for this investigation.

9.2.5 Results

9.2.5.i Volunteer pilot experience

Despite the fact the control group had all held their licenses for a longer period of time than the experiment group, they had less mean flying experience (Table 21), although exploratory statistical analysis found this difference not to be significant.

Table 21: Volunteer pilot experience

Control Group	Pilot 1	Pilot 2	Pilot 3	Pilot 4	Pilot 5		Mean
License type	**PPL**	**PPL**	**PPL**	**PPL**	**PPL**		
Length of licensure (months)	33	21	21	21	19		**23**
Experience (hours)	60	52.5	51	56	45		**52.9**
PA-28 Type Experience (hours)	15	52.5	51	56	45		**43.9**
Last 90 days experience (hours)	0	0	0	2	0		**0.4**
Last engine failure (months)	9	13	10	8	19		**11.8**
Experiment Group	**Pilot 1**	**Pilot 2**	**Pilot 3**	**Pilot 4**	**Pilot 5**	**Pilot 6**	**Mean**
License type	**PPL**	**PPL**	**PPL**	**PPL**	**PPL**	**PPL**	
Length of licensure (months)	8	8	9	9	9	9	**8.7**
Experience (hours)	76	90	45	55	65	62	**65.5**
PA-28 Type Experience (hours)	38	45	43	45	50	50	**45.2**
Last 90 days experience (hours)	1	2	0	0	2	0	**0.8**
Last engine failure (months)	8	8	9	9	9	4	**7.8**

Table 21 also demonstrates that the control group had slightly less experience on the aircraft type the simulator was set up to represent, as well as less flight time in the 90 days preceding the study. Again, analysis showed the differences between the two groups to be statistically insignificant.

Specific reference to engine failure in the questionnaires revealed all but one member of the control group had experienced or practised an engine failure since their training, but only one of the experiment group had achieved this. It was also confirmed from the questionnaires that all the volunteer pilots had received training and licenses from the same flight school.

9.2.5.ii Airspeed

The data indicated that during the climb immediately prior to the failure, the control group had established a mean airspeed of 76.8 knots, the experiment group climbing at a mean airspeed of 84.1kt. Statistically, this difference in airspeed was shown to be significant; $t[36] = 16.870$, $p < 0.05$.

Following engine failure the control group lost a mean of 5.1kt at a rate of 0.6kt/s, whilst the experiment group lost 11.6kt at 1.5kt/s. Mean glide speed established post failure was 75.7kt by the control group and 79.1kt by the experiment group. Again, this was calculated to be a significant difference; t[129[= 4.424, $p < 0.05$. (Figure 24).

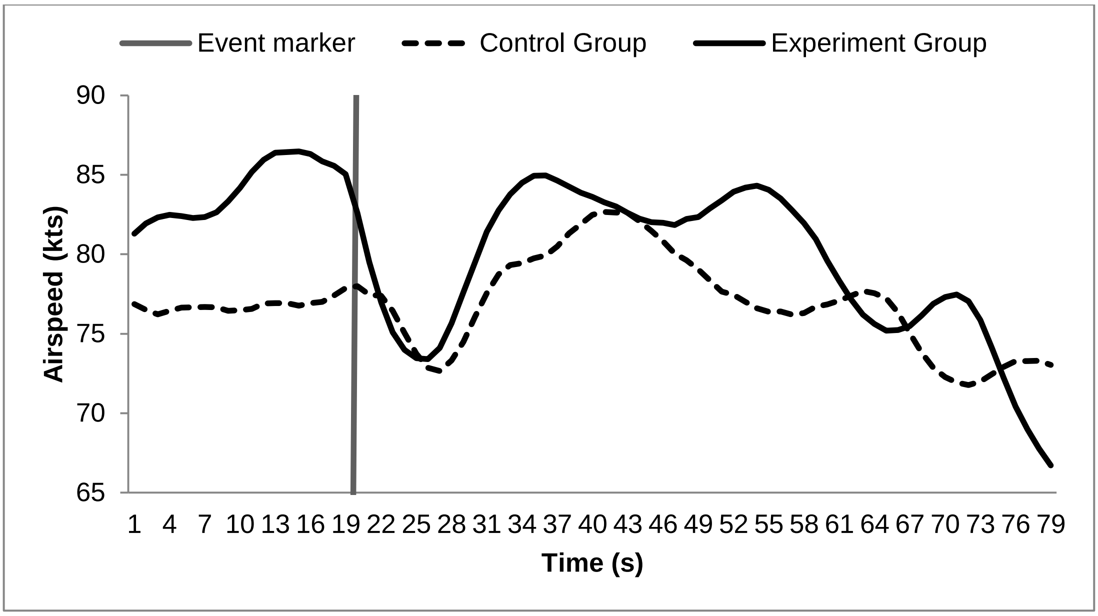

Figure 24: Airspeed over time for both groups, both prior and post engine failure

9.2.5.iii Pitch angle

Complementing the associated airspeeds achieved in the climb, the control group maintained a mean pitch angle of +12.4°, whilst the experiment group climbed at a shallower angle of +9.1°; a significant difference between the two: t[36] = 10.387, $p < 0.05$. Following the engine failure, the control group made a maximum mean change of 13.9° to a negative (downward) pitch angle at a maximum mean rate of 1.3°/s, subsequently maintaining a mean of +1.9° until landing. The experiment group made a maximum mean change of 17.4° to a negative pitch angle at a maximum rate of 1.8°/s, achieving a mean post failure angle of -0.5°, explaining their higher airspeed during the descent. The difference in mean post failure pitch angles were also demonstrated to be of statistical significance; t[132] = 4.412, $p < 0.05$. The rate of change of pitch angle was statistically shown not to be significant; t[9] = 1.985, $p < 0.05$ (Figure 25).

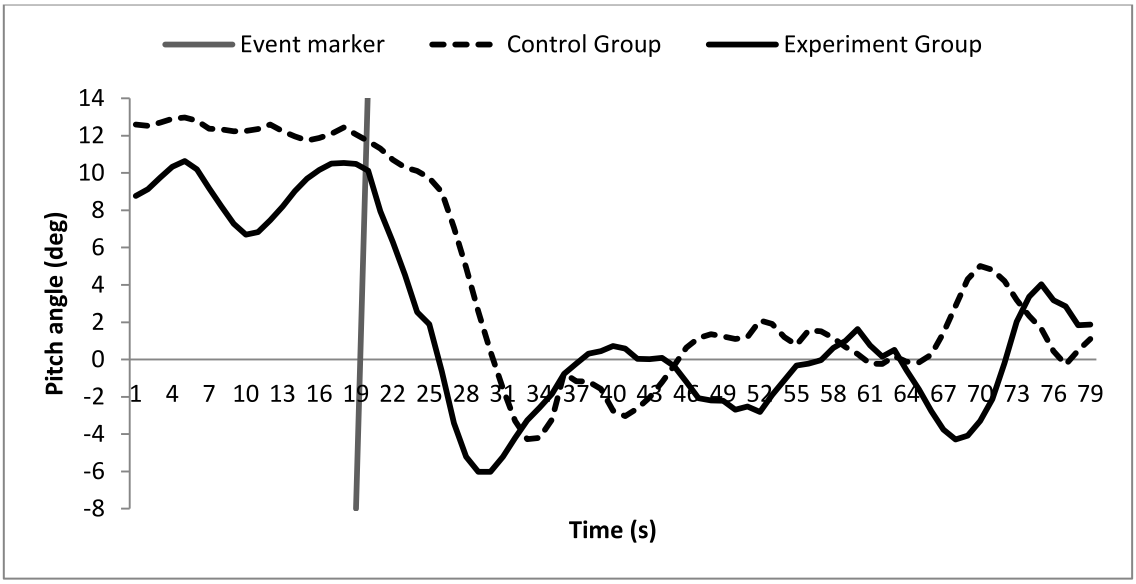

Figure 25: Pitch angle over time for both groups, both prior and post failure

9.2.5.iv Descent profile

A review of the descent airspeed and pitch angle of each group suggests the descent profile of the experiment group was steeper than that of the control group. This is confirmed by the data that shows the control group to have descended at a mean rate 920ft/min (Figure 26).

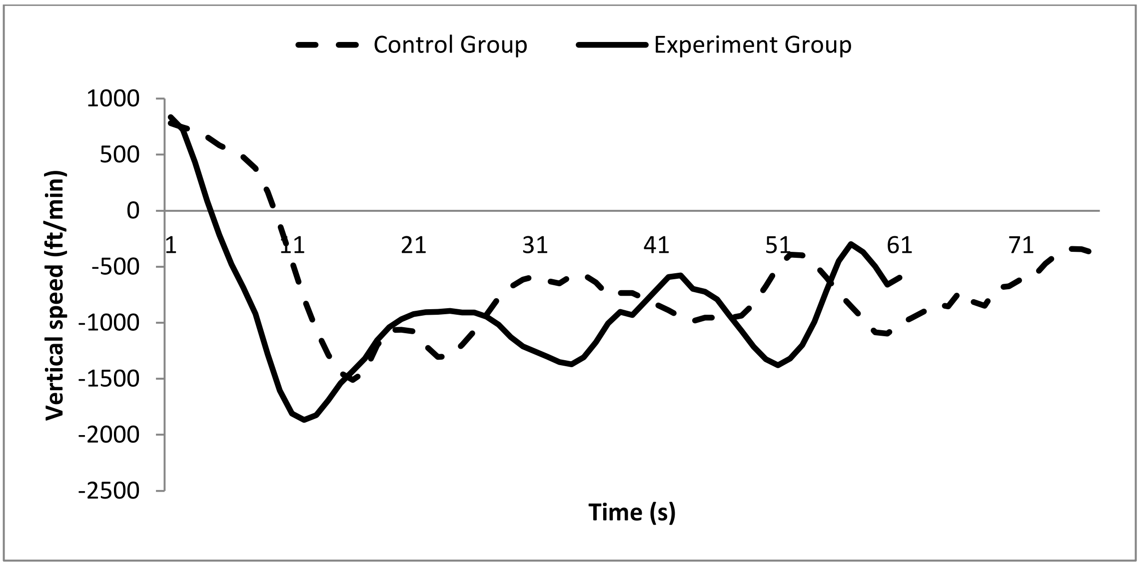

Figure 26: Descent profiles for both groups following the induced engine failure

Using the data for all 11 pilots gathered for each second post engine failure, the difference between the two rates of descent was calculated to be significant; t [136] = 2.849, $p < 0.05$. As can be seen from Figure 26 and as calculated from the data, the subsequent time available for the pilots in the experiment group to successfully conclude the flight was appreciably less (61s) than for the control group (77s).

9.2.5.v Bank angle

Prior to the engine failure, the control group flew at a mean bank angle of +1.7° (to the right), reaching a maximum mean of 17.4°, whilst the experiment group maintained a steeper mean turn to the right of +7.9°, achieving a maximum of 16.8°. The mean angle difference was significant; t[36] = 4.227, $p < 0.05$. Following engine failure, after a pause of three seconds, the control group returned the wings to a near level position (+1°) at a mean rate of 0.9°/s. The experiment group also paused, but only for one second before returning to a wings level attitude (+0.4°) at a mean rate of 0.6°/s. The control group, on average made no discernible turns to the left following the failure, mean bank remaining to the right at +6.4°, whilst the experiment group deviated slightly to the left with a mean maximum of -3.9° to the left, but an overall mean bank to the right of +4.6°. Once more, this difference of mean bank angle post failure was calculated to be significant; t[132] = 2.397, $p < 0.05$ (Figure 27). From the 40s to the 66s point the experiment group makes a series of turns, firstly to the right, then to the left, producing a mean change of bank angle of 3.5°/s, 2.3°/s, 1.7°/s, 1.9°/s and 1.5°/s respectively.

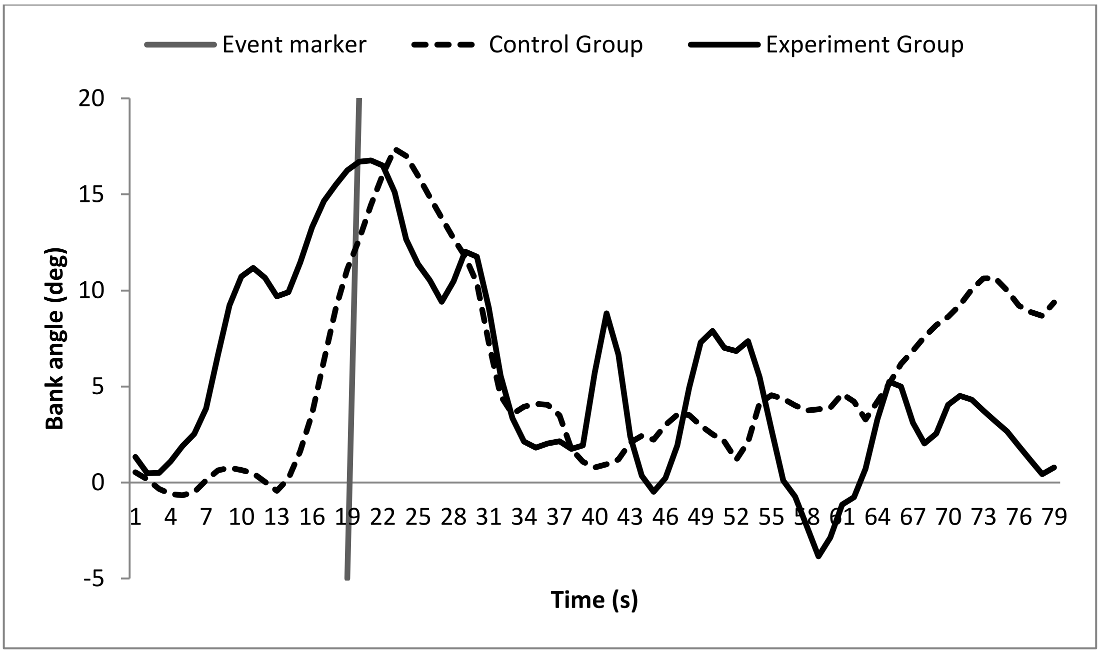

Figure 27: Bank angle over time for both groups, prior and post failure (+ve = right, -ve = left)

9.2.5.vi Other observations

Whilst the 'DACS' aspects of the tool could not be quantitatively measured, it was noted that the control group made shorter, more concise emergency (mayday) radio calls then the experiment group, who tended to give detailed information such as persons on board, altitude, heading and intentions.

9.2.6 Discussion

The most important aspect of every pilot's job is to fly the aircraft. If not done diligently and according to the procedures and recommendations laid down in the pilot's operating handbook (POH), there should be no issues arising from induced technical problems, incorrect configurations or inappropriate use of equipment. The POH, however does not cover pilot decision making, cannot affect inherent pilot skill and is not an instruction manual on how to react in an emergency situation; all these are traits of being human that to some extent are naturally occurring and, in terms of aviation, are perhaps more facets of piloting that can be taught, trained and practised.

Upon encountering an emergency situation, such as an engine failure, it is imperative that the pilot's main focus is on maintaining the aircraft in a positive flight mode. Regardless of how thorough the pilot's checks are completed or how detailed the radio call, if the aircraft does not remain in flight, all will have been in vain. This does not just apply to emergency situations, but also to general flight.

In any given situation during flight, the definition of a positive flight mode is one where the pilot has conscious, deliberate and positive control of the aircraft; the airspeed is appropriate for the configuration of the aircraft, manoeuvre being performed and the prevailing environmental conditions; the engine power is appropriate to maintain the airspeed for the duration of the conditions outlined previously.

The aim of this experiment was to determine if concentrated training aimed at the importance of flying the aircraft can, at least in the short term, improve a pilot's ability to cope with an in-flight emergency and the results demonstrate this to be the case. Whilst pilots are trained for the most common and likely eventualities that may be encountered, there is no precedence for making pilots regularly practise these procedures or for them to be monitored in terms of their continued ability to complete them post licensure. Thus the pilots who had been licensed for the longest period of time were designated the control group as they are less likely to have recently practised any emergencies. The experiment group pilots however, were all recently qualified and theoretically should have retained more information and associated skills concerning emergency procedures than their counterparts. Given this assumption, prior to the experiment it could confidently be assumed that the control group would be less skilled at emergency procedures, due to their assumed lack of practise. As the questionnaires consequently revealed, not only were the control group less practised at emergencies (by an average of four months), but they also had less flying experience than the experiment group both in terms of total experience and experience on the simulator aircraft type. Furthermore, they had flown less, on average in the preceding 90 days than the experiment group and had qualified (i.e. received their last official training) on average, more than 14 months earlier.

The lack of statistical significance of these figures does not in any way negate the importance of the difference between them. In GA it is expected that a pilot should fly at least 1 hour per month to remain sufficiently current to remain competent and safe, as stipulated in CAP 804 (CAA, 2013). Some basic calculations on the data in Table 21 demonstrates that on average, the control group had 0.9 hours per month less experience (since licensure) than the experiment group, effectively making them much less current in terms of legal recognition.

9.2.6.i Airspeed

Maintaining a fixed wing aircraft in flight after an engine failure is dependent on maintaining airspeed to ensure sufficient airflow over the wings to produce lift. This is demonstrated by the lift equation, stipulating that lift (L) is relative to the density of the air (ρ), airspeed (v), the maximum pre-determined coefficient of lift (CL Max) and the surface area of the wing (S), C_L Max being derived from the angle of attack (the angle between the wing and the relative airflow) and wing shape (Equation 1):

Equation 1: The Lift equation

$$\boxed{L = \ ½\, \rho v^2 C_L MaxS}$$

If the airspeed falls below that required to maintain lift, the aircraft can no longer sustain flight and the aircraft stalls. For the Piper PA-28, the published stall speeds are 44 knots (kt) when configured to land (i.e. with full flap set, called V_{SO}) and 50kt in a clean (zero flap) configuration (V_{S1}) (Piper, 1979).

In order to maintain lift in the event of engine failure, the nose of the aircraft is lowered and adjusted to an attitude that allows the aircraft to maintain a glide speed of approximately 73kt ($V_{BEST\ GLIDE}$). At this speed, the aircraft descends at the best ratio of distance covered to height lost, subsequently giving the pilot the maximum available time to investigate the engine failure, attempt a re-start, contact ATC and search for an appropriate emergency landing site. Below this speed the aircraft will not maintain enough momentum from the downward glide to sustain speed and constant adjustment of the pitch attitude will be required to prevent the onset of the stall. Above 73kt, although the danger of stalling is eliminated, the amount of time available to the pilot is diminished and impact with the ground is hastened, due to the associated faster descent.

Furthermore, these published speeds are not exact and may be different according to the condition of the aircraft, variations in weight (number of passengers, luggage, fuel on board), turbulence and manoeuvring (this can increase loading on the wing, effectively increasing weight). Following takeoff, the PA-28 published best rate of climb speed is 79kt, giving the maximum altitude gain per unit of time.

The data recorded and subsequent analysis demonstrated that the control group flew significantly better than the experiment in terms of maintaining the correct airspeed both prior to and post engine failure. This suggests that the provision of the FDACS tool combined with a small amount of tutoring immediately prior to the simulator flight influenced the piloting behaviour of the group. As noted by Godwin (2004), an aircraft's performance is a resultant factor of power set, combined with the selected attitude and whilst the power setting is only occasionally referred to, in visual conditions (such as those presented in the simulator) it is the horizon which provides the external reference for attitude (and bank angle). The continuous cross-checking of these two main parameters is known as the 'scan' and is an important skill for pilots to cultivate in order to maintain critical parameters such as airspeed. Without a good scan, it is difficult to set an aircraft into a steady climb, stable cruise or a controlled descent. Clearly in the case of the control group, FDACS has served to remind them of the importance of airspeed, not only following the emergency, but also prior to it in during a normal climb.

The result is that prior to the engine failure, for a given period of time, the control group would have gained more height than the experiment group (had the failure been instigated at a set time as opposed to a pre-determined height). More importantly, following the failure, flying closer to the prescribed glide speed allowed the control group more time for the important process of decision making, communication and accurate handling of the aircraft.

9.2.6.ii Pitch angle

Following an engine failure, as described previously, the aircraft's nose must be pitched down. However if this is done too rapidly, the changes made to the relative airflow can actually cause the aircraft to stall, even if it is above the stall speed; it is often impressed upon student pilots by their Instructors that published stall speeds are for given conditions only and an aircraft can stall at any airspeed, any flight attitude (Oxford Aviation Services, 2007). The rotational action of the aircraft pitching down produces a new relative airflow to the wing that physically increases the angle of attack. If the rotation is sufficient, the angle of attack produced will be above that at which an aerodynamic stall is induced, thus removing the aircraft's ability to sustain flight. This is demonstrated in Figures 28 and 29; in straight and level flight, there is a small angle of attack which allows the wing to maintain lift (Figure 28); this is manufactured into the design of the aircraft by attaching the wing at a slight angle to the horizontal plane and is called the angle of incidence. During the climb, the angle between the wing and the relative airflow can cause a stall if it is above the *critical* angle of attack. With an engine failure, if the pilot forces the nose of the aircraft down too quickly in an attempt to prevent a stall, the increase in the angle between the wing and the new induced relative airflow may have a negative effect on the situation and independently cause the wing to prematurely stall. (Figure 29).

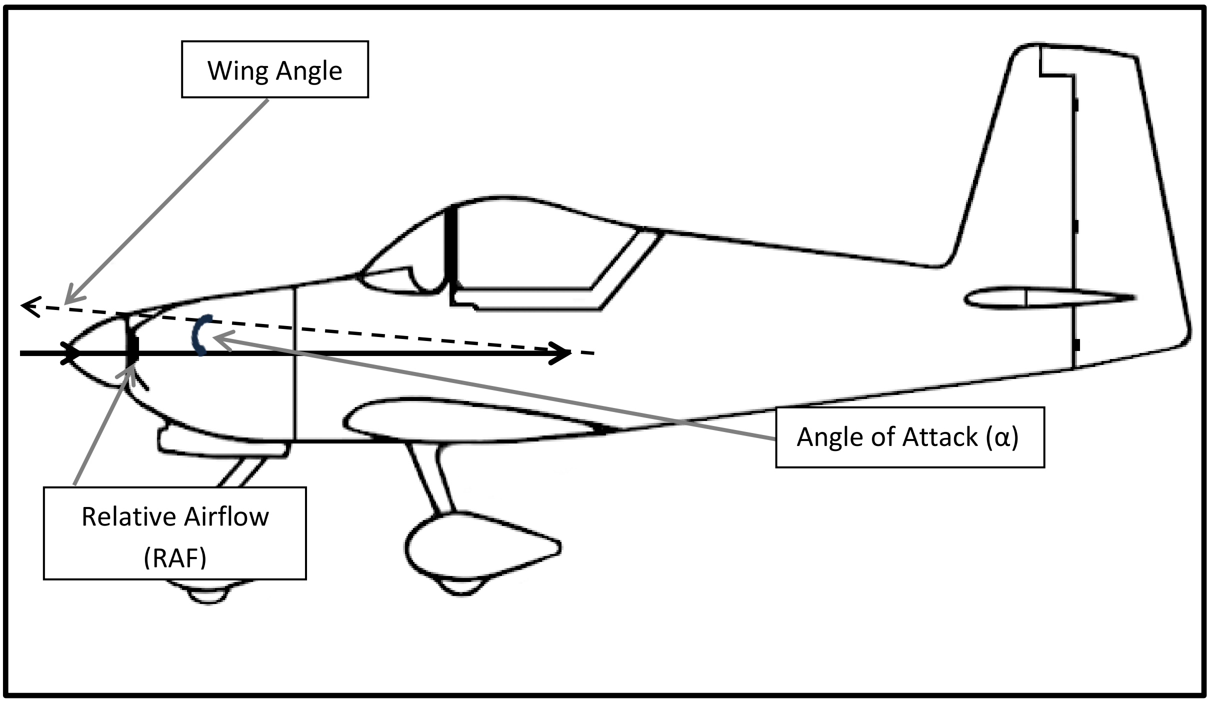

Figure 28: Aircraft in straight and level flight

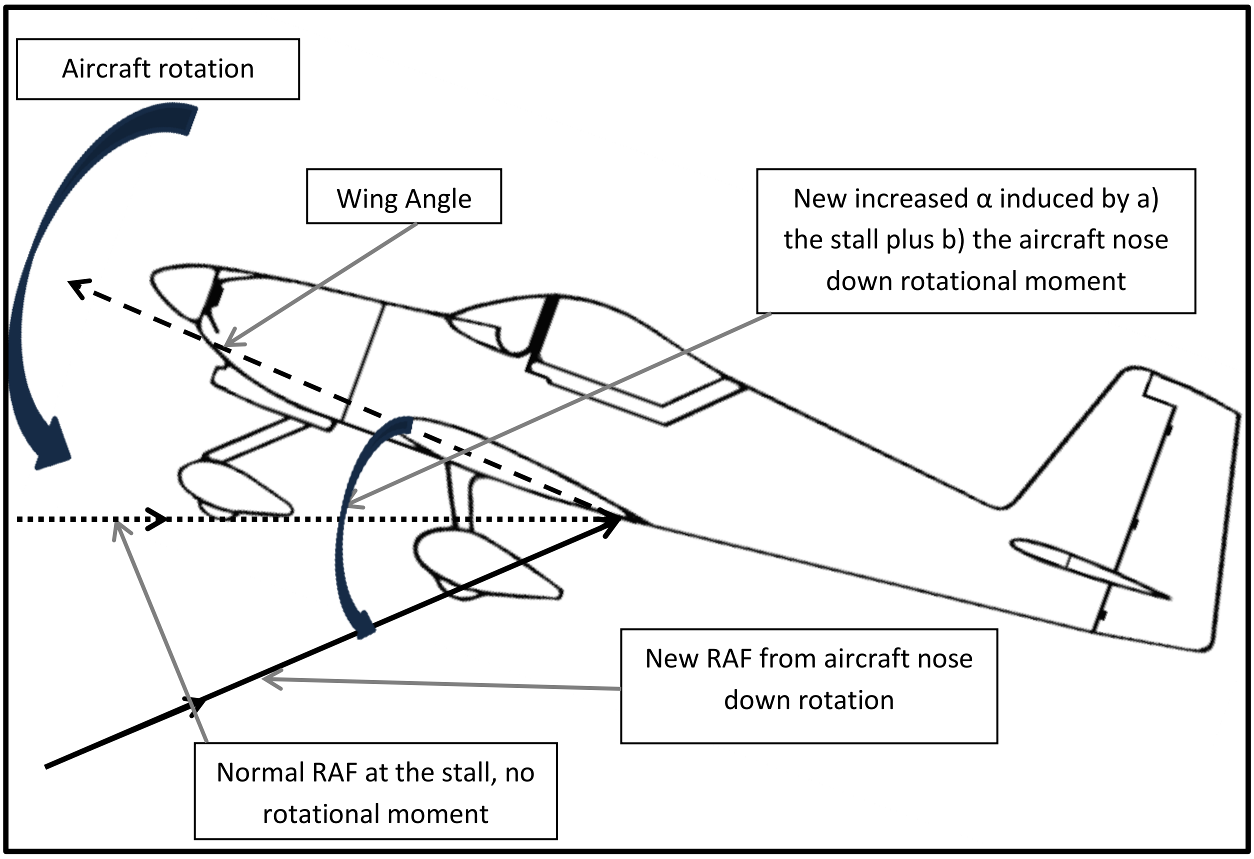

Figure 29: Aircraft in the climb, with high nose down rotational moment, inducing increased angle of attack

Although recoverable from altitude, at lower altitudes, as was the case in the experiment (just after take-off), the additional time required may impede the pilot's ability to effect a full recovery.

From the data gathered, it can be seen that the experiment group generated a faster nose down rotation, compared to the control group following the engine failure, putting the aircraft at greater risk of an unexpected, induced aerodynamic stall. Although not statistically significant and at this rate, unlikely to cause such a phenomenon, it suggests that the control group were more judicious in their response to the failure, following the guidance given in relation to FDACS. It is also recommended in CAP 737, Chapter nine that before making a decision following any emergency situation, single pilots should allow themselves a few seconds to get over the initial fear and anxiety in order to facilitate good decision making (CAA, 2006). In making the pilot first fly the aircraft and gain initial control of the situation, FDACS achieves this and once the aircraft is stable, the pilot can then take time to draw information from whatever resources are available by following the rest of the acronym and make informed and appropriate decisions.

Indeed, prior to the failure, the control group also maintained a significantly better pitch (climb) angle. The failure in this experiment was initiated at a pre-determined altitude of 1000ft in order to give each volunteer the same recovery potential. However, had it been initiated at a pre-set time, the control group would have gained more altitude than the experiment group, due to their more precise flying, thus giving them more recovery potential. Using the mean climb angle of each group and an assumed ground speed of 60 kts, simple trigonometry allows the difference in potential altitude to be calculated.

9.2.6.iii Bank angle

Principles of aerodynamics state that in order for an aircraft to remain in flight, the lift produced by the wings, must equal (or be greater than in the case of a climb) the weight of the aircraft (Figure 30, [a]). In this experiment, the engine failure was induced during a turn, when the aircraft was in a banked turn. In such a manoeuvre, the lift component is inclined away from the vertical, whereas weight always acts vertically downwards (Figure 30, [b]).

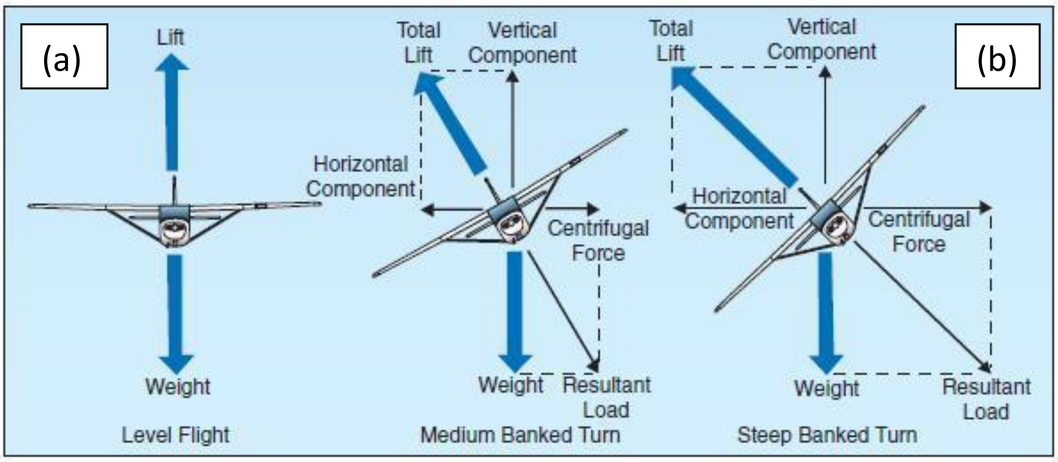

Figure 30: Forces of lift and weight acting on an aircraft in a banked turn; source: airplanegroundschools.com

Thus the lift produced must be increased to compensate; Equation 2 demonstrates that the lift (L) is a function of the bank angle (Ø):

Equation 2: Lift component required in a banked turn

$$L = \frac{1}{\cos \emptyset}$$

From this it can be been calculated that in a 45° banked turn, the lift produced must be increased by 41% and in a 30° turn, by 15%. The relationship between lift and speed, from Equation 1 and lift and bank angle from Equation 2 can be transposed to derive an equation demonstrating how the stall speed (V_S) also increases during a banked turn (V_{ST}), i.e. the aircraft stalls at a faster speed (Equation 3).

Equation 3: Stall speed in a banked turn

$$V_{ST} = V_S \sqrt{\frac{1}{\cos \emptyset}}$$

Given the PA-28 stalls at 50kt in a clean configuration (as would be the case at the point of the induced engine failure in the experiment), in an 18° turn, such as that being made on average by both groups at or just after the failure, this would increase to 51.3kt. Although mathematically insignificant, this 1.3kt difference could be crucial in maintaining the aircraft in flight; consider a wind with variations of 10kt and an aircraft gliding after an engine failure at 60kt as opposed to the recommended 70kt. In level flight a negative wind variation of 10kt would see the aircraft barely maintain flight, but in a normal glide turn of 20°, where the stall speed increases to 52kt the aircraft would enter a stall.

In an engine failure scenario where the aircraft is in a turn, the correct course of action with regard to bank angle is to slowly return the wings to a level attitude to reduce the risks associated with aerodynamically induced stalling as described in Chapter 9.2.6.ii above, where an excessive rate of turn could stall one wing due to the aforementioned down and/or upward movement of either wing.

Neither group was excessive in their rate of turn to level the wings, following the engine failure and both made various turns whilst making decisions as to where to land. The difference is in the amount of bank used without power and the exchange between left and right turns. The control group flies a much less aggressive pattern, keeping the aircraft close to wings level, with a slight tendency to turn right (Figure 27). The experiment group, however, makes large, rapid changes in bank angle, the first of which involves a rate of change of 3.5°/s which, in a situation with no power could be considered excessive. Although these figures are a mean of the group's performance, they suggest that the experiment group were both less decisive in their actions and more aggressive in their flying; both undesirable traits in a pilot's reactions to an emergency situation.

9.2.7 General Discussion

Despite their reduced levels of both currency and experience compared to the experiment group, the control group flew better and more accurately, significantly so in some areas. With all volunteers being of a similar age, educational standard and having received flying instruction from the same flying school, the only disparity between the two was the FDACS training given to the control group prior to the experiment. The study demonstrated that this training and actual use of the tool during the emergency enhanced the control group's awareness of the need to fly smoothly and accurately and to prioritise this skill.

Whilst all volunteers made a radio call to declare the emergency, the fact the control group made briefer announcements, reflected the FDACS training, suggesting that such a call be made, but is adapted to the time available in the given situation. Whilst the experiment group's attempts to give accurate information were worthy, it is reasonable to consider this reduced their mental capacity resulting in less accurate flying than the control group.

Although this experiment centred on the emergency condition of an engine failure, the concept of FDACS could be translated to a number of different GA, single pilot situations such as getting lost, inadvertent flight into poor visibility or cloud, electrical failures, on board fire and so on as it reminds pilots of their priorities for any situation. If a pilot omits to fly the aircraft, then all other tasks undertaken in an emergency will likely be in vain.

This experiment has shown that a simple reminder to pilots to retain positive control of their aircraft in any situation results in a safer approach to flying technique following an in-flight emergency. This allows the pilot time to gather information and improve situational awareness, subsequently providing the pilot with the capacity to make better decisions in terms of actions to take to resolve the situation.

9.2.8 Summary of Part 2

A simple acronym tool can enhance the awareness and focus of a single pilot in an emergency situation to the point where they fly more accurately than those who have greater and more recent experience. Having just one general single pilot resource tool such as FDACS can eliminate the potential confusion and distraction of a multitude of possible check lists and concentrate a pilot's mind onto the single most important aspect of flying, particularly in a high stress situation such as an engine failure; to maintain the aircraft in a positive flight attitude

Considering the discussions in the previous three chapters, the following chapter will explore the possibilities for improving support for pilots after they have gained their license, not just in the days and months immediately after licensure, but for their entire flying career in UK GA.

Chapter 10: Post Licensure Support and Monitoring

Chapters 8 and 9 looked at the various ways in which training and GA operations can be improved to enhance safety, through SPRM and better emergency procedures training.

This chapter will discuss current licensing systems within UK GA and how they only provide local support to newly qualified pilots. It will also demonstrate how those who have been licensed for longer periods of time are not sufficiently monitored, assuming they maintain minimum flying requirements as laid out by the aforementioned flying clubs.

10.1 The current system and currency for infrequent flyers

Once an individual has gained their PPL they are free to fly within GA according to the privileges of their license. At no time post licensure will they be required to prove their competence, unless requiring a license revalidation. As cited in Chapter 3, minimum flying hours are stipulated, but there is no suggestion within the rules to say these minimums must be evenly spread over the period suggested, providing a loophole whereby a pilot may not fly for two months, then make a return trip totalling four hours and then not fly again for another two months. Whilst the pilot now has currency of four hours recent flying, it was done after a lengthy hiatus and as such cannot indicate that the pilot is in good flying practise.

This situation has the potential to allow a pilot’s skills to deteriorate to a level where they are no longer safe to fly, especially if the pilot flies infrequently. Even if they fly regularly, bad habits, complacency and poor airmanship may be allowed to creep in as the pilot’s flying experience grows. For commercially qualified pilots this may not be the case, but if they fly jet airliners on a day to day basis, it is conceivable that transitioning to a single engine piston (SEP) light aircraft when off duty has the potential to be problematic, particularly if their familiarity with the SEP is limited.

Most flying clubs subject their members to minimum flying currency and enforce these regulations stringently. It is suggested, however that the ambiguity concerning number of required hours per fixed period of time (12 hours flying in 12 months; CAA, 2012), as mentioned above, does not directly tackle issues of pilot currency and the regulations need to address this more specifically, requiring that GA pilots fly a minimum number of hours per month. A recommendation would be to retain the same overall value of currency at one hour per month plus a training flight with an

Instructor for those who have not flown a minimum 24 hours in any 12 month period (i.e. they have flown one hour per month, but in total have flown less than 24 hours in the 12 month period).

To ensure compliance, it is additionally suggested that flying clubs annotate pilot log books to verify hours flown after each qualifying currency flight is completed (e.g. at the point every month where the mandatory hour is completed, whether that be after one flight or a number of shorter flights). Thus a pilot wishing to fly from a different club will have a quick reference log to demonstrate to the new club that currency compliance has been maintained, without having to demonstrate competence to an Instructor as is often the case upon joining a new club.

Arguments for currency to be maintained via restricted use of simulation were raised by Allerton (2002) and are supported here, the GA survey having shown that for 43% of respondents, the cost of flying affects how often they fly and as such negatively impacts on their currency which, in Chapter 7 was shown to be an important causal factor in accidents. Accordingly it is advised here that up to three of the mandatory monthly hour flights be allowed to be performed in a basic flight training device, under the supervision of either an Instructor or a club representative to ensure proper procedures are adhered to in the more forgiving confines of a simulator.

10.2 Skills retention and periodic assessment

The sample data demonstrated that many UK GA pilots maintain a good level of currency, but to do so risks them eroding skill levels through a mixture of complacency, developed bad habits, lack of practise of certain manoeuvres and natural degradation of the memory concerning certain procedures over time. This in turn presents an issue of safety, particularly as it is likely that the degradation of skills will not be noticed by the individual.

Supporting pilot skills through periodic assessment after they have qualified is a possible method through which GA safety can be improved. The logistics of such a scheme would however pose some problems; who would the assessors be, what would be involved, when would it be required and at what cost to the pilot?

The UK has an established network of Flying Instructors who would be the first choice for the assessor roles, but the needs of the 20 000 or so PPL pilots in the UK would potentially put a strain on that network. A secondary solution would be the introduction of designated skills assessors, regular GA pilots with a given minimum of experience who would be prepared to undertake training to qualify as an assessor. They would then be able to perform those duties as and when they were needed or available. Of course a training course would have to be devised and volunteers selected, but there is a community feel to UK GA and given the power to manage this sort of project internally, the community is more than capable of producing results. Any such course would need to satisfy conditions of EASA's Acceptable Means of Compliance, Part FCL and be supported by the UK CAA if it were to be formally implemented.

The assessment would take the form of a short flight encompassing the main skills of aircraft handling; take-off, climbing, turning, descending and landing. This could be achieved in one half hour flight, keeping expense and use of pilot personal time to a minimum. Prior to the flight a short oral or written test to ensure the fundamentals of navigation, bad weather, technical knowledge and emergency procedures are understood could be undertaken (to practise these in the air would be time consuming and add to expense).

The results from the sample data as presented in Chapters 7 and 8 and other studies would suggest the best time for assessment would be at or around the 200 hour mark, with a 50 hour margin either side for completion. As there is evidence to suggest that good currency reduces accident risk, there would be scope to offer a postponed assessment to 400 hours for those who can demonstrate a pre-determined level of acceptable currency. Beyond this point there is little evidence solid enough to maintain the assessments should continue, but prudence would infer that a second appraisal should take place at around the 600 hour mark, again with 50 hours grace either side for completion. Some pilots may take years to reach this point and indeed some never will, but for those that do, if they consider themselves to be competent pilots then they should feel no malice at being asked to confirm that assumption for the sake of safety.

Given the intention of these assessments would be to improve safety through maintaining skills, it is not unreasonable to expect the cost to be shared equally between the regulatory authorities, insurance companies, flying clubs, pilots and associations such as AOPA and the General Aviation Safety Council. The issue of cost is of continual concern, especially in GA and proper discussion and debate would no doubt be required to agree on a fair system.

10.3 Planning and performance

Small aircraft such as those used in GA are sensitive to factors such as weight distribution and environmental conditions in terms of their performance. If not loaded correctly, they can become unstable and difficult to control, whilst added weight can have a negative impact on performance (e.g. increasing the take-off and landing distances required).

Similarly, the characteristics of a runway can influence the performance of an aircraft. Surface type influences the amount of runway required for both take-off and landing; grass for example can increase these requirements, particularly if long and wet. Any slope on the runway will also affect performance, but in which sense depends on the direction of either take-off or landing. Surroundings can also dictate performance requirements, obstacles such as trees, for example, effectively shortening the amount of useable runway due to the clearance needed to avoid the obstacles.

Even the weather affects aircraft performance. A lack of wind makes for a more controllable aircraft on landing, but to attain (on take-off) or maintain (on approach) the correct airspeed in still air results in a faster over-ground speed ultimately necessitating a longer distance to either take-off or stop after landing. Warm air is less dense than cold air and reduces engine power, thus on a warm day, the aircraft will not accelerate as quickly as it would in cold air, again increasing the distance required for take-off.

All of these factors (weight, balance and performance) can be taken into account and the correct requirements for safe take-off and/or landing calculated for a given aircraft. These performance calculations should form part of the planning process, but are not a legal prerequisite and as such are not perhaps made as often as they should be, particularly when the conditions may demand that they are (at small aerodromes with short runways for example). This may be the case when a pilot flies to an aerodrome with which they are not familiar, previous perceptions about aircraft performance at their home aerodrome dictating the assumption that landing and/or take-off will not pose any problem as that is what the pilot has been used to.

The sample data has shown that accidents have occurred due to a pilot attempting to land or take-off from a runway not suited to the aircraft's available performance. Had the pilots completed performance calculations, this would have been evident in the results and the manoeuvre not attempted.

Thus it is suggested that a means of monitoring be implemented in the form of pilots being required to submit completed performance and weight and balance sheets to the departure aerodrome club/school in order for them to verify the aircraft is capable of the intended flight. To appease arguments of wasted time, where the aircraft is not due to carry more than what is considered a normal load (two persons plus a flight bag for example) or be flown to an aerodrome posing any difficulties in performance (adequate runway length, suitable surface and no obstacles for example), then the pilot may be permitted to submit a declaration of normal operations.

10.4 Refresher theory training

As has been maintained throughout this thesis, sound theoretical knowledge is vital to pilots as it forms the basis for gathering of information in the decision making process. Whilst some theory taken for the (N)PPL will be regularly used by most pilots (navigation, meteorology, communications, for example) there are those that are not and it is recommended that specific modules are refreshed periodically, given the importance of the content in each.

Knowledge of human performance is vital if pilots are to remain aware of the affects that flying can have on the human body and the potential effects on pilot skill that certain conditions and consumables (alcohol and drugs) can have. Principles of flight is also a subject containing vitally important information that a pilot must retain in order to maintain a healthy level of awareness in terms of why an aircraft is able to fly. Similarly, aircraft general knowledge is important in that a pilot needs to know how an aircraft works. Whilst it is not suggested that pilots are made to re-sit these examinations, it is recommended that they are given refresher tuition on the contents of each subject which should be recorded either in the club's files and/or the pilot's log book. One hour per subject should be sufficient and a frequency of every five years is considered to be adequate.

Additional to the subjects named above, the new emergency procedures module proposed within this thesis would be an ideal candidate for refresher training, given its potential importance in instructing pilots in all aspects of emergency situation management.

10.5 Summary

Outlined in this chapter are potential additions and extensions to the current post licensure support and monitoring system that would ensure good pilot currency, retention of skills, improved planning and a solid level of aeronautical knowledge, all essential for safe flying. The changes suggested would not require an overwhelming re-organisation of regulations, but a simple addition to some of the administrative processes procured at the flying club level.

The following chapter will formally summarise all the proposals and recommendations made throughout the thesis concerning UK GA pilot training, theoretical instruction, implementation of SPRM and post licensure support and monitoring.

Chapter 11: A Summary of Thesis Proposals

Within this chapter, the main proposals and recommendation presented throughout the thesis will be summarised. They fall into three categories, namely theoretical instruction, practical flight training, and support and monitoring.

11.1 Theoretical instruction

The following proposed additional modules are considered appropriate for those studying at (N)PPL level, but could easily be integrated as sub-headings in modules for the ATPL examinations.

11.1.1 Emergency procedures module

It is proposed that a module be devised to raise awareness in the student pilot of the main conditions and precursors that lead to accidents. Topics covered should include the correct method of lookout, the value of a considered instrument scan, pre-flight planning errors and omissions, principles of the go-around and advice on stall prevention through better situational awareness.

Reference should be made to other relevant modules studied as part of the required theoretical knowledge course and contextualised in terms of the topics mentioned above (e.g. principles of flight and stall prevention, human performance and the lookout or instrument scan).

Use should also be made of accident reports to highlight issues such as levels of type experience compared to total experience, poor decision making and the sunken cost theory related to continued flight into impoverished weather conditions or continuation of a landing when good airmanship should dictate that a go-around is necessary. Examination should take place in accordance with the requirements for existing theoretical modules.

11.1.2 Resource management theory for the single pilot

Whether contained within the aforementioned emergency procedures module or, as is recommended, devised as a standalone subject, the principles of resource management should be taught to student pilots. Suggested learning outcomes would be that pilots would have a better understanding of all the resources available to them both in normal and ab-normal situations. Topics should include best use of the radio, making the most of what is already to hand (maps, operating handbooks, instruments etc.) and how to guide passengers (if carried) on how they may be of assistance (lookout, reading the altimeter or air speed indicator, map reading etc., to a point where the passenger is both competent and confident).

Decision making should also be addressed, including the processes involved, the importance of good information and the psychology of certain conditions, such as being close to the intended destination, but deteriorating weather approaching the planned aerodrome. Complimenting this, skills of task and time management should be taught with a view to some emergency situations being prevented in the first place.

Again, accident reports should be used to demonstrate scenarios where a lack of resource management skills was implicit in the causal factors.

Additionally, use of an SPRM tool, similar to FDACS should be implemented within the module, with the sole intention of highlighting to students that the most valuable resource at any time is their skill in flying the aircraft and that this is to be prioritised at all times.

Examination would also be as per the requirements for the existing theoretical modules.

11.1.3 Refresher theory training

As stated in Chapter 10, refresher training for (N)PPL theory does not imply that pilots should receive lengthy instruction and examination of all the modules taken during flight training. Instead, one hour of refresher instruction or discussion is proposed for each of the following subjects: human performance, principles of flight, aircraft general knowledge, emergency procedures and SPRM. The suggested frequency is every five years and does not have to be on a one-to-one basis. Instead group discussion, led by a qualified instructor (or volunteer) is encouraged as it allows greater opportunity for pilots to raise relevant issues they may have encountered themselves or pose questions they may have in a more informal manner, inducing a better absorption of information than might otherwise be achieved by a lecture style presentation.

11.2 Practical flight training

In line with the theoretical instruction proposals, the practical flight training suggestions here would serve their purpose effectively in both (N)PPL and CPL/ATPL training.

11.2.1 Stall prevention

It is proposed that in addition to stall recovery techniques, pilots are shown how to recognise threats that if ignored, may lead to an aircraft stalling. Lack of attention to air speed, recognising high nose attitudes and understanding how they can result in the critical angle of attack being reached should all be discussed in the pre-flight briefing and where possible, demonstrated in the air. Demonstration of how an aircraft can stall in a normal flight attitude should be included, with a view to expressing to a student that stalls do not always occur after the aircraft has been robustly placed into a position where the stall is actually falsely induced, but can in fact occur in seemingly benign flight conditions.

11.2.2 Advanced landing and take-off skills

At a stage either later in training, when a student has more confidence and is comfortable with the aircraft, or indeed post licensure as an additional rating, training in conditions that are within structural limits of the aircraft, but outside the experience of the student/pilot is encouraged. The nature of flying results in some people learning to fly without ever having encountered acceptable, but gusty conditions and being able to maintain positive control of the aircraft in the conditions is vital to safety. Thus it is proposed that training be permitted in cross-wind and/or gusty conditions to familiarise individuals with the associated techniques that they otherwise may not have had the opportunity to do.

In line with proposals yet to be summarised, it is recommended that use of basic flight simulation devices be permitted to demonstrate the principles of cross-wind landing and take-off techniques prior to or instead of performing them in a real aircraft.

11.2.3 Currency regulations

Current regulations concerning levels of minimum currency should be clarified to dictate that pilots should fly one hour per month in order to retain flying privileges, as opposed to just 12 hours in the previous 12 months. It is also suggested that these regulations include the clause about a training flight with an Instructor, but specify this is only applicable to those who have flown less than 24 hours in the preceding 12 months. The minimum requirements for number of take-off and landing manoeuvres is sensible and adequate and assuming a pilot maintains the above minimum requirements, is likely not to be an issue.

Given the evidence presented in the thesis concerning type experience, there is reason enough to recommend that pilots who transition to another aircraft type not requiring a specific type rating should be subject to a minimum of two hours flight time on the new aircraft, supervised by an Instructor or other suitably qualified and authorised (by the Chief Flying Instructor) person.

11.2.4 Simulation needs authorisation

Given the arguments presented within this thesis and despite potential issues of initial financial outlay to flying clubs, it is proposed that regulatory authorities grant permission for basic flight simulation devices (both visual and non-visual) to be used both for (N)PPL flight training and maintaining of currency requirements.

This would allow the five hours of current instrument appreciation to be extended to seven hours, a further three hours being recommended in a real aircraft to allow adjustment to aircraft movements and other potential distractions, such as ATC communications.

Up to an agreed, sensible maximum, the use of simulators is proposed as a means to enable many pilots to retain minimum levels of currency when factors such as bad weather or cost might otherwise prevent it. It is accepted that there is no substitution for flight experience in a real aircraft, but to perform token sessions in a simulator to retain basic skills is recommended in that it is preferable to not flying at all.

11.2.5 Go-around training

It is recommended that the go-around manoeuvre be implemented as a separate exercise within the flight training schedule. Often cited in commercial operations as routine, going around is a measure taken for the sake of safety when the pilot is not happy with the approach or landing attempt, or the runway has not been cleared of traffic. It should therefore follow that the manoeuvre itself does not pose any threat to either the occupants of the aborting aircraft or those on the ground and as such should be thoroughly trained as a specific exercise as opposed to being a periphery subject within exercise 13 (circuit, approach and landing; Chapter 3). It is recommended that following a thorough brief on the principles and actions, initial practical training be completed at altitude in a safe area to establish a solid appreciation of the procedure before making aborted approaches within the circuit. The set of go-arounds performed in the circuit should start at a sensible initial height, reducing in stages for each subsequent practise. It is further recommended that wherever possible, this manoeuvre is practised at least once at an unfamiliar airfield.

11.2.6 Refresher training and competence assessment

As discussed in detail in Chapter 10, a proposal is made here to introduce compulsory refresher practical flight training and competence assessments at stipulated stages in a pilots flying career. The recommended point of training is suggested at between 150 and 250 hours experience on GA aircraft. This would encompass those pilots who may also have thousands of hours experience on commercial airliners, but limited flight time on small piston engine aircraft, which again refers back to the issues identified with type experience. A second recommended competence test should be considered at between 600 and 700 hours, beyond which there would be no further compulsory assessment, given that only 30.9% of (N)PPL pilots in the sample had over 700 hours total experience. For those who can demonstrate good levels of currency (suggested here to be more than one hour per week) the competence test may be waived in a move to placate those who may feel despondent at having to demonstrate their competence despite being regular fliers.

To alleviate pressures on the instructing framework, as suggested in Chapter 10, designated persons may be permitted to act as skills assessors following demonstration of minimum levels of their own experience and currency and a short training period to qualify.

Both the training and competence assessment should consist of all the elements laid out in this chapter, plus those that may not be regularly practised as part of a recreational pilot's regular regime; namely stall prevention (and recovery), instrument appreciation, the go-around, practise forced landings and the engine failure after take-off.

11.2.7 Oral testing prior to practical flight examination

Before being permitted to take their practical flight test, it is proposed that pilots demonstrate their understanding of the theoretical modules studied in an oral test, which may take the form of structured questions of a formal discussion at the discretion of the Examiner. Failure of the oral test will result in cancellation of the practical flight test until such a time as the pilot can exhibit a level of acceptable theoretical understanding.

It is recommended that the test last approximately 30 minutes and cover at least three subjects vital to flight safety such as emergency procedures, human performance, principles of flight, aircraft performance or technical subjects from the aircraft general knowledge module; these may be at the discretion of the Examiner.

11.3 Support and Monitoring

11.3.1 Greater powers and responsibilities for flying clubs and schools

To enable enforcement of the proposals made in this chapter it is proposed that clubs and schools take a greater responsibility in ensuring that pilots adhere to the minimum standards and requirements set. To support this it is suggested they are given greater authority to refuse hire of aircraft, based on the evidence presented to them by pilots concerning their license privileges and currency (e.g. pilots should be refused aircraft hire if the weather forecast for their route and/or destination is marginal unless they can provide evidence of a valid IMC or IR. If such a flight is permitted without appropriate checks, the despatching club or school should accept joint legal responsibility along with the pilot for any consequences).

11.3.2 Verification of currency

Pilot should present their log books for verification stamping/annotation upon achieving the one mandatory hour per month flight time. For those who do not manage to achieve the minimum, their log book should be appropriately annotated following the required flight with an Instructor. These stamps/annotations should be recognised by all flying clubs in mutual recognition of a pilot's level of currency, thus reducing the necessity for pilots joining new clubs to be forced to perform a competence check with one of the clubs Instructors. It is still, however recommended that new pilots submit themselves for a circuit familiarisation flight with an Instructor or other authorised pilot.

11.3.3 Weight, balance and performance calculations

Where a pilot intends to fly an aircraft where the load is greater than that normally carried in a particular aircraft type (two passengers plus luggage in a Cessna 152 or three persons in a PA-28 for example) they must not be permitted to fly unless they have completed appropriate weight, balance and performance calculations, the results of which must be verified and accepted by the departing club/school as correct.

Similarly, if a pilot intends to fly to an aerodrome where runway length, surface or surroundings are known to be restrictive, again the pilot must not be allowed to depart until the aforementioned calculations are made for both arrival and departure at the destination. The destination aerodrome must be informed of release to depart, before they accept the aircraft for its arrival; this can be done by phone, fax or e-mail.

These regulations should be enforced by clubs and schools under threat of penalties, such as exclusion or restricted flying if not followed by pilots.

11.4 Summary

The proposals submitted here are derived from analysis of the sample accident report data and 2011 survey results discussed within this thesis and are designed to be as practical, applicable and effective as possible with the aim of improving the professionalism of pilots within GA and ultimately improving safety. They are not inflexible and are open to modification and improvement as necessary.

Chapter 12: Conclusions

This thesis has shown that despite a robust training and examination system in the UK, GA pilots (particularly those at (N)PPL level) are not being fully prepared for the multitude of potential problems they may encounter in their flying career. Moreover, they are not being refreshed on some of the more critical areas of flight safety and thus if/when they encounter an issue, they are not sufficiently practised in the appropriate procedures to recall the skills needed to produce a positive resolution.

Where many emergency situations required timely and good decision making, training in both theory and practical does not necessarily provide pilots with the ability to gather reliable and useful information with which they can formulate appropriate decisions.

In connection to this, UK GA pilots are not offered important theoretical knowledge specifically surrounding emergency situations.

GA pilots are also not furnished with a suitable single pilot resource management tool, or the theoretical knowledge to support such a concept, despite its recognised value in multi-pilot commercial operations.

Levels of currency have been shown to be important factors in accident causation and the issue of cost has been determined as a likely reason, yet simulation is still not a viable option within GA despite the clear potential that this apparatus can have on both of these factors.

Concurrent with simulation, instrument appreciation is not sufficient to help pilots who find themselves in conditions of impoverished visibility. Arguments that to enhance this aspect of training will only serve to supply pilots with an excuse to purposefully fly into such conditions are dismissed as nonsensical, the majority of pilots being more sagacious than they are generally given credit for.

With regard to practical training, the current resolve to train pilots to recover from a fabricated, unrealistic stall, following a briefing does not adequately appraise pilots of the possibility for an aircraft to stall at what could be considered benign attitudes and flight conditions. Prevention must be advocated as a sensible addition to this exercise.

There is a statistical likelihood that pilot experience on aircraft type is a major influence in GA accidents and there is an insufficient level of attention to this factor, pilots seemingly being allowed to fly solo on aircraft with less than one hour's flight time on type.

The accident rate and number of accidents resulting in a fatality compared to commercial operations is considerably higher, but there is no reason why the UK GA industry should submit to this situation and should, in conjunction with regulatory authorities, make serious consideration to the proposals made in this thesis, with a view to enhancing what is already a good training and examination regime.

Moving forward, the GA industry needs to invest in research to further that undertaken in this thesis and in particular should focus on training methods best suited to ensuring that amateur pilots take the controls of their aircraft with an appropriate level of knowledge and understanding and skills biased towards preventing, as opposed to recovering from dangerous situations.

With the progressive introduction of 'glass cockpit' GA aircraft and those powered by diesel and (eventually) electric engines, research should determine whether current post license monitoring provides appropriate training, advice and assistance to those who decide to transfer to such aircraft.

Most importantly, future research should ascertain the level of human factors knowledge and understanding GA pilots possess and how they utilise it in their everyday operation of light aircraft. It is a lack of understanding and awareness in this area that has the greatest potential to put pilots and their passengers at risk of accident involvement.

Whilst commercial aviation enjoys the benefit of research by top level organisations such as NASA, producing the safest form of transport in modern society, UK GA and GA in general does not earn similar interest or importance, resulting in a level of safety far below that experienced by airline passengers and an average fatal accident rate of approximately one death per month in the UK alone.

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Appendix A: The General Aviation Survey Questions

1. Your age
2. What level of license do you hold
3. What additional ratings do you hold?
4. What kind of flying do you mostly partake in?
5. What type of GA aircraft do you fly?
6. How many hours experience do you have?
7. If you have experience on more than one aircraft, please state how many hours you have on the most recent GA aircraft you flew
8. How many hours have you flown (on any aircraft type) in the last
    a. 90 days
    b. 28 days
9. On average, how often do you fly?
10. How much is the frequency you fly affected by:
    a. Cost
    b. Personal free time
    c. Weather
    d. Aircraft availability
    e. Airfield operating times
    f. Daylight hours
    g. Distance to airfield from home
11. Have you ever been forced to divert or make a precautionary landing due to bad weather?
12. Have you ever had suspected engine carburettor icing?
13. If you answered “yes” to Q. 12, in what phase did the suspected icing occur?
14. Have you ever had to perform a go-around?
15. For what reason(s) was the go-around performed?
16. Have you ever aborted a take off?
17. Was the abort successful (i.e. you did not overrun the runway, lose control or damage the aircraft)?
18. For what reason(s) was the take off aborted?
19. How often, when flying, do you consider the actions you would take in an emergency?
20. How often do you perform PFLs?
21. Please rate the following on a scale of 1 – 10 in terms of difficulty where 1= not difficult at all and 10= extremely difficult

a. Taxiing
b. Taxiing in wind
c. Take off
d. Take off in wind
e. Climbing
f. The cruise
g. Descent
h. Approach (no wind)
i. Approach in wind
j. Round out and flare (no wind)
k. Round out and flare in wind

22. How do you rate yourself as a pilot?
23. If a quality simulator was available to you at a cheaper rate than aircraft hire, would you use it to practise flying skills, emergency scenarios, navigation, instrument flying, PFLs etc.?
24. Do you consider there to be room for improved simulation in GA?

Appendix B: Letter sent to flying clubs and schools requesting participation in the 2011 GA survey

13th September 2011

Dear Aviator

Please find enclosed a small number of General Aviation survey forms. I would be most grateful if you could ask club members/students/instructors to complete it. You may or may not have received my e-mail about the survey online, but following a few requests for hard copies, I have decided to send some out to a small number of selected clubs/schools (chosen by the fact that I have flown to/from your home airfield at some point in my flying career). I have included an information sheet about the survey and my PhD project which may be of interest to those who kindly agree to complete the survey and the consent form which responders may initial or sign on the back. The information sheet also includes my University contact details.

For your convenience I have enclosed a pre paid envelope, addressed to me at home to ensure that I personally receive all the forms. It would be greatly appreciated if completed forms could be returned to me by Tuesday 11th October.

If any other persons (UK GA pilots) are interested in completing the survey, they can access it directly at: www.surveymonkey.com/s/GAquestionsAT (or feel free to photocopy the form).

Many thanks for your time and assistance and I look forward to hearing from you soon.

Yours sincerely

Andy Taylor

Aviation Post Graduate Research Student

The University of Leeds

Appendix C: 2011 GA survey participant information sheet

Research Project Survey Information Sheet

Research project title: The Viability and Effectiveness of Implementing Single Pilot Resource Management into UK General Aviation.

Dear Aviator

You are invited to take part in a research project being undertaken by an aviation PhD student at The University of Leeds. Before deciding whether or not to complete the questionnaire, please take some time to read the following information which will offer you the opportunity to understand the purpose of the project, its aims and how your contribution will help achieve those aims.

1. Purpose of the project: Since January 2005 there have been on average 143 general aviation (GA) accidents per year as reported by the UK Air Accidents Investigation Branch. Thankfully 90% resulted in just minor or no injuries to those involved. This still leaves 10% who were seriously injured, or worse. The implementation of a new tool to help pilots in emergency situations to bring the event to a successful end has the potential to reduce that 10% figure. The tool is based on the Crew Resource Management (CRM) currently used in commercial aviation which has had a positive impact on safety, but is adapted for pilots who are the sole commander of a GA aircraft and is called Single Pilot resource Management (SPRM). This project aims to determine how viable such a tool would be to implement in the UK and measure its potential impact on safety. To do so requires data concerning the activities of UK GA pilots to be compiled and analysed – data that is currently not available from any aviation authority in the UK.

2. The participants: The questionnaire has been sent to more than 120 flying clubs and schools around the UK and all members, guests and staff with pilot licenses have been invited to take part.

3. Choosing to take part: Completing the questionnaire and returning it is completely voluntary and no one is in any way obliged to take part or otherwise persuaded to do so if they have any doubts. If you do decide to take part you will be asked to fill in a short consent form before starting and may withdraw at any time by simply informing the author. You do not have to give any reason for withdrawing

4. Taking part: If you decide to take part you will be directed to an online questionnaire which should take no more than 10 minutes to complete. You do not have to answer all the questions if you do not wish to and may ignore any you prefer not to answer. After submission you will not need to do

anything else and your participation in the project will be complete. Completed questionnaires need to be returned by 31st December 2011

5. Confidentiality: Any personal information you provide will be treated in the strictest of confidence and will only be available to the author and his project Supervisor. They will not use personal information for any purpose other than to identify your answers should you wish to withdraw. The answers you give in the questionnaire will be collated with those from other participants and statistically analysed as group data. No individual's answers or information will be reproduced in any report or publication. Only the combined results will be published or reported on, but may be used more than once whilst the project is ongoing (expected completion date, September 2013) and for future research beyond that date.

6. Information you will provide and why it is needed: The Questionnaire (22 questions) will ask you about your flying to date, for example; the number of hours experience you have, the aircraft type you fly, how often you fly, any difficulties you have encountered and some basic personal information such as your age. It is hoped that the information gathered will provide a "snap shot" database of the UK GA pilot population which has not yet been achieved. In time the data will become invalid because the information gathered will change as participants add hours to their log books, get older, change aircraft type, etc. It will however be sufficient to allow the author to make statistical comparisons with pilots who have been involved in accidents and subsequently determine any trends that contribute to accidents so that they may be reduced or eradicated via SPRM.

7. The author: Andrew Taylor holds a valid Private Pilots License and has over 200 hours experience on single engine GA aircraft. He also has a First Class Degree in Aviation Technology with Pilot Studies from The University of Leeds.

8. Contact information: Should you have any questions concerning the project, questionnaire or use of the information gathered, please do not hesitate to contact the author or his Supervisor;

Andrew Taylor (Author).

E-mail: pre4at@leeds.ac.uk

Address: Post Graduate Research Student

SPEME

The University of Leeds

Leeds

LS2 9JT

Dr Darron Dixon-Hardy (Supervisor)

E-mail: d.w.dixon-hardy@leeds.ac.uk

As a potential participant you are welcome to save or print this information sheet for your own records and future reference. Thank you for taking the time to read this information and many thanks in advance should you choose to take part in the project.

Appendix D: Sample of data presented in spread sheet form, columns 1 – 11

A/C Reg	Year	Total	Type	Last 90	Last 28	Age	Injuries	License/training	HF/NHF	Cause/info
G-BPJV	2005	340	220	7	4	52	m	ppl	hf	CFIT
G-BGIB	2005	813	514	169	54	38	n	cpl/training	nhf	technical
G-EEKY	2005	90	4	4	1	29	n	ppl	nhf	technical
G-BSHY	2005	1712	375	2	1	65	s	ppl	hf	Airmanship
G-FOXX	2005	696	13	11	5	71	n	ppl	hf	LOC/meteorological
G-OFSA	2005	631	10	2	1	67	m	nppl	nhf	LOC/meteorological
G-BVHF	2005	815	8	129	24	32	n	cpl/training	hf	LOC
G-BZDT	2005	480	290	60	45	42	m	ppl	hf	LOC
N61MF	2005	274	51	10	5	45	m	ppl	hf	Airmanship

Appendix D : Columns 12 - 15

Cause/info	Cause/info	Phase	Weather
VFR-IMC	snow storm	Cr	P
engine failure	carbice during PFL	D	I
engine failure	poss fuel restriction or carbice	D	I
collision	hit tree on GA+fwd vis limited	GA	
air movement	turbulent conditions	GA	W
air movement	down draught	GA	W
stalled	Instructor Vs student correcting roll	GA	
air movement	severe turb+d'ndrafts=stalled	GA	
collision	baulked landing=collided with fence	GA	

Appendix E: Location of Mid-air collision (red circle) as