Review of existing Class G airspace risk studies

What do we know?

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Executive Summary

Introduction

The UK CAA “Class G in the 21st Century” report contained a recommendation to undertake an in-depth analysis of the UK Airprox database, to develop an improved understanding of how safety in Class G airspace can be enhanced. The CAA contracted Helios to conduct this review.

The primary aim of the study is to investigate and document, using UKAB and supporting data, the specific causal and mitigating risk factors that increase the likelihood of a mid-air collision (MAC) within Class G airspace. This includes identification and analysis of mitigating factors or ‘barriers’ and the development of leading indicators to strengthen the proactive management of MAC risk in the future. The output of the project will help inform the CAA’s work to reduce their ‘Significant 7’ Airborne Conflict risk, the Airspace & Safety Initiative (ASI) and Future Airspace Strategy (FAS) as it relates to Class G. The MAA will also use the project’s results in their work to address MAC in the military environment.

The study has been divided into three distinct tasks:

- Task 1 (this document): A detailed review of existing risk studies (specific to Class G airspace) was carried out, enabling key elements of the research to be consolidated into a safety ‘barrier’ model and underlying functional map. This also informed the development of a methodology for analysis of safety risk factors.
- Task 2: Airprox reports will be analysed in terms of the causal (contributory) and mitigating factors specific to each incident. The factors will be included in the airprox database, allowing analysis to be carried out to determine patterns, trends and priorities.
- Task 3: From the analysis, objective conclusions can be drawn on factors impacting the risk of MAC, in particular their frequency and effectiveness. This may differ per airspace user and phase of flight. The aim will be to identify potential leading indicators by which the frequency and effectiveness of identified controls can be improved. This task will not include any policy or regulatory development.

Understanding the context

Any analysis of the risk factors must take into account the changing environmental context in Class G airspace. This includes the traffic levels, airspace structure, availability of air traffic services, technical enablers and so on. The study therefore carried out a review of the evolution of the environment, to assist in the analysis stage in interpreting findings correctly. The factors discussed are not novel, so the value of this activity was in bringing together multiple sources and establishing a well-understood baseline for the analysis of airprox reports.

Any aircraft may use the airspace under the Rules of the Air. The exact traffic levels within Class G airspace are impossible to measure, since it is not obligatory to file a flight plan or be under surveillance, and therefore data is not available. In lieu of this, total aircraft numbers were collated. The number of civil aircraft on the UK register has doubled since 1985, with particularly strong growth in gliders, helicopters and microlights. These figures should be used with care as they do not account for aircraft registered outside the UK and do not correlate exactly to the level of flying hours within Class G Airspace. Military flying rates and in particular low-flying inside Class G airspace have decreased by more than 50% over the same period.

The airspace structure itself has altered over the period being examined (1990s through to current). Specific local changes are noted in the report, although changes to the overall volume of Class G airspace available are not known. Anecdotally, there appears to be more controlled airspace but objective evidence was not available.

Whilst an Air Traffic Service may be available in Class G airspace, it is not mandated. This autonomy is a fundamental concept within Class G operations. In air traffic management (ATM) terms not all information on aircraft is known as it is not mandated that users file a flight plan, carry a radio or transponder, or be in receipt of an air traffic service (ATS). This is a factor in defining the level of service provision and risk mitigation that can be achieved by ATS, impacts both service provision that exists to reduce risk and the ability of the ATS systems to recover from an incident should a conflict situation develop. The unknown element of the system may also impact on the situational awareness of the pilot and the ability of aircraft systems to detect aircraft on a conflicting trajectory.

The air traffic services available outside of controlled airspace were updated in 2009 in order to improve the common application and understanding of the services. However the impact of the change has been difficult to assess due to the wide number of variables present within Class G airspace. Decreased availability of the Lower Airspace Radar Service (LARS), particularly during evenings and weekends when GA flying is frequently most prevalent, impacts the level of mitigation available to airspace users.

One of the major conclusions of the UK CAA Strategic Review of GA (2006) was that a serious threat to flight safety still exists from infringements. Avoidance of controlled airspace (CAS), danger and restricted areas is reliant on the briefing and planning process prior to flight as well as an ability to interpret charts and navigate effectively. The number of infringements rose sharply between 2005 and 2009 although this may be attributed in part to improvements in reporting. Measures such as awareness campaigns, improved charting, and an uptake of mobile GPS devices has seen that trend reversed in recent years. The presence of GPS in the cockpit was noted as one of the major trends in recent years.

The increase in transponder fitment in airspace users flying in Class G airspace has an impact on the ability to provide ATS, but is not mandatory. More recently, the advent of air-to-air surveillance through transponder-based Collision Avoidance Systems, FLARM (gliders) and Automatic Dependent Surveillance – Broadcast (ADS-B) has an impact on risk.

Other initiatives identified included the introduction of mandatory transponder or radio zones and the use of ‘listening’ squawks.

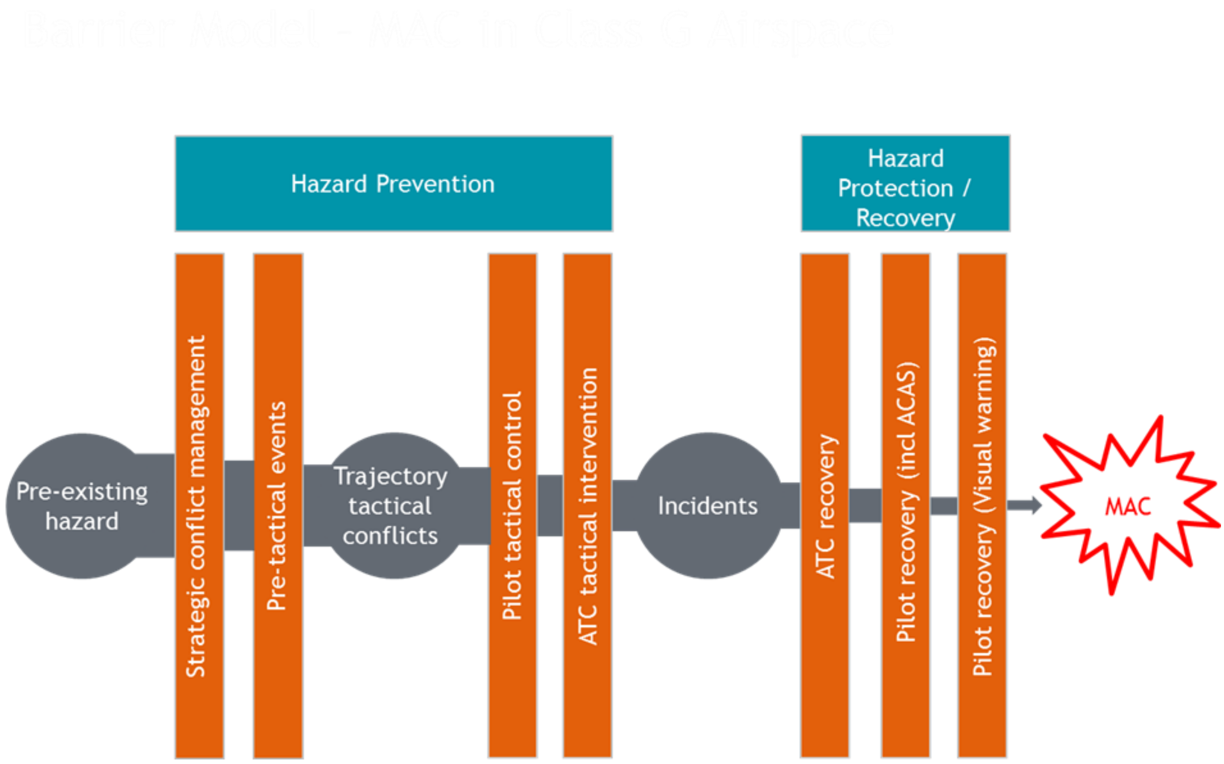
State-of-the-art: what do we know about risk in Class G airspace?

The focus of this study is on those risks which are specific to Class G, or because of some characteristic of Class G, have a higher than average likelihood. In general, this focuses upon the risk of MAC, since the unique characteristic of Class G airspace is its uncontrolled nature.

A detailed literature review was conducted, examining the documentation for any conclusions on safety risk, barriers or effectiveness measures in Class G airspace.

Utilising the findings from existing research, it was possible to group actions and events into a series of barriers that mitigate risk. The barriers can work collectively or individually to prevent the occurrence of a MAC. Furthermore, due to the diverse nature of airspace users, services, and equipment in use, the sequence of the barriers may change or the barrier(s) may be removed altogether.

The figure below illustrates the 7 key barriers that mitigate the risks that lead to a MAC.



Safety Barrier Model for Class G airspace

Key barriers mitigating risk in Class G Airspace

The barriers are grouped in two classifications, the four on the left which focus on hazard prevention and the three on the right which focus on recovery once an incident has occurred. Incident here is defined as something where it was perceived that a risk was present such that the safety of the aircraft could have been compromised (e.g. an airprox). If all of the barriers fail the conflict will not automatically lead to a MAC as there is an element of chance involved.

Strategic conflict management is anything inherent in the Class G concept of operation that mitigates the risk of a MAC occurring. Some examples are airspace and procedure design and the quality and availability of aeronautical information. They are not specific to individual flights.

Pre-tactical events such as effective briefing and planning are an important mitigating factor in hazard prevention. This includes route planning and ensuring any aeronautical data used is up-to-date. These are specific to individual flights and personnel.

A significant element of Pilot tactical control is the visual scan, as this remains the primary means for the pilot to detect and avoid other traffic in Class G airspace. However, due to aspects such as the physical limitations of the eye, environmental conditions, and aircraft design, the effectiveness of see and avoid is not 100% reliable. Furthermore, the amount of time devoted to scanning outside of the cockpit was at best only 51% of those pilots analysed. The bulk of the research suggests that see and avoid is more robust when additional ‘cues’ are available such as those provided under an ATS, radio, or electronic conspicuity. Other important elements of pilot tactical control include good airmanship skills such as implementing the Rules of the Air with due regard for other airspace users and correct application of procedures.

In order for ATC to provide effective Tactical Intervention, appropriate communication, navigation, and surveillance infrastructure must be in place. This barrier is reliant on an ATC service being available when it is requested and the skills and knowledge of an ATCO are important factors in ensuring ATC services are discharged in a safe and expeditious manner. Positive control of the visual circuit (where a service is available) is also an important factor in ensuring the safe sequencing of aircraft whilst enhancing the situational awareness of pilots.

In terms of ATC Recovery, this barrier could include the use of Short Term Conflict Alerts (STCA). However, the utility of STCA in Class G airspace is reduced compared to inside CAS due to the dynamic nature of flight paths and the impact of such on ‘nuisance’ alerts. The provision of avoiding action is also included in this barrier.

Pilot recovery is split into two barriers – assisted (e.g. ACAS) and late visual acquisition and avoidance. For ACAS to be effective, both aircraft must be fitted with a serviceable transponder which has the appropriate modes selected. Furthermore, the conflict trajectories must be sufficient to trigger a TCAS RA. Reaction by the pilot is also a vital part of this barrier in that they must react to the TCAS RA as opposed to any ATC instructions that may be issued.

See and avoid in the (earlier) pilot tactical control barrier was the ability to visually acquire other aircraft in sufficient time to maintain safe separation. In hazard recovery it is assumed early acquisition has failed, an incident has occurred, and the pilot is required to make an avoiding action manoeuvre to prevent a MAC.

Analysis of airprox data will enable the effectiveness of each barrier to be determined. In many cases it is likely that a combination of barriers will have worked together to prevent an incident such as an airprox occurring and this can also be analysed.

A methodology for data analysis

The aim of the analysis of the Airprox database is to provide more evidence for the contributory factors. These will tend to focus on the negative factors (i.e. which induce risk), due to the reports characteristics. However, the airprox reports do include some descriptions showing what prevented a potential airprox becoming more serious, and in these cases, the data will be used. It is hoped that statistical significance can be gained by the volume of contributory factors within the airprox reports.

There are many factors that influence each of the barriers such as human behaviour, equipment availability, and the operating environment. These factors have been summarised within a functional map and then further developed into an appropriate taxonomy with which to code the Airprox database.

Rather than attempt to validate the proposed barrier model, the methodology uses a grounded theory approach. Grounded Theory is a research method where the theory is developed from the data as opposed to validating an existing hypothesis. This ‘bottom up’ approach will enable us to identify and categorise each report according to the contributory factors that lead to the Airprox.

A first look at a sample of the airprox reports allowed us to develop our own taxonomy for categorising the contributory factors. These categories were then validated and the terminology adjusted to reflect ICAO’s Common ATC taxonomy. This is not a rigid taxonomy and will be updated throughout the analysis to accommodate additional contributory factors identified.

The methodology and taxonomy will be assessed via an initial pilot study prior to a full review of the Airprox database back to 1999. We will use this analysis to develop a prioritised list of safety risk factors and further analysis will be completed to establish the hazards, threats, and risks to all airspace users in Class G airspace, during each phase of flight. Through analysis and prioritisation of the hazards, leading indicators can be identified.

Contents

List of figures

List of tables

1 Introduction

1.1 Background

The Civil Aviation Authority (CAA) has contracted Helios to conduct a review of operations and interactions within Class G airspace in order to develop an improved understanding of how safety in Class G airspace can be enhanced. A Steering Group comprising members of the CAA, UK Airprox Board (UKAB), and Military Aviation Authority (MAA) has been established to guide and oversee the study. The purpose of the study is to build on the work undertaken by the CAA in their report “Class G in the 21st Century” (2013) [1].

The primary aim of the study is to investigate and document, using UKAB and supporting data, the specific causal and mitigating risk factors that increase the likelihood of a mid-air collision (MAC) within Class G airspace . This will include identification and analysis of mitigating factors or ‘barriers’ and the development of leading indicators to strengthen the proactive management of MAC risk in the future. To understand the barriers preventing a MAC and to improve their effectiveness, an analysis of airprox reports and global state-of-the-art will be carried out. Particular focus will be given to identifying contextual or systemic factors which alter the effectiveness of existing barriers.

Additionally, the project will seek to identify gaps in existing data collected on airprox occurrences, in order to improve monitoring, data analysis and identification of risk in the future. This will be done in consultation with the UK Airprox Board. The output of the project will inform the CAA’s work to reduce their ‘Significant 7’ Airborne Conflict risk, the Airspace & Safety Initiative (ASI) and Future Airspace Strategy (FAS) as it relates to Class G. The MAA will also use the project’s results in their work to address MAC in the military environment.

1.2 Scope

The study has been divided into three distinct tasks underpinned by project and quality management support. The three core tasks are summarised below:

Task 1: Conduct a full review of all key existing studies relating to the Class G airspace concept of operation. A report is provided (this document), and methodology developed for further analysis of safety risk factors through additional research within Task 2. The content of this document relies heavily on the quality and detail in the review material as now new analysis is performed at this stage.

Task 2: Task 2 will develop a prioritised list of safety risk factors for Class G airspace. This task will include consultation with UKAB to establish a clear methodology for analysing Airprox reports. The mechanisms for reporting both Airprox and other occurrences will be reviewed. Airprox reports will be analysed in terms of the causal factors which led to the incident. This will enable a clear and updateable method for Helios to assess common causal factors across many incident and accident reports, and enable ordering of causal factors by their importance to create a priority list.

Task 3: Having established a prioritised list of safety risk factors through Task 2, further analysis will be done on these factors to establish the hazards, threats, and risks to all airspace users in Class G airspace, during each phase of flight. Through analysis and prioritisation of the hazards, leading indicators can be identified.

The study is necessarily focused on the use of existing data; no new data collection through research activities is envisaged. For that reason, there is a reliance on the quality of the existing data and the project's analysis methods in deriving findings or recommendations. The airprox data in particular will be used "as-is", without further validation of individual reports.

1.3 Structure of this document

In understanding what we know about Class G airspace, this report considers the following:

- What is the changing context of Class G airspace? – Section 2 contains a summary of the main factors impacting the Class G environment and how they have evolved.
- What are the main risks in Class G airspace? – Section 3.2 contains a summary and shows the focus on MAC as a specific Class G airspace issue.
- What are the main controls to these risks? – Section 3.3 lists the identified controls, or barriers, to the risks in Class G airspace, particularly MAC.
- Why do these controls work, or why don't they work? – Section 3.4 and 3.5 explain the effectiveness of the controls, and highlight some key contributory factors to this effectiveness.
- What are the key references and resources for an understanding of Class G airspace risk? – Annex C contains a detailed listing, including the key points included in each reference.

There are also annexes containing acronyms (Annex A), references (Annex B) and a summary of specific Class G characteristics for ease of reference (Annex D).

2 Evolution of the UK Class G environment

2.1 Why is understanding the environment important?

This study aims to understand what we know about Class G airspace risk and the factors impacting upon it. Prior to doing this, it is important to understand what we mean by Class G airspace; the criteria and rules, traffic, services, and functions available (communications, navigation, surveillance). A supplemental description of the Class G airspace concept of operations is contained within Annex D – it refers primarily to existing AIP and CAA publications, and is included for ease of reference.

The environmental context is continually evolving and has a clear impact on the resultant risk to individual aircraft. For example:

- new barriers could be added over time in geographical areas, such as transponder mandatory zones or changes to ATS provision;
- other barriers could be taken away or modified, such as a reduction or enhancement in the availability of Lower Airspace Radar Services (LARS);
- contextual factors may change such as the complexity of the airspace, the presence of new users, or variations in traffic density.

When analysing the factors leading to risk-bearing situations (perceived or actual), the study must therefore understand the context within which these situations occur.

The following sections provide some of the environmental context against which we will conduct our analysis. Notably, if the analysis of the airprox reports (and MACs) gives additional detail on certain environmental factors which appear to impact risk, we will include those and characterise their impact over time.

2.2 Airspace and its structure

It is only by the use of Class G airspace, and the application of other airspace classifications set out in the ICAO Airspace Classifications Policy Statement, that the CAA, on behalf of the UK, can ensure that the requirements of owners and operators of all classes of aircraft are met. Selection of airspace classifications in the UK is based on the principle that the least restrictive classification of airspace (Class G) should be the norm, with more restrictive classifications only being established where necessary. This is one of the key means by which the CAA meets its statutory obligations for the safe efficient use of airspace permitting the expeditious flow of all air traffic, whilst ensuring that all airspace users have reasonable and safe access to the national asset that is airspace.

The airspace in the UK is constantly evolving with different airspace change proposals being considered each year. The growth in regional airports and commercial air traffic (CAT) in general has led to increasing requests for additional controlled airspace. The expansion of Controlled Airspace over the last 50 years, and especially in the last 20 years, has seen the volume of airspace available to GA in areas that are most accessible to them (i.e. overland and in the large urban conurbations) reduce [1].

It is likely that the pressure on the UK's airspace system will continue to grow in the long term with a changing profile of demand from different users groups leading to a tightening in the supply and demand balance for airspace. Even if there is only limited growth in air traffic demand, there are already 'hot spots' in the airspace today [28]. However, analysis of the mid-air collision data from 1975-2008 by the LAA appears to show that MACs were not impacted by precise “hot-spot” locations, but more by general traffic density. The statistical significance of solely looking at accidents could be challenged and it is hoped that using a larger body of precursor data available from airprox reports will give significantly more richness and detail in our analysis.

2.3 Uncontrolled airspace and the use of ATS

Any aircraft may use the Class G airspace whilst complying with the Rules of the Air. Within Class G airspace, it is not mandatory for a pilot to be in receipt of an ATS, even where one is available, or to have a radio or navigation/communication equipment fitted to his air vehicle. This autonomy is a fundamental concept within Class G operations.

The Rules of the Air and related procedural aspects give an element of predictability to the airspace – for example, rights of way, and altitude norms for direction travelled. This is enhanced by the pilot’s lookout (see-and-avoid), where they form a situational awareness picture using the visual information available to them. This can be supplemented by radiotelephony (R/T) information where this is available.

In certain circumstances, an ATS may be available. However, the nature of the Class G environment means there is an unknown element to the traffic environment, for example due to the inability of ATC surveillance systems to detect all aircraft in all circumstances. Due to the existence of traffic within Class G airspace which may not be in receipt of an Air Traffic Service (ATS), it is possible that the flight details and specific intentions of some traffic may not be known by other pilots or any ATCO/FISO.

“Due to the uncontrolled and unknown Class G airspace environment, it is important that pilots recognise, fully understand, and appropriately manage, any limitations or reductions in ATS capability”. [29]

Per the Statutory Notice quoted above, this unknown element of the traffic environment requires pilots to be mindful that the ATS provision is limited by the uncertain nature of the airspace and the unpredictable workload of the controller. In addition, the nature of traffic within Class G airspace may result in sudden and variable behaviours of traffic as pilots, quite properly, conduct their flights to meet their unique needs within the bounds of the ATS and Rules of the Air. This rightly places the emphasis on the pilot’s own actions when attaining situational awareness and conflict avoidance.

Another contributing factor to the Class G airspace environment is the variability of transponder equipage and utilisation. According to the Light Aircraft Association (LAA), a total of 19940 General Aviation (GA) aircraft were on their register in 2013. Of these aircraft, 60% were not equipped with transponders. Inclusive of approximately 7000 unregistered aircraft, 73% of GA aircraft are not equipped with a transponder. A lack of transponder equipped aircraft dilutes the amount of information available to other users (e.g. for collision avoidance) and controllers. This is a factor in defining the level of service provision and risk mitigation that can be achieved by ATS, as it impacts both service provision that exists to reduce risk and the ability of the ATS systems to recover from an incident should a conflict situation develop.

To date there has been conceptual, societal, technical and economic constraints that preclude mandatory equipage of navigation and communication equipment for air vehicles operating in Class G airspace. Newer technologies such as ADS-B offer benefits but also have constraints, such as the need to integrate GPS, concerns over data protection and personal privacy (for the same reason that GPS trackers are resisted in motor vehicles), and the immature market for low-cost, low-power devices. A CAA ASI Electronic Conspicuity Working Group has been established to examine the options, and low cost surveillance devices are in development.

ATS are provided in Class G under the ATSOCAS provisions (CAP774), by a variety of civil and military air traffic units. Where available, controllers will make all reasonable endeavours to provide the ATS that a pilot requests. However, due to finite ATS provider resources or controller workload, tactical priorities may influence ATS availability or its continued provision. Therefore, a reduction in traffic information and/or deconfliction advice may have to be applied, and in some circumstances an alternative ATS may have to be provided in order to balance overall ATS requirements (e.g. Basic Service).

The availability of an ATS is therefore a factor in the management of risk in Class G airspace. The mixed provision of en-route and off-route services on the same sector may lead to the controller having to downgrade the level of ATSOCAS provided as workload or intensity increases. Services inside Controlled Airspace (CAS) cannot be downgraded so the only option, if a downgrade is necessary, is to impact users inside Class G airspace. Any such downgrade could come at a time when ATSOCAS are essential due to poor weather conditions thus increasing risk to airspace users. However, it is acknowledged that demand for ATSOCAS may reduce during periods of poor weather.

The Lower Airspace Radar Service (LARS) was introduced in 1979 as a funding scheme to reimburse Air Traffic Service Units (ATSUs) for the provision of the radar service element of ATSOCAS. Under the scheme, ANSPs provide a radar service to a range of users operating in Class G airspace up to and including FL100 within the limits of radar/radio cover. However, service provision is somewhat fragmented and not necessarily available at weekends when the amount of GA flying tends to peak [34]. Lack of an available service provider reduces the level of mitigation against the risk of MAC, particularly for aircraft that are operating in busy airspace close to aerodromes. A CAA LARS working group has proposed a series of recommendations aimed at improving the availability of LARS.

Traffic information provided through ATSOCAS increases the likelihood of a pilot identifying a conflicting aircraft and therefore maintaining a safe separation [31]. Conversely, inaccurate traffic information may lead a pilot to scan the wrong area and therefore a conflicting aircraft may be missed or an incorrect one sighted.

There has been a fourfold increase in the use of wind turbines over the past 5 years and the total number of on–shore/off-shore turbines now exceeds 5,000. Wind farms have the potential to create primary radar clutter on ATC radar screens. This clutter can obscure primary returns from aircraft and can interfere with radar tracking resulting in erroneous radar returns. This in turn reduces ATCs ability to observe primary only (non-transponding) aircraft and increases the risk of ATC not detecting a conflict between aircraft. A common solution to the issue of clutter has been to 'blank' areas of primary surveillance cover. Whilst this removes clutter created by wind turbines it also prevents detection and display of primary returns from aircraft. Introduction of new technology, such as Holographic Radars, will address some of the issues that wind turbines present to aviation.

2.4 Airspace use

Several studies have characterised the use of Class G in the UK, most recently the Class G airspace for the 21st Century report ConOps [1] and related QinetiQ Class G modelling feasibility study survey report [2]. The RAF FS Mid Air Collision analysis [14] also contains an in-depth analysis of the airspace characteristics.

Class G airspace continues to support a wide variety of users, including Commercial Air Traffic, high energy military aircraft, business aircraft, flying training companies, emergency and utility aircraft, and all types of sport and recreational flying. New users such as those operating Unmanned Aerial Systems will also appear in the coming years.

In general, for the GA community, there has been a steady trend away from traditional single engine powered aircraft towards microlights, ultralights and other Very Light Aircraft [25]. This is partly economic (i.e. cost per flying hour), but also due to an increase in market supply of these aircraft and the more ‘back to basics’ nature of the flying. The question is whether the changes in aircraft numbers per annum, and thus assumedly number of flights, have a material impact upon the number of airprox. Percentage-wise, the changes each year are fairly small (e.g. +/- 1% for each grouping), but this may add up over several years. Figure 1 below shows this in more detail, per type of aircraft with landplanes and helicopters below 750kg split out. Therefore, it may be worth normalising the results for airproxes (and causes) against the number of aircraft (either overall or by type) to obtain a more accurate picture of risk per aircraft.

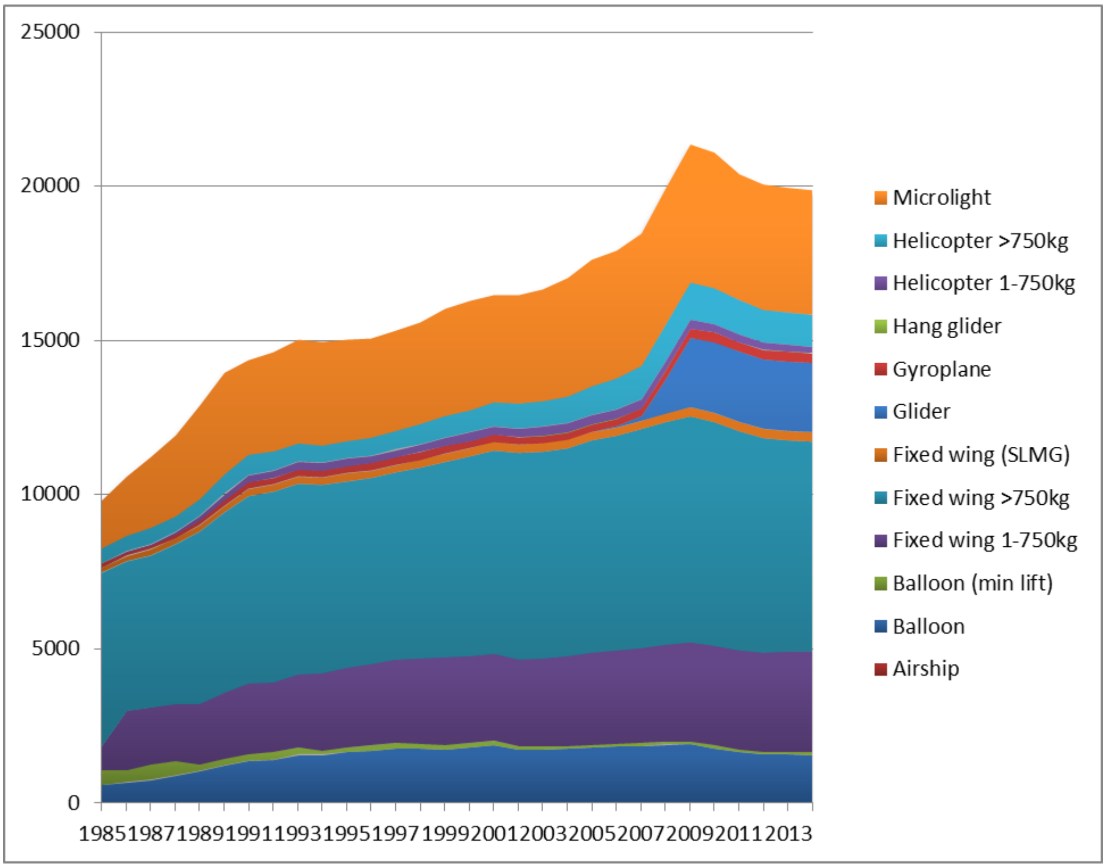


Figure 1: Evolution of registered aircraft in UK [30]

Some caution must be taken when looking at the figures in the chart above:

- Some increases are down to new regulatory requirements for registration and reporting (e.g. gliders);
- The number of aircraft registered does not correspond to the number of aircraft flying. A separate data set from the UK CAA shows that roughly 6685 aircraft had an invalid Certificate of Airworthiness or Permit to Fly as of 1st January 2014. This means that some aircraft were registered i.e. with a tail designation, but were not fit to fly on an annual basis; i.e. likely to be sat in a hangar. However, the trends in registered aircraft should be able to be correlated with hours flown, even if the absolute figures cannot be used easily;
- The data considers UK as a whole, and therefore includes some aircraft that usually only operates in controlled airspace;
- The number of aircraft registered does not correspond to the exact number of flights achieved in UK airspace, or in Class G airspace as a sub-set. With fuel costs being reduced for very light aircraft (e.g. ultralights) over standard single engine fixed wing (e.g. Piper Warrior), the number of flights per pilot may be increased – no firm data is available to support this hypothesis.
- There are numerous paraglider and para-motor air vehicles for example which do not require registration but which have seen large increases in numbers with no visibility to the regulator.

It is worth noting the impact of the 2008-2009 financial crisis and resultant economic downturn. Fixed wing >750kg fell by around 8% over the next 5 years, helicopters >750kg by 17%, microlights by about 10%, and balloons by 19%. Gliders and fixed wing 1-750kg showed a slight growth in number. The number of paragliders and para-motors are believed to have increased over the same period although official data is not available as they do not have to be registered.

The CAA Strategic Review of GA in 2006 [26] noted that in the period 1996-2006, actual flight hours for GA remained steady at 1.4 million flight hours per annum. No definitive data was received to update this figure in the last eight years.

Detailed military flying rates for the UK airspace alone were not available. However, following analysis of data provided by the MAA, there is a clear downward trend in overall flying rates since 1990 with the number of movements reducing by over 50% by 2013. During operations overseas, the UK Class G airspace typically sees a reduction in missions performed by the military, particularly rotary wing aircraft and fast jets. As the overseas operation ends, the aircraft come back to the UK and resume training.

Over the past decades, the Gulf War (1991-2), Iraq War (2003-2011) and Afghanistan (2002-2014) have taken platforms outside the UK. The drawdown of military activity in Afghanistan is not expected to impact flying rates in the UK primarily due to the drawdown of a number of squadrons[1]: However, due to the rebasing of rotary wing squadrons, there may be an increase in activity in the Oxford and Hampshire airspace.

For Commercial Air Transport, their contribution to the airprox data in Class G airspace is low. However, even a small number of risk-bearing airprox has a major significance for CAT. As with the wider picture above, some indication of the

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[1] Information supplied by RAF Dep ATM Force Commander

changing situation can be seen using the aircraft registration data [30]. The figure below shows aircraft above 15t MTOW (e.g. large business jets, small regionals) up to 50t, and aircraft over 50t MTOW (corresponding to B737 or A320).

Whilst the regional and business jets have increased slightly over the thirty years, the chart shows the rapid growth in Airbus, Boeing and more recently Embraer aircraft. This has been driven by the low-cost carriers who, over the years, have developed scheduled flights into aerodromes in Class G airspace and this must be taken into account during the airprox analysis.

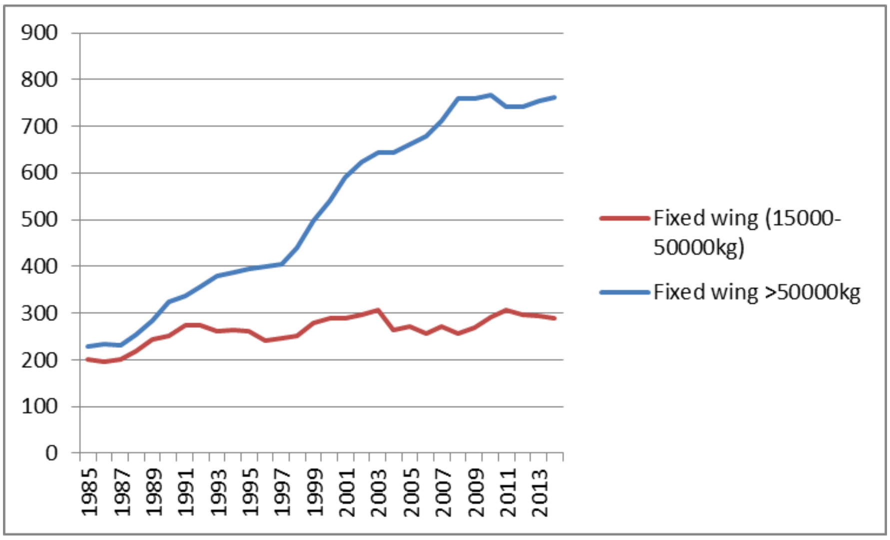

Figure 2: Changes in large aircraft registrations in the UK

2.5 Pilot actions

Whilst airspace design, regulatory policy and Rules of the Air lay the foundations for safe operation in Class G airspace, the actions and the risk appetites of the pilots themselves have the major bearing on the management of risk. Adherence to procedures, such as recognised positioning and reporting in the visual circuit, reduces the chance of a conflict developing. Poor understanding of individual responsibilities under rules-of-the-air and ATSOCAS may lead to non-compliance and thus increase the level of risk to others. The CAA has established the Visual Circuit Procedures Sub Group (VCPSG) under the Airborne Conflict Action Group (ACAG) to specifically study issues relating to the visual circuit.

2.5.1 See and avoid

See and avoid is recognised as a method for avoiding collision when weather conditions permit and requires that pilots should actively search for potentially conflicting traffic, especially when pilots are operating in airspace such as Class G where traffic may not be operating under the instruction of ATC.

The effectiveness of see and avoid is not 100% reliable and increases in air traffic density and complex airspace that requires greater attention on navigation may impose additional strain on its effectiveness.

In Class G airspace, whilst other means of obtaining information on other aircraft's position can be used, visual acquisition remains the primary means; the main tool for the pilot in avoiding MAC is visual lookout or see and avoid. SMEs in the

VCPSG and the Australian Transport Safety Bureau [31] concluded that alerted see and avoid is significantly more effective than when no information is available. Separate research by Moore (1998) [32] found that with visual scanning and TCAS information alone only 39% of 'required'[2] traffic was visually acquired. This figure increased to 58% when additional cues were available. However, there is the potential that 'cued' lookout could reduce the effectiveness of visual acquisition for the following reasons:

- There may be a danger of focusing the pilot's attention in one area and therefore they can potentially miss objects that are just outside this or in different parts of the sky
- It risks the target aircraft being placed in the fovea part of the retina which is less efficient at detecting motion
- Pilots may become over reliant on information provided on other aircraft at the expense of effective scanning techniques

An indication of where to look could occur via an Air Traffic Service (e.g. Basic Service, or Deconfliction Service if available), via party-line situational awareness (Radio), or electronic conspicuity (e.g. ADS-B).

Unless dispensation has been granted by the CAA (or military risk accepted by the MAA), the default speed limit for flights within Class G airspace is 250kt IAS below FL100. An aircraft travelling at a greater speed may increase the chance of visual acquisition, especially if the conflict geometry does not hinder detection. However, the time available to react decreases as the relative closure speed increases.

The underlying ability of the pilot to scan the airspace around them is difficult to measure objectively. Various papers [14, 22, 23] suggest that 15-20 seconds is required for effective visual scans – or put another way (in a recent GA magazine article), around 75-80% of a pilot's time should be spent scanning outside the window. However, research conducted in the USA [33] found that, at best, pilots scanned outside of the cockpit only 51% of the time in an environment where the onus was on see and avoid to maintain separation. Furthermore, for the time spent scanning outside of the cockpit, much was devoted to the centre of view as opposed to the edges.

There is nothing currently to suggest that pilot scanning skills have maintained a trend up or down in the past decades, or any impact from specific changes. For example, no research identified any impact from the introduction of the JAR-PPL in 1999 or NPPL in 2002.

Instead, individual pilot factors such as training, refresher learning, (recent) experience and background may play a part. Likewise, certain aircraft types may be susceptible to a reduced effectiveness in the visual scan, due to the design of the cockpit and the amount of perspex/obstructions that might enhance/impede a pilot's view. For the experience factor, it may be interesting to identify any correlation over the years with airproxes – both in the overall experience (age and total flight hours) and in recent experience (e.g. last two years).

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[2] Required traffic defined as that which ATC would notify the pilot due to its proximity

2.5.2 Situational Awareness

Class G airspace is fundamentally an environment of autonomous traffic where it is not mandatory for a pilot to file a flight plan, carry a transponder, be in receipt of an Air Traffic Service (ATS), or even be equipped with a radio. Not knowing who is operating in a specific area or what their intentions are, limits the situational awareness of pilots and controllers and hence requires them to factor this into their operations as they manage the risk to themselves and other airspace users.

A significant amount of collisions (71% of GA collisions since 1975) in the UK occur close to the airfield where aircraft are operationally placed in close proximity to one another. The use of radio communication aids pilots to build their situational awareness of other users. This can be particularly important in areas where the conflict geometry may hinder the opportunity for a pilot to visually acquire the other aircraft.

Entry into an ATZ should, where suitably equipped, be preceded by a call, either to gain clearance (if an ATC service is provided), information (if a Flight Information Service) or to indicate intentions (A/G Radio). Civilian pilots in Class G airspace flying through a MATZ are not required to contact the aerodrome ATS. It is, however, good airmanship to contact the relevant ATC of the MATZ to request a transit (known as a MATZ penetration) to improve flight safety, efficiency and the situational awareness of the controllers and traffic within the zone.

With many military aerodromes accommodating either high numbers of aircraft and/or fast moving aircraft, a controller is often established to manage transit traffic in order to increase the safety of station based and visiting aircraft. By providing a service to military and civilian transit aircraft in the vicinity, ATC are able to increase their situational awareness and coordinate movements with arriving and departing traffic. This is particularly beneficial when aircraft without transponders utilise a service. Their altitude and intentions can be requested if required to enable the safe separation of aircraft. Furthermore it facilitates the accurate passing of traffic information as the altitude of the non-transponder equipped aircraft is now known.

A traffic or Deconfliction Service is not necessarily required in order to increase situational awareness for controllers. A pilot in receipt of a Basic Service may provide useful information such as their route and approximate transit altitude which may increase the situational awareness of both the controller and other pilots on frequency. Furthermore, information can be shared amongst controllers on aircraft without transponders and also, where surveillance equipment is used, on those equipped with a transponder but without the availability of Mode C (no altitude displayed).

As mentioned previously, the level of risk in the vicinity of an airfield is greater than that for en-route transits, particularly for GA. The provision of an aerodrome control service assists pilots in building their situational awareness and aids adherence to circuit procedures. Some tower controllers may have surveillance data available to assist them in building their own situational awareness and therefore enhance the quality of information available.

2.5.3 Airspace infringements

Overview

Another key skill that minimises the level of risk is effective navigation. Avoidance of controlled airspace (CAS), danger and restricted areas is reliant on the briefing and planning process prior to flight as well as an ability to interpret charts and navigate effectively. Failure to do so would increase the risk of an airspace infringement which could potentially lead to a conflict with another airspace user.

One of the major conclusions of the UK CAA Strategic Review of GA (2006) was that a serious threat to flight safety still exists from infringements, aircraft outside CAS entering CAS without permission. The statistics show that the number of infringements has risen in recent years[3]. Figure 3 shows a peak in 2009 (1,086). The true impact of these initiatives may be masked somewhat by education in the reporting of incidents; more robust reporting of infringements, both from pilots and from NATS, could attribute to some of the increase from 2005-2007, and aside from an outlier in 2009, the total infringements have remained roughly constant between 2007 and 2011. The trend into 2012 (not shown on this figure, but appears to be around 800) was downwards, and this may be attributed to the initiatives such as awareness campaigns, improved flight planning and navigation applications.

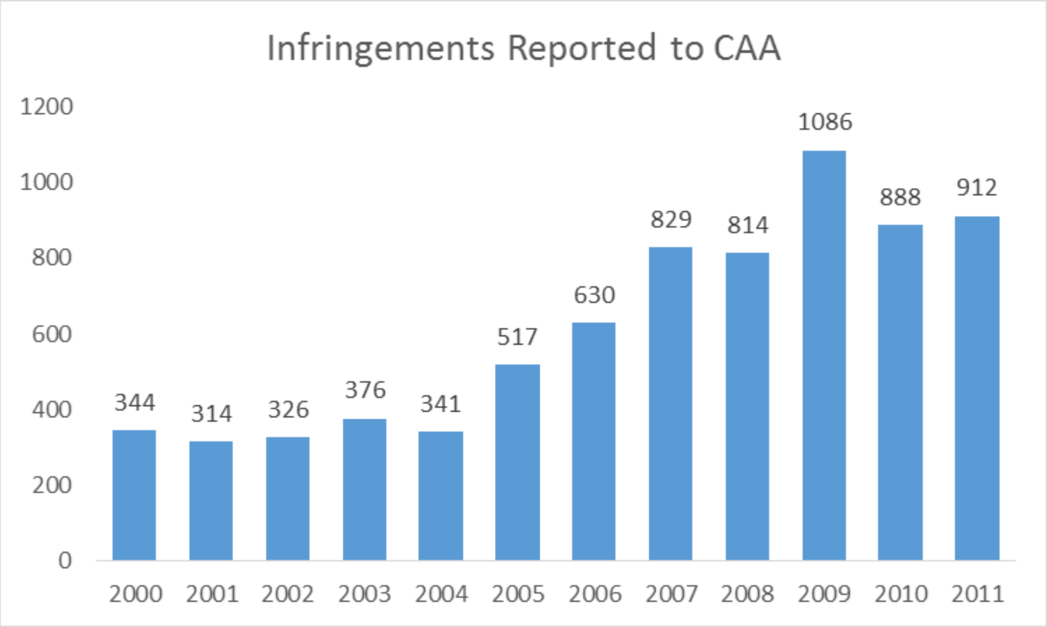

Figure 3: The trend of increasing aircraft infringements in CAS

The statistics also show that the large majority of these infringements are due to GA pilots, and of those, most are down to navigational error.

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[3] http://flyontrack.co.uk/wp-content/uploads/2013/08/20120815FlyontrackInfringementBackground.pdf

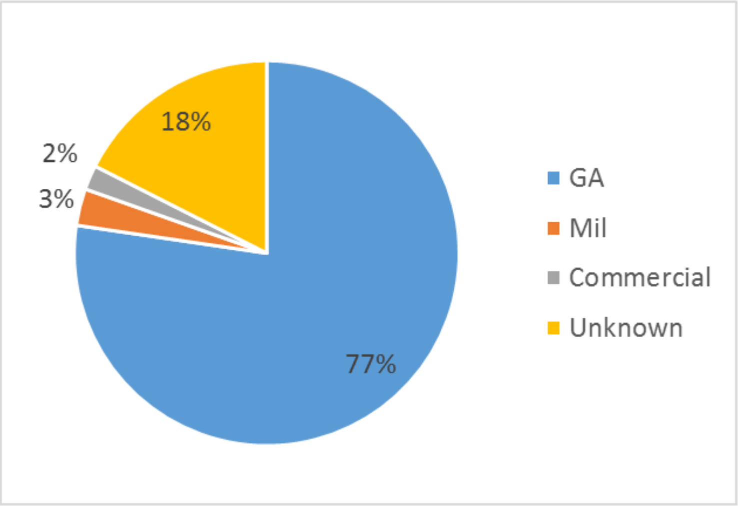

Figure 4: Percentage of infringements attributed to airspace user group

These statistics from Fly on Track highlight the impact users of Class G airspace can have on the safety and efficiency of the entire UK airspace system. Thus in recent years there have been a number of initiatives and procedural changes in an attempt to improve the safety of those airspace users in Class G and their impact on the safety of users of other airspace.

Improved charting

The introduction of new VFR charts is also designed to aid navigation and improve safety in Class G and adjacent airspace. In March 2014 new editions of 1:500k and 1:250k VFR charts depict the airspace in a new style scheme to increase the clarity of the information. The changes were based on consultation with the aviation industry, and include:

- Colour scheme changes to improve readability;
- Removal of repetition of airspace names to reduce clutter; and
- Introduction of boundary tints to all airspace boundaries regardless of classification, to aid pilot situational awareness and reduce infringements.

In what could, on the surface, be considered a minor change, this initiative is a good example that impacts pre-flight events and in flight navigation.

Frequency Monitoring Codes

Another initiative to help control risks associated with airspace infringements was the introduction of Frequency Monitoring Codes or Listening Squawks. Pilots are able to set a SSR code to indicate they are monitoring a certain frequency within the vicinity of busy controlled airspace. Each region has a unique code and frequency.

Controllers are hence aware that a pilot is listening to their frequency and can directly warn pilots of impending infringements, permitting avoiding action. However, when aircraft are not infringing on CAS they are not increasing the workload of the controller by requesting an ATS, nor are they increasing radio traffic on the frequency.

This service is only available to those aircraft with transponders, and does not guarantee an ATC service. This type of initiative is an excellent example of how the level of risk can be reduced whilst minimising the impact on the user community and service providers.

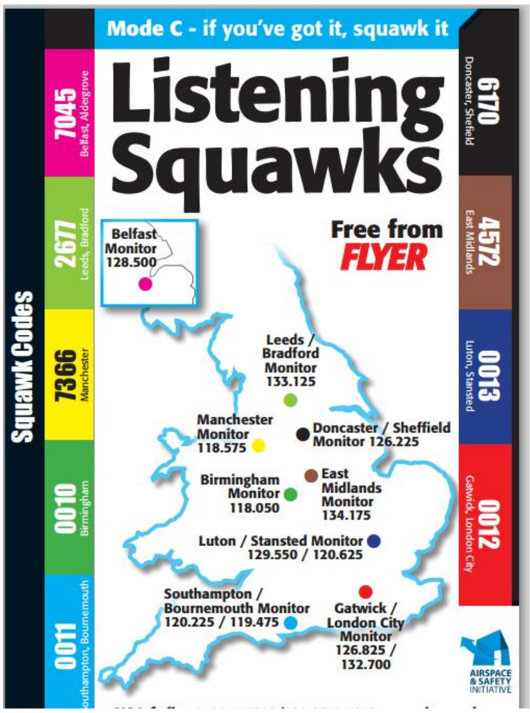

Figure 5: Listening Squawks across the UK

Mandatory Zones

Transponder Mandatory Zones (TMZs) have been introduced which require all aircraft to be equipped with a transponder capable of operating in Mode A and Mode C regardless of the airspace classification or whether in receipt of an ATS.

The Class G Airspace surrounding the Stansted TMA vertical and lateral bounds became a TMZ in 2009 and extends from the surface to 1500ft.

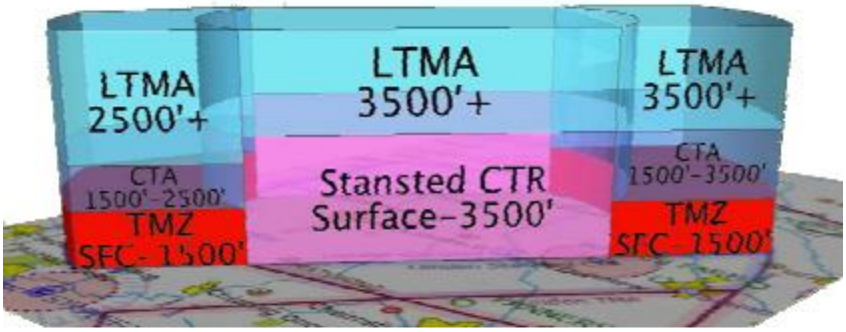

Figure 6: Airspace surrounding Stansted showing the location of the TMZs[4]

Mandating the usage of a transponder equipped with Mode C, providing controllers with height information of aircraft operating in the area, was introduced due to the large number of serious infringements into the controlled airspace in the vicinity of Stansted Airport and the impact they have on standard airport operations.

Due to the number of GA aircraft that are not transponder equipped, TMZs are only introduced where absolutely necessary in order to control a high level of risk.

Linked to these, temporary Radio Mandatory Zones have been introduced as a tool into the regulatory “armoury” recently. These require radio equipage in a certain portion of airspace, sometimes in response to a temporary change (e.g. a radar being replaced).

In the future, other combinations of mandatory zones could be introduced based on the risk in the airspace and available technology; for example, the LDLCA report [3] postulated a future Surveillance Mandatory Zone, with transponders or ADS-B used on-board aircraft.

2.5.4 Training

Despite a growth in GA, the amount of flight training conducted by UK schools has declined[5]. A CAA report on GA in 2006 concluded that the following factors had impacted flying training in the UK:

- Reduced amount of Class G airspace
- Busier regional airports (reduced slots/parking)
- Growth of CAT increased airport costs

The report noted that the VAT treatment for UK flight training is tougher than that of some other countries, and this can, in addition to the factors above, affect the ability of UK-based flying schools to compete effectively with schools abroad. The report recommended that the Government consider whether the current VAT treatment applied to flight training places UK flying schools at a competitive disadvantage to those based in other countries and imposes too great a burden on the self-sponsored trainee.

However, training provided overseas is less likely to include some of the difficulties that may be encountered in Class G airspace within the UK. Also, initial training tends to focus on aircraft handling as opposed to airmanship and see and avoid techniques. However, it is techniques such as effective scanning that enable pilots to manage the level of risk they are exposed to and their ability to recover should an incident occur.

The ability of infrequent flyers to remain current also presents a hazard and pilots are encouraged to utilise an instructor if they have not flown for some time. Equally, over reliance on simulators to maintain currency may also impact on the visual scanning techniques required to mitigate risk in Class G airspace.

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[4] http://flyontrack.co.uk/wp-content/uploads/2013/08/TMZv4.pdf

[5] CAA data for issue of Private licenses in the UK – below statistical average since 2006/7

2.6 Technology improvements

Advancements in technology, particularly in hand-held devices, have enabled a number of initiatives that are aimed at reducing risk in Class G airspace. Flight planning apps and GPS handheld devices are examples of the latest technology being utilised by pilots to improve their situational awareness, reduce risk and avoid infringing controlled airspace. However, the impact of focusing more attention on devices inside the cockpit (i.e. heads-down time) on see and avoid is less well understood. Additionally, over-reliance on GPS devices for navigation purposes may present its own hazards.

The CAA and NATS recommend applications and websites like SkyDemon for flight planning purposes. SkyDemon Light is a free web app available on PC or tablet to quickly plot routes, enter basic aircraft data and then download relevant weather, NOTAM and airspace information for their flight. The programme also offers a vertical profile to help the pilot visualise the airspace and the CAS around which they will be operating. This can then be loaded into the SkyDemon GPS navigator and displayed tactically to the pilot, along with notification of upcoming airspace, terrain and NOTAM’d issues. Likewise, the Airbox Aware system showcases airspace and presents alerts to the pilots in-flight for potential airspace infringements, with data provided by NATS.

Whilst this information has been readily available online through the Aeronautical Information Service (AIS) and Met Office, these new sites and systems offer a one-stop shop which is easy to use and the interactive visual representation increases the efficiency of planning, aids understanding and reduces the chance of error. The addition of in-flight support should help the pilots to track the flight and increase their situational awareness as the flight progresses.

In 2013, NATS introduced Frequency Reference Cards as digital downloads. This helped ensure that pilots are only ever in receipt of the most up to date information and have access to the latest versions. It also enables access to the information with a mobile device or tablet computer. This type of initiative enhances safety by capitalising on advancements in technology that are cost effective to acquire compared to traditional dedicated aircraft systems and there is considerable scope to continue this trend.

Some pilots also use ADS-B traffic displays, receiving and processing signals to display surrounding traffic to aid in situational awareness and visual acquisition. For gliders, the device used is FLARM, which only shows other FLARM users in the first instance. More recent versions, such as PowerFLARM, are aimed at GA users and include interoperability with ADS-B 1090MHz and transponder technology.

For some years, some basic conflict alerting devices have also been available to the GA market, taking a range of forms. Some give a clock direction and range to traffic (visually and audibly), whilst others show a full traffic display and issue alerts. An alerting application for GA is currently being standardised by RTCA as “Traffic Situational Awareness with Alerts (TSAA)”. It is not currently available in devices on the market.

2.7 Safety management and culture

Safety management, and aviation’s awareness of the issues, has evolved over the last two decades. From initial systems seeking to investigate past occurrences and react on the findings, the aviation domain is now proactive in seeking out potential risks and mitigating them.

For organisational safety management, clear links can be made between strategic objectives and risk controls, allowing decisions to be taken on which mitigations to employ. Organisations also have some level of governance over the behaviour of the employees, and can set procedures and processes to ensure information is collected and acted upon.

Thus, the introduction of Safety Management Systems in airlines, the military, corporate operators, airports and ANSPs may have had a material impact on:

- The level of reporting and its depth – this can be attributed to an improved awareness of the benefits, better safety culture (attitudes, behaviours), and more transparent risk measurement;
- The mitigations applied - CAT operators are mandated to complete a Safety Case acceptable to the Authority for any new routes conducted outside controlled airspace (CAP 789) as part of their SMS. The mitigations applied (or requested through the CAA) change over time, but may include a request for Controlled Airspace. Similarly, the MoD has introduced additional mitigations over time, including restrictions on flight in IMC outside of a radar or Procedural Service being provided.

General Aviation, in particular private pilots, are not required to develop an SMS through regulation. Many of the principles are applied through the State Safety Programme and subsequent CAA activities, aimed at improving reporting rates and information received. Awareness campaigns have been run on the benefits of reporting, with particular emphasis on airspace infringements. Feedback has been improved, with new GA-focused magazines and communication channels showcasing airprox reports and findings, and highlighting easily implemented mitigations.

Nevertheless, some of the research identified in Annex C, most prevalently the MoD safety models, seems to suggest that only a small percentage of the airprox are reported. It is worth noting that the acceptance of level of risk will be very different across user groups such as a military fast jet to that in a CAT aircraft.

2.8 Summary of changes over time

A summary of changes over the years, including recent initiatives aimed at reducing risk in Class G airspace, is depicted in Figure 7 below.

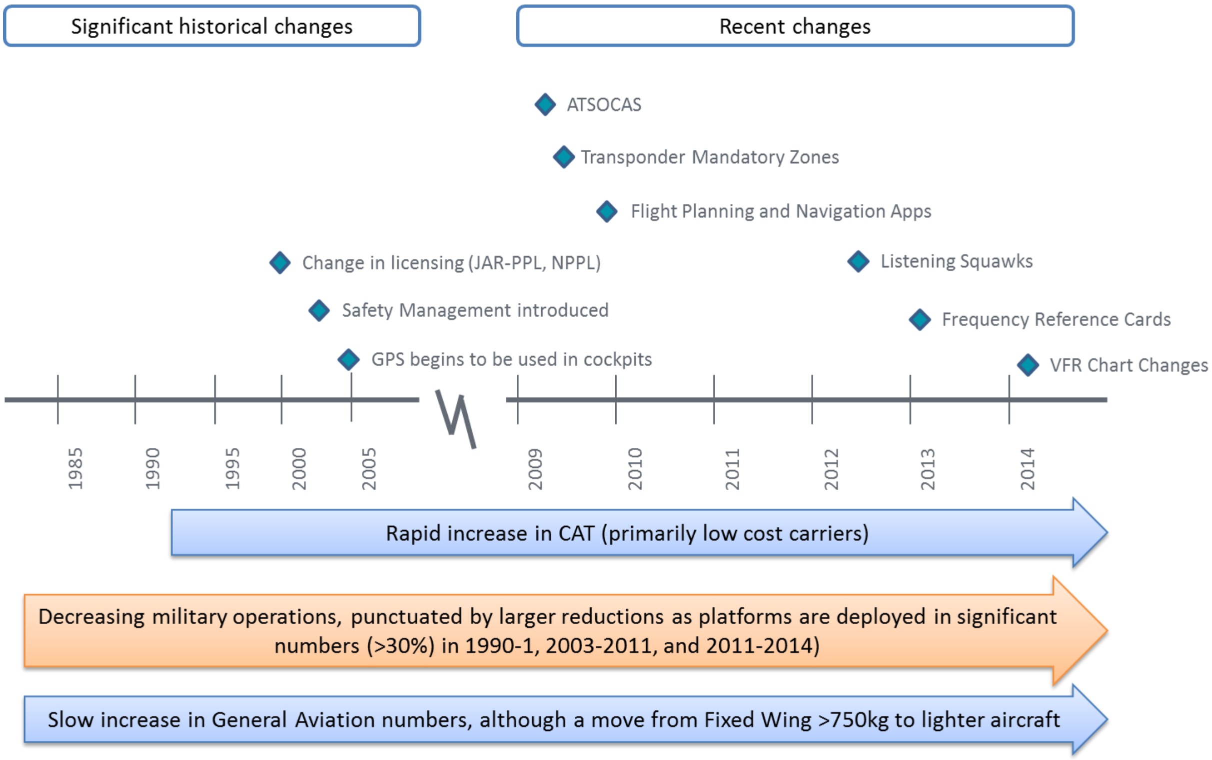

Figure 7: Timeline of recent initiatives

3 State-of-the-art: what do we know about risk in Class G airspace?

3.1 What are the main risks in Class G airspace?

3.1.1 High level outcomes

Risk, in the context of safety, is an unintended outcome (or event) involving danger, harm or loss.

The focus of this study is on those risks which are specific to Class G, or because of some characteristic of Class G, have a higher than average likelihood. In general, this focuses upon the risk of Mid-Air Collision, since the primary characteristic of Class G is the uncontrolled nature of the airspace (and/or aerodrome).

Other risks were identified in the course of the literature review, which may be impacted by the airspace classification. They are referred to in the table below in line with the ICAO ADREP taxonomy. In each case, some notes are made about the impact of Class G airspace upon the risk. The first two are primary occurrence categories, whilst the remaining three refer to secondary categories which may contribute to the first (for example, unintended flight in IMC causes loss of control in-flight). Note also that aerodrome incidents are generally not considered as the scope of this study is Class G airspace, rather than any services provided locally at an aerodrome.

Category	Risk	Relevance in Class G
CFIT	Controlled Flight Into Terrain	Whilst CFIT can occur in any airspace, the contributory factors may differ in controlled airspace to uncontrolled. The Air Traffic Service (requiring a controller to vector the aircraft above the Minimum Descent Altitude) and factor that many aircraft are flying IFR lead to more barriers in controlled airspace. Without these barriers, CFIT in uncontrolled airspace may carry an increased risk, but none of the other contributory factors was assessed as being unique to Class G airspace (e.g. improper non-precision approaches, lack of pilot situational awareness) except unintended flight into IMC (see below).
LOC-I	Loss Of Control In-Flight	Similarly to CFIT, LOC-I may occur in controlled or uncontrolled airspace, but the contributory factors may differ somewhat. Three main secondary categories (contributory factors) are captured below.
MAC	Mid Air Collision	The focus of this study. An analysis of UK MACs over 10 years [14] concluded that mid-air collision risk (probability per flight) was 400 times higher in uncontrolled airspace to that in controlled, suggesting specific factors in Class F or G airspace lead to increased risk.
LALT	Low Altitude	Identified by the RAF as a contributory factor to

	operations	CFIT. Whilst more prevalent in Class G for certain aircraft types (e.g. military), there is not thought to be a specific characteristic of Class G which causes CFIT due to low altitude operations (i.e. the normalised likelihood remains the same).
AMAN	Abrupt Manoeuvre	Identified by the RAF as a contributory factor to CFIT. As per low altitude operations above, abrupt manoeuvres are more likely in Class G, and thus risk arising from them is higher. This is not necessarily due to a characteristic of the airspace classification.
UIMC	Unintended flight in IMC	Risk in Class G (uncontrolled airspace) tends to be higher than in controlled airspace. There are more flights flying VFR in Class G than in controlled airspace, and it is these flights which carry the greatest risk when unintentionally flying into IMC. This can lead to CFIT or a loss of control (e.g. spin). The underlying properties of unintentional flight into IMC are not different for controlled or uncontrolled airspace.

Table 1: Risk categories and relevance in Class G

3.1.2 Statistics on risk in Class G airspace

For mid-air collisions and risk-bearing airprox in UK Class G, several studies are available to help understand trends. A reference used here is the LAA analysis of mid-air collisions from 1975 – 2012 [11], which states the following:

"*There is no recorded collision involving a commercial air transport aircraft in Class G airspace. In the 37 years since 1975, a total of 218 aircraft have been involved in 108 mid-air collisions of which 45 involved 86 fatalities. Disregarding hang gliders and the events which are irrelevant to the analysis of airspace safety (*i.e. flying displays and formations) *leaves 178 aircraft involved in 89 collisions*…"

The key finding of the analysis is summarised into the table below, which shows the average rates of collision per annum between different aircraft types.

Aircraft type	Powered aircraft	Glider	Military
Powered aircraft	1.68	0.16	0.11
Glider	0.16	2.27	0
Military	0.11	0	0 (*)

Table 2: Rates of MAC (measured as aircraft per annum)

* Note that for the military-military collisions, these were discounted in the analysis since they involved formation flying or displays.

There also appears to be a concentration in the location of mid-air collisions, with most occurring near an aerodrome, ATZ, or glider launch site.

- 56% of powered aircraft collisions occurred over or near an airfield;
- 91% of glider collisions occurred over or near a glider launch site.

For airproxes in the UK, the UK Airprox Board undertakes extensive analysis and trend analysis which will not be repeated here [e.g. 5, 6, 7, 8]. Figure 8 shows the trends of airprox reports received by category of aircraft over 16 years (1996-2012).

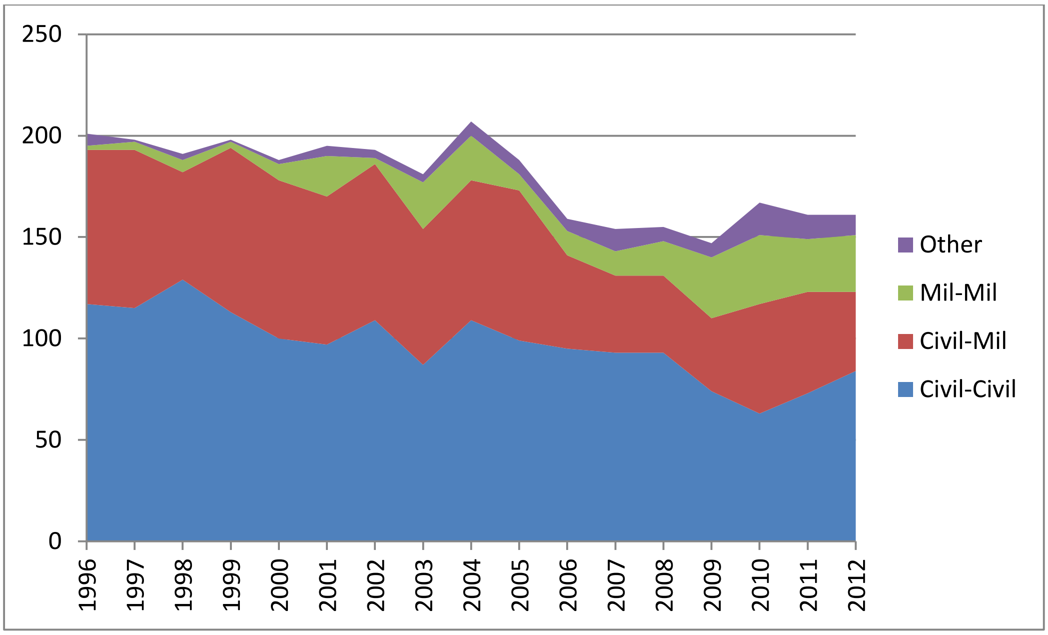

Figure 8: Airprox reports per user category 1996-2012

From the figure above, the overall trend can be seen to be slightly downwards. The next stage of the analysis should aim to normalise this against user numbers and types of report, to understand whether this is indicative of an actual increase in risk per aircraft, or a change in traffic levels or reporting practices. Within this headline figure, the following is noted:

- Civil-civil airprox reports have decreased slightly over the years. This is surprising in that overall civil numbers have been increasing during this period, and there have been several initiatives to improve reporting rates.
- Civil-military airprox reports have seen a significant decrease from 70-80 in the late 1990s to around 40 currently.
- Military-military airprox reports have increased; this may be due to improved reporting, as the SMS safety culture and individual initiatives improve airprox reporting to the UKAB.

GAPAN [23] has also conducted an analysis from Jan 1999 – Dec 2008, seeking to identify a safety level for the airspace (for use in UAS). In addition to analysing the MAC data, they compared it against the airprox reporting rates. They concluded that the military reported Cat A airproxes at twenty times the actual mid-air collision rate, whilst GA pilots only reported Cat A airproxes four times the MAC rate. The indication is that military pilots are more likely to report an airprox than GA pilots (or put another way, under-reporting for GA-GA encounters is far higher than for Military encounters).

3.1.3 Current UK activities focusing on risk in Class G airspace

There are several high level contributory factors and barriers which have been traditionally focused upon:

- Level busts (generally a property of controlled airspace)
- Airspace infringement – either in vertical or lateral dimension
- Collision Avoidance Systems, mostly prevalently ACAS
- Electronic Conspicuity – use of transponders and/or ADS-B
- Visual Conspicuity – both seeing and being able to be seen visually

Within the CAA a significant amount of work has been completed and is ongoing in terms of identifying and managing risk in Class G airspace. Several groups are working to reduce the risk of airborne conflict by focussing on the precursor events such as level busts and airspace infringements. Table 3 below summarises the current working groups and their main area of focus.

Subject	Working Group	Purpose
Airborne Conflict	Airborne Conflict Action Group	Oversee the work of any airborne conflict issues
Level Busts	Level Bust WG	To monitor the occurrence rate, understand the causes behind events and develop strategies to counter level busts
Collision Warning	Airborne Collision and Avoidance Systems (ACAS) WG	To monitor ACAS developments and issues arising from the use of ACAS and non-ACAS Collision Warning Systems (CWS) by all categories of pilot in all classes of aircraft
Airspace Infringements	Airspace Infringement Working Group (AIWG)	To monitor the occurrence rate, understand the causes behind events and develop strategies to counter the occurrence of Airspace Infringements
Business Aviation Safety	Business Aviation Safety Partnership (BASP)	To monitor the occurrence of Safety-Significant Events involving Business Aviation and to work closely with industry to incrementally raise safety within the sector
Safety Outside Controlled Airspace	Airspace Safety Initiative (ASI)	Enhancing safety outside controlled airspace, identifying and prioritising the hazards associated with the use of UK airspace, developing a strategy to mitigate those risks while meeting the needs of all airspace users

Table 3: CAA Class G airspace risk working groups

Of course, work is also on-going in the Military Aviation Authority (MAA) and UK Airprox Board (UKAB). Bow-tie models have been developed by the MAA looking at airprox contributory factors in Class G [27], whilst the RAF has undertaken an analysis of mid-air collision risk between 1980 and 2008 [14].

From the research, the situation in terms of evidence for MAC and causal factors can be summarised as in Figure 9 below.

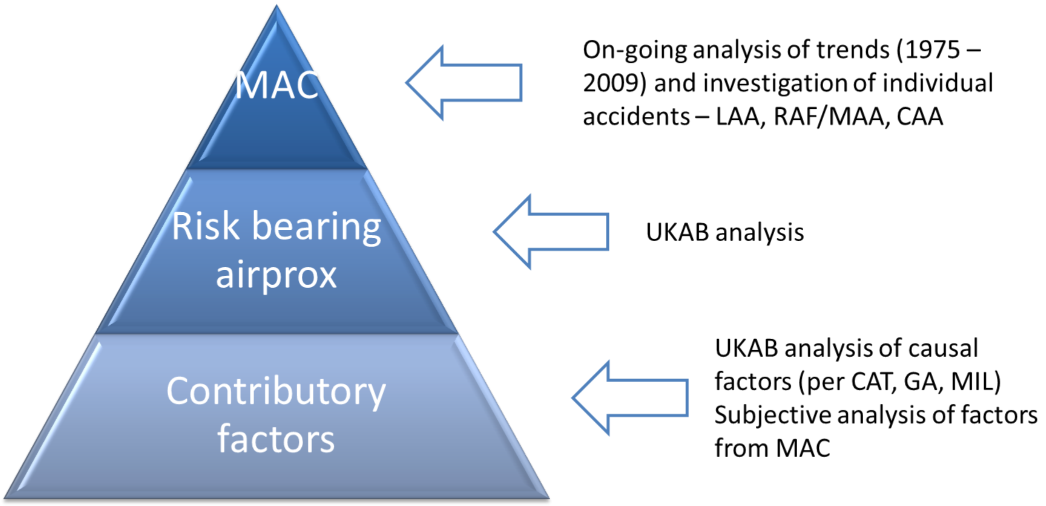

Figure 9: Evidence for MAC in the UK

The aim of this study is to provide more evidence for the contributory factors. These will tend to focus on the negative factors (i.e. which induce risk), due to the reports characteristics. Pilots and controllers have less incentive to report “when something goes right” – they tend to report in the event of failures in the system. However, the airprox reports do include some descriptions showing what prevented a potential airprox becoming more serious, and in these cases, the data will be used in this study.

It is hoped that statistical significance can be gained by the volume of contributory factors and airprox reports.

3.2 What are the main barriers preventing a risk-bearing occurrence?

3.2.1 A barrier model

Utilising the findings from existing research at Annex C, it is possible to group actions and events into a series of barriers that mitigate risk. The barriers can work collectively or individually to prevent the occurrence of a MAC. Furthermore, due to the diverse nature of airspace users, services, and equipment in use, the sequence of the barriers may change or the barrier(s) may be removed altogether.

Figure 10 illustrates the 7 key barriers that mitigate the risks that lead to a MAC.

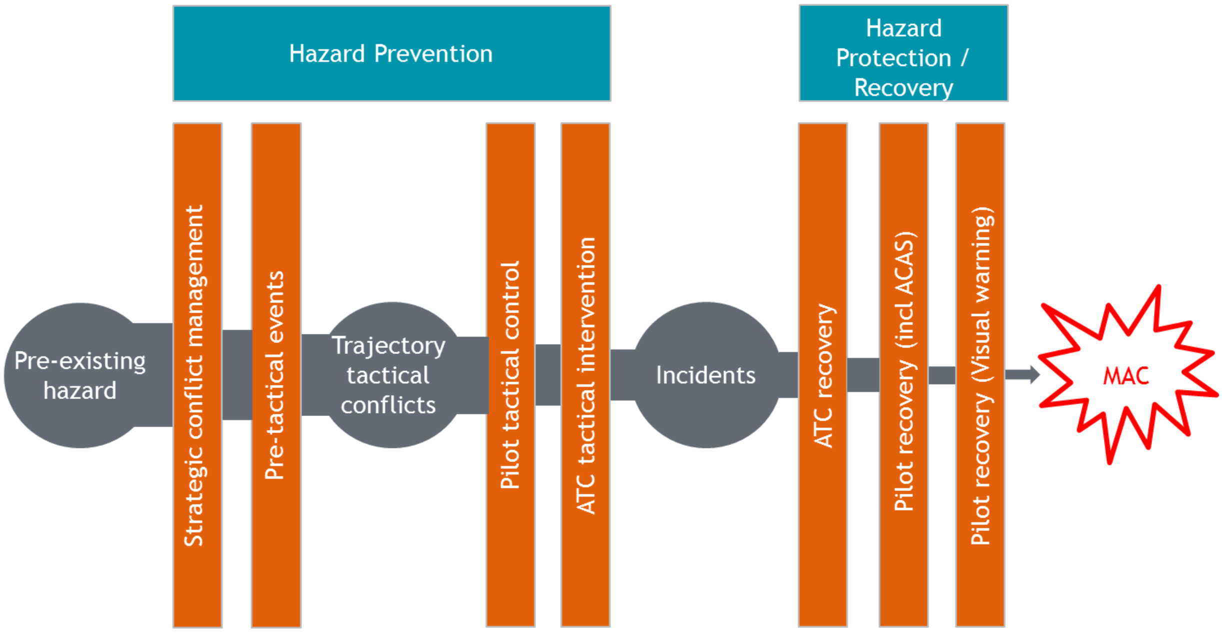

Figure 10: Key barriers mitigating risk in Class G Airspace

The four barriers to the left of the model under the heading ‘hazard prevention’ are those which prevent an incident occurring. If there is a failure in all of the preventative barriers then the remaining three to the right of the barrier are there to prevent an incident developing into a MAC. Whilst the recovery barriers provide strong mitigation against the risk of a MAC occurring, it could be argued that they should not form part of a safe concept of operation since they come into play only once an incident has occurred.

If all of the barriers fail the conflict will not automatically lead to a MAC as there is an element of chance (providence) involved. However, the barrier model reflects only what we can influence.

Analysis of airprox data will enable the effectiveness of each barrier to be determined. In many cases it is likely that a combination of barriers will have worked together to prevent an incident such as an airprox occurring and this can also be analysed. A description of each barrier is contained in the sections below.

Strategic Conflict Management

Strategic conflict management is anything inherent in the Class G concept of operation that mitigates the risk of a MAC occurring. This is a different proposition than in controlled airspace with IFR routes. In Class G airspace, the overarching airspace design is of interest, such as the safe segregation of certain activities/user groups, boundaries that are not overly complex, and effective VFR arrival and departure routes at airfields. Robust procedures are also an important aspect of operations in Class G airspace particularly those associated with ATSOCAS and joining visual circuits. Other aspects include the availability and clarity of aeronautical information and effective management of unusual or large scale events. This list is by no means exhaustive and there are many other factors which contribute towards creating a safe operating environment.

Pre-tactical Events

Effective briefing and planning is an important mitigating factor in hazard prevention. Some key areas include accessing and understanding NOTAMs (Notice to Airmen) and other important aeronautical information. Route planning, including contingency planning, is also important. The research material in Annex C shows that if a pilot has an increased awareness of where a hazard may present itself, they are more likely to both look for it and detect it. Accurate route planning also minimises the risk of infringing adjacent airspace which can lead to a loss of separation. Another aspect of pre-tactical events is ensuring equipment is checked such as navigation devices having up-to-date maps. The pilot should also be sufficiently current on the aircraft type and any equipment carried. Much of this will be routine for professional pilots but much less so for recreational pilots who only fly on an occasional basis. The barriers need to be robust for all airspace users, not just particular groups.

Pilot Tactical Control

Visual scan remains the primary means for the pilot to detect and avoid other traffic in Class G airspace. Pilots may use radio communications and internal surveillance information to enhance their situational awareness. Strategies can be formed, such as circuit joining, passing manoeuvres, and appropriate vectors and heights selection. This barrier also includes elements of procedural knowledge, such as the recent move from the quadrantal rule to a semi-circular rule per EASA’s Single European Rules of the Air.

Pilot tactical control can work in isolation or in conjunction with ATC tactical interventions. Good airmanship skills are required, particularly in dense areas of traffic, to ensure any separation does not cause unease to other airspace users. Interpretation of adequate safe distance may vary between user groups and particularly CAT. Knowledge of rules and procedures are an important factor to ensure common understanding and appropriate reaction to instructions and information. This knowledge becomes even more important when receiving a Basic Service or no ATC service. For example, at an airfield where only a Basic Service is provided pilots must be relied upon to follow the correct joining procedures and make timely and accurate radio transmissions to ensure other airspace users are aware of their position and intentions.

Numerous limitations, including those of the human visual system, the demands of cockpit tasks, and variations in physical and environmental conditions combine to make see and avoid an uncertain method of traffic separation [31]. Furthermore, ATC surveillance equipment may not detect 100% of all targets due to limitations in cover and non-transponder equipped aircraft may be missed by a controller in areas of high traffic density or clutter.

For the purposes of this barrier see and avoid is used to detect other airspace users in sufficient time to enable safe separation between them as opposed to late sighting and subsequent manoeuvre.

ATC Tactical Intervention

The word intervention is used here, as it may be in the form of information being passed, or advisories, or clearances, depending on the service being provided.

In order for ATC to provide the full range of ATSOCAS, appropriate communication, navigation, and surveillance infrastructure must be in place. However, the presence of aircraft that are not transponder equipped degrades the situational awareness of controllers. The impact may be reduced if the aircraft are in radio contact with ATC but it may still hinder a controller's ability to detect a change in level that has not been communicated. The impact of non-transponder equipped aircraft is greatest where primary radar is either not available or is offline due to failure or maintenance. At this point, the ATC barrier becomes largely ineffective against such aircraft.

This barrier is reliant on an ATC service being available when it is requested. As noted earlier, service provision within LARS is somewhat fragmented and not available on a continuous basis. Furthermore, service provision may be unavailable if an ATC unit is operating at capacity and focused on the controlled airspace.

The skills and knowledge of an ATCO are important factors in ensuring ATC services are discharged in a safe and expeditious manner. Traffic information needs to be timely and accurate to give the pilot the best possible chance of locating an aircraft that is on a converging flight path. Good planning and coordination also help prevent conflict scenarios from developing.

ATC tactical interventions are not limited to the surveillance environment. Positive control of the visual circuit is also an important barrier in ensuring the safe sequencing of aircraft and appropriate situational awareness for pilots.

ATC Recovery

If available, this barrier could include the use of Short Term Conflict Alerts (STCA). However, the utility of STCA in Class G airspace is reduced compared to inside CAS due to the dynamic nature of flight paths and the impact of such on 'nuisance' alerts. This barrier could also be present if the controller detects the conflict very late and issues avoiding action (subject to the ATC service being provided).

The parameters for the activation of STCA are usually set at a sufficient distance that a TCAS RA is unlikely to have occurred at the point of activation. However, if the alert goes unnoticed then a TCAS RA may follow. The effectiveness of the STCA is reliant upon the conflict model being appropriate for the unpredictable nature of flight in Class G airspace. Additionally, in order to prevent nuisance alerts, not all reductions in separation (such as two aircraft squawking 7000) will trigger an alert.

This barrier is of course predicated on the fact that both aircraft that are in conflict are equipped with serviceable transponders, that the transponders are switched on (including Mode C), and that both aircraft are within surveillance cover. Furthermore, at least one of the aircraft should be in contact with ATC. The research [11] suggests that the greatest area of risk is below 3,000ft which may place some conflicts below the level of surveillance cover.

Once a STCA has been triggered, the barrier relies on the controller identifying the conflict in sufficient time to formulate an effective plan of action, communicate the plan to the pilot, and there be sufficient time for the pilot to carry out the manoeuvre. The type of information communicated to the pilot will depend on the ATS being provided. Even if an effective plan is put into place, the relevant aircraft trajectories could change and therefore the potential for a MAC would remain.

Pilot Recovery (ACAS)

ACAS includes any system that operates independently of ground-based equipment and air traffic control in warning pilots of the presence of other aircraft that may present a threat of collision. The primary system in use is TCAS although more cost-effective and low-power versions such as FLARM and PowerFLARM are gaining in popularity.

For TCAS to be effective both aircraft must be fitted with a serviceable transponder which has the appropriate modes selected. Furthermore, the conflict trajectories must be sufficient to trigger a TCAS RA. Reaction by the pilot is also a vital part of this barrier in that they must react to the TCAS RA as opposed to any ATC instructions that may be issued. Eurocontrol Voluntary ATM Incident Reporting (EVAIR) data for 2012 states that the correct response to standard RAs was 76% but to changing RAs only 28%.

There is a risk that the pilot visually acquires the wrong aircraft and elects to ignore the RA. There is also the potential for a TCAS RA to place the aircraft in conflict with an aircraft which is not transponder equipped. Multiple RA instructions, including reversal instructions, must be followed for TCAS to be effective. As with several other barriers the dynamic nature of the airspace, such as continued changes to aircraft trajectories, may reduce the effectiveness of this recovery event.

3.2.1 Pilot Recovery (Visual Warning)

See and avoid in the pilot tactical control barrier was the ability to visually acquire other aircraft in sufficient time to maintain safe separation. In hazard recovery it is assumed early acquisition has failed, an incident has occurred, and the pilot is required to make an avoiding action manoeuvre to prevent a MAC. The effectiveness of this barrier relies on the pilot acquiring the conflicting aircraft in sufficient time to assess the trajectories and affect a manoeuvre that is within the limits of the aircraft design.

This barrier relies on effective scanning by the pilot and conflict geometry which permits the other aircraft to be visually acquired. Other factors such as visibility, weather conditions, aircraft marking, cockpit design, relative speeds, fatigue, and lighting may all reduce the effectiveness of this barrier.

Key considerations

It is clear that the dynamic nature of Class G airspace has a bearing on both the barriers that prevent an incident occurring and those which aim to recover from the incident and thus prevent a MAC. The unpredictable nature and cross section of user groups makes for a very different environment to that which typically exists inside controlled airspace.

It is also evident that the effectiveness of a number of barriers is impacted by the use of transponders. Transponders may assist pilots in identifying aircraft which are on a conflicting trajectory (equipment dependent) and aid the situational awareness of ATCOs and their ability to plan and provide tactical separation. Therefore once aircraft are on conflicting trajectories, both barriers that prevent an incident occurring are weakened if aircraft are not fitted with transponders. Furthermore, the ability to recover from the incident is significantly impacted as both ACAS and STCA would be ineffective. This would leave a single barrier (see and avoid) preventing an incident developing into a MAC. As noted above, there are many factors which may weaken what may be the only recovery barrier.

Mode of flight

When considering the effectiveness of the barriers it is useful to consider two particular modes of flight, transit and aerodrome. Transits may include any activity away from the aerodrome including, but not limited to, balloons, gliders utilising thermals, military training sorties, and GA navigating from one aerodrome to the next. Aerodrome activity includes the initial and final phases of flight and activity in and around the visual circuit.

An aerodrome may or may not have ATC or FISO services available yet is an environment which, by its very nature, tends to have aircraft in a more concentrated area which require using the same pieces of airspace (e.g. final approach). Recovery barriers such as ACAS and STCA are less likely to be present and conflict trajectories may be such that see and avoid is more difficult.

Additional factors

An effective safety management system (SMS), or appropriate application of a State Safety Programme, underpins all the barriers. This is a combination of monitoring trends through the use of lagging indicators such as occurrence reports and also proactive management such as safety surveys, risk analysis, and monitoring through leading indicators.

Another important area underpinning each barrier is a quality system of training, education and licensing, including the on-going maintenance of skills and knowledge. Issues identified through the SMS can be fed back into appropriate stages of training and potentially backed up specific communication/education initiatives.

3.2.2 Class G research summary on barriers

A detailed summary of the findings from the research documents can be found in Annex C. Uncontrolled airspace below 3,000 ft. is found to be the most dangerous [14]. Collisions are also most likely to occur in regions of high traffic density, over or near busy airfields and within visual circuits [12]. It is also found that powered aircraft usually collide with other powered aircraft and gliders with gliders [11]. However, the statistics for collisions do not reflect the airprox data where we see far more powered-to-glider airprox than glider-to-glider.

Strategic conflict management

It is reported that there have been no collisions in high density areas around choke points and very few in the surrounding areas [1]. It was proposed that pilots flying such a track will be aware that traffic density is high and be alert. However, infringements of CAS do occur. These airspace infringements have been found to be caused most commonly by navigation failure, distraction, misreading the map and bad weather [9]. This could be mitigated by pilot navigation and communication skills, airspace design and management, aeronautical information provision, FIS and safety awareness.

Showing the positive impact of this barrier will be very difficult through analysis, since it is often taken for granted and not mentioned in specific reports.

Pre-tactical events

Minimising time spent in high-risk areas, or avoiding them all together where possible, is a primary means of reducing MAC risk [14]. Here pre-flight route planning is important, which can also minimise the risk of infringements. If a pilot has increased awareness of where a hazard may present, they are more likely to detect it, here pre-flight planning through accessing and understanding NOTAMS and AIP information is important.

Similarly to strategic conflict management, positive indications of effectiveness of this barrier may be difficult to identify. Nevertheless, indication of trends in airprox (e.g. using Airbox Aware and SkyDemon reducing airspace infringements and subsequent airprox) may be helpful in setting actions for the community.

Pilot tactical control

Good airmanship, including interpretation of adequate safe distance and knowledge of rules and procedures are particularly important when only a Basic Service is provided. Over-reliance on ATC services and other safety aids, over time, may reduce the effectiveness of crews' lookout scans. Whilst systems are imperfect, and uncontrolled, low conspicuity, non-squawking ac such a microlights share the operating environment, lookout skills must be reinforced at every opportunity [14].

However, visual search is not 100% effective, and even in ideal conditions there is no guarantee that a conflicting aircraft will be sighted in sufficient time to avoid a collision. The limitations of lookout are determined in part by eye physiology, including effects such as fatigue, hydration level, and cockpit obscuration in addition to the environmental conditions [14]. Therefore, there are limitations in a system that ultimately relies on see and avoid for collision prevention. Studies have shown that visual search is more effective when the searcher knows there is a target to find and where to look [1]. Therefore, visual search aided by the provision of ATS, electronic conspicuity and traffic alerting systems may be preferential.

ATC tactical intervention

Resourcing issues with service provision can affect risk and it is important to ensure regulation is robust and that controllers and aircrews understand their services and responsibilities [14].

The effectiveness of ATC control relies on the skill, knowledge and communication of the ATCO, as well as on workload. There are many Airprox cases where a controller has seen a clear conflict on a Radar screen but the communication of the hazard has failed to prevent a near-miss. This may be due to controllers not communicating the degree of conflict sufficiently well to alert the crew, or providing TI that is not accurate enough. Recent amendments to CAP 413 have sought to clarify TI phraseology.

Other possible reasons for the lack of effective avoiding action being taken by pilots are: lack of assimilation of clear TI by the pilot; inability to decide on appropriate avoiding action; or a preference to 'wait and see' and hope to get visual. Indeed, it may be that most called traffic is sighted in good time resulting in a confidence that this will always be the case. This suggested a perverse presumption that offering a service when not all traffic could be detected was worse than offering none at all, and that aircrew reduced their lookout when under a TS, even when warned of the limitations of their service by controllers [14].

Also, a very busy control service can become a distraction, may provide limited reduction in MAC risk, and may actually increase other risks through distraction and overload of the crew if they do not prioritise their ATS accordingly [14]. The Visual Circuit Procedure Sub-Group actually suggested that most pilots are pretty poor at listening out and building a picture of the traffic around them, suggesting this would not be a good mitigation [17]. Additionally it was suggested that the provision of an ATS service at an airfield does not prevent collisions, but that well practised lookout skills could help, as well as understanding the situation and the likely intentions of other aircraft [12].

The Australian CAA study concluded that mandatory carriage and use of transponders without dispensation would enhance safety [10]. However, whilst it is acknowledged that transponder use increases the situational awareness of ATCOs and impacts a number of barriers in the model, it is difficult to quantify the overall impact on safety.

Currently, of registered aircraft, transponders are estimated to be fitted to 51% fixed wing aeroplanes <1500kg, 35% microlights and 10% gliders [13].

Pilot recovery (ACAS)

It is reported that aircraft operating some form of traffic alert system have found they increase pilot situational awareness, thereby reducing collision risk. However, for ACAS to be effective both aircraft must be fitted with a serviceable transponder which has the appropriate modes selected and depends on the reaction of the pilot.

Avoiding action can be taken by pilots based on TI without a visual sighting, but weakness includes poor assimilation of TI or an unwillingness to act on TI alone, even when notified by ACAS [14]. There are also issues with the lateral representation of the conflict on ACAS displays and the potential reliance/utilisation of this information by pilots.

Pilot recovery (Visual Warning)

In order to aid visual warning, historic conspicuity trials identified dark colour schemes as the most effective for visual detection resulting in their adoption for the majority of military training ac [14].

Main risks and mitigations

The top causal factors identified by the UKAB for airprox incidents in 2010 and 2011 were found to be a failure to see traffic, FIR conflict, flying too close and late sighting of traffic [6, 8]. Sighting issues remain to be the most common cause of Airprox involving GA aircraft. However, such descriptions do not provide a full picture as to what factors led to a failure to see traffic or why an FIR conflict occurred. The methodology in section 4 will focus on extracting that greater level of detail from the Airprox database.

The main issues involved in incidents in Australia have been found to be education and training, and frequency management and workload issues. Other issues were congestion on the national advisory frequency and radar information service limitations [4]. The categories used in this example provide a better indication of ‘why’ an event occurred as opposed to the high level causal descriptions used by the UKAB.

3.3 What are the main actions that contribute to effective barriers?

For each barrier to be effective certain components need to be present and correct actions taken. This can be summarised by use of the functional map shown in this section. This is an initial view only – one of the outputs of the analysis will be to annotate this with findings.

Each barrier is annotated in the left hand column.

The top row within each barrier contains the components necessary for the barrier to be effective and the bottom row contains the human actions that need to occur.

The exception is the strategic conflict barrier which does not contain specific human actions.

SAFETY FUNCTIONAL MAP - MID AIR COLLISION - CLASS G AIRSPACE							
BARRIER	**COMPONENTS**						
Pilot Recovery (see & avoid)	Other aircraft is visible to the flight crew	Flight crew observes visible aircraft in time	Flight crew initiates effective avoiding action	Avoidance manoeuvre not invalidated by other aircraft			
	Visual conspicuity of other aircraft (colour, lighting) enables it to be visually acquired Conflict geometry permits threat aircraft to be visually acquired Visibility enable the threat aircraft to be visually acquired						
	Pilot maintains effective scan technique	Pilot maintains effective scan technique	Pilot makes correct assessment of flight trajectories Pilot maintains a good situational awareness of other threats Pilot initiates the correct course of action in good time	Pilot has sufficient time to react to changes in the threat aircrafts trajectory			

SAFETY FUNCTIONAL MAP - MID AIR COLLISION - CLASS G AIRSPACE

BARRIER	COMPONENTS						
Pilot Recovery (ACAS)	ACAS is installed and functional	Threat aircraft has a functional transponder that is switched on	ACAS provides effective Resolution Advisory on time	Pilot implements RA correctly	RA manoeuvre is possible		
		Aircraft are equipped with serviceable transponder equipment	Geometry of conflict trajectories is sufficient to trigger ACAS Position of other aircraft in the vicinity do not hamper the ability of ACAS to provide an effective RA		Aircraft performance limitations do not constrain ability to react RA is not compromised by movements of other aircraft Additional aircraft in the vicinity do not become a threat if the RA is followed		
	Pilot ensures ACAS is selected		Selection of Alt/Mode C	Pilot correctly follows single RA instruction Pilot correctly follows multiple RA instructions (reversal RA) ATC instructions are not contrary to the RA or confuse the situation Pilot does not utilise see and avoid and ignore the RA Pilot does not decide the RA is false	ATC instructions are not contrary to the RA or confuse the situation Threat aircraft also follows RA and not instruction from ATC		

SAFETY FUNCTIONAL MAP - MID AIR COLLISION - CLASS G AIRSPACE

BARRIER	**COMPONENTS**						
ATC Recovery (e.g. STCA)	Short-term conflict alert (STCA) forms part of the ATM system and is available	Transponder available on both aircraft	Surveillance information is available	Adequate display of the alert	Sufficient time for ATCO to detect and formulate correct course of action	ATCO provides clear and correct instruction to the pilot	Avoidance not invalidated by other aircraft
	Settings for STCA alerts maximise the effectiveness of the safety net Conflict model is adjusted for Class G airspace operating environment as opposed to en-route (where possible) Any parameters/limitations set within the system do not hinder its effectiveness	All aircraft are equipped with a serviceable transponder Maintenance/checks are completed to ensure transponder is serviceable	Adequate surveillance around aircraft under control which enables threat aircraft to be detected	Visual and audible warnings provide sufficient 'attention getters'	STCA conflict model and settings provide sufficient advance warning that permits action to be taken	Serviceable communication available and no blocked/ garbled transmissions	Change in aircraft trajectories
	ATCO does not deselect due to false alarms		ATCO selects appropriate radar feed (where applicable)	ATCO does not ignore STCA due to multiple false alarms ATCO is not distracted by other tasks	ATCO has sufficient capacity and allocates the correct priority to resolve the threat ATCO course of action is sufficient to resolve the threat	ATCO provides an unambiguous message to the correct aircraft	Pilot does not visually acquire the wrong aircraft and elect not to implement ATC advice Pilot correctly implements the ATC instruction

SAFETY FUNCTIONAL MAP - MID AIR COLLISION - CLASS G AIRSPACE

BARRIER	**COMPONENTS**						
ATC Tactical Intervention	Adequate surveillance picture	Adequate communication	ATSOCAS are available	ATCO provides effective service	ATCO detects potential pilot or controller induced conflict	ATCO implements effective resolution	Avoidance not invalidated by other aircraft
	Availability of non-cooperative surveillance to detect aircraft without a serviceable transponder	Serviceable radios available in both the aircraft and ATC	Service is requested during the hours a service is available A service is requested in a location where ATSOCAS are available (e.g. LARS)	Required ATM equipment is available			Change in aircraft trajectories
	ATCO selects of appropriate surveillance feed(s) ATCO maximises use of surveillance display settings such as range, filters, label management, and menus ATCO situational awareness is not compromised by operating without primary radar (not available/on-maintenance) or by aircraft that are not equipped with any form of transponder	ATCO has the correct radio frequencies selected when more than one is in use	ATCO workload permits the provision of the service requested	ATCO provides sufficient and timely information which enables the pilot to maintain situational awareness and advice to assist safe separation from other aircraft ATCO planning ensures aircraft in receipt of a service are not placed into conflict with each other Navigational assistance provided by the ATCO does not increase the threat to an aircraft Any coordination is timely and effective ATCO is sufficiently current to provide a safe ATS	ATCO maintains an effective scan technique Workload does not compromise the ability of an ATCO to detect a potential conflict The ATCO is not distracted to the extent a potential conflict is missed	ATCO correctly assesses aircraft trajectories and formulates an effective plan ATCO passes timely information that enables the pilot to maintain safe separation	Pilot does not visually acquire the wrong aircraft and elect not to implement ATC advice Pilot correctly implements the ATC instruction

SAFETY FUNCTIONAL MAP - MID AIR COLLISION - CLASS G AIRSPACE

BARRIER	**COMPONENTS**						
Pilot Tactical Control	Effective navigation	Effective situational awareness	Effective airmanship skills	Effective reaction to instructions	Effective application of procedures	Correct readback of instructions	
	Navigational aids are available from a simple paper map through to electronic devices and complex flight systems	Electronic equipment may be used to enhance the pilots ability to maintain situational awareness					
	Pilot navigates effectively and does not infringe any other airspace Pilot requests ATC assistance if required (Eg position fix)	Pilot maintains an effective scan Pilot maintains awareness of other airspace users around them Pilot maintains awareness of the prevailing meteorological conditions Pilot maintains awareness of any navigational warnings in place Pilot requests an ATC service, if required, such as areas of high traffic density	Pilot pays due regard to other airspace users and applies the rules of the air Pilot reports his/her position correctly if communication with ATC (Eg within the visual circuit or during transit)	Pilot complies with ATC instructions, when given, to prevent level busts	Pilot selects correct pressure setting when required ensuring adherence to allocated height/altitude/level The correct quadrantal flight level is selected during IFR transit flights Pilot follows correct procedures for joining an airfield traffic pattern	Pilot does not provide an incorrect readback Pilot does not provide a correct readback but then complete an incorrect manoeuvre	

SAFETY FUNCTIONAL MAP - MID AIR COLLISION - CLASS G AIRSPACE

BARRIER	**COMPONENTS**						
Pre-tactical events	Pilot briefing	Pilot equipment	ATCO briefing				
	NOTAMs easily available and understandable for all airspace users Aeronautical information, including maps, is readily available and easy to interpret Meteorology information is easily accessible	Navigation devices have correct maps	Effective and up-to-date briefing system available				
	Pilot reads and understands the NOTAMs pertinent to his/her flight Pilot plans route and understands airfield procedures Pilot has a contingency plan including knowledge of alternative airfields Pilot has a full understanding of the meteorological conditions and warnings pertinent to his/her flight	Pilot is sufficiently current on aircraft type, including emergency procedures	ATCO is fully conversant with the latest orders, instructions, NOTAMS ATCO has a good understanding of the current and forecast meteorological conditions along with any warnings ATCO has a good understanding of the traffic situation in their area				

SAFETY FUNCTIONAL MAP - MID AIR COLLISION - CLASS G AIRSPACE							
BARRIER	**COMPONENTS**						
Strategic conflict management	Safe Airspace Design	Procedures to reduce risk	Segregation to protect airspace users	Effective management			
	Increases in controlled airspace do not create 'hot spots' within Class G airspace by funnelling aircraft into constrained areas Airspace design is not too complex for users to understand	Speed restrictions are applied to reduce risk between user groups Mandatory transponder zones Mandatory radio areas Conspicuity codes Clear aerodrome joining procedures published	Danger areas, glider areas, low flying system, and air traffic zones are used effectively to afford protection to different user groups	Large scale events are coordinated through the joint and integrated approach to airspace management and details published to all airspace users. Foreign military pilots receive adequate briefing on UK procedures			

Figure 11: Initial safety Functional Map – MAC – Class G Airspace

3.4 What contributory factors impact each barrier?

The initial functional map above shows some of the key actions and factors impacting the effectiveness of each of the identified barriers or controls.

Various contextual factors may also impact the effectiveness, as outlined in section 2 of this report. Many of these are also referred to in the research material summarised in Annex C.

These include:

- Flight crew training (and culture), including issues such as workload management, competence, procedural adherence, teamwork (e.g. with instructors), fatigue etc.
- Corporate cultures, including application of Safety Management practices and willingness to engage with other stakeholders in reducing risk.
- Airspace. This includes the quality and complexity of airspace design, route layout, extent of controlled or uncontrolled airspace, proximity of military operational or training areas etc.
- Flight planning – inappropriate planning may lead to the aircraft traversing a higher risk area when there was no need to do so (*e.g. overhead a circuit)*. This includes awareness of specific aeronautical information for the flight in question.
  Note the opposite may also be true – good flight planning may lead to no airproxes taking place. However, the situation where appropriate flight planning prevents issues will be near impossible to evidence, since no reports will be available.
- Traffic conditions, including density, complexity, and the mix of aircraft types and capabilities (*e.g. if there are two powered aircraft involved in an airprox, were they travelling at significantly different speeds in the circuit or on approach?)*
- Availability of an Air Traffic Service (ATSOCAS), including the level of that service (basic, traffic, procedural, deconfliction). This includes the presence and effectiveness of surveillance for the airspace in question.
- Effectiveness of the ATS: looking at the performance of the ATCO and systems available to them. Includes issues such as workload, competence, teamwork, procedures, safety culture and so on.
- Availability and use of aircraft equipment, including autopilots, GPS, transponders, radios, ACAS, electronic conspicuity, traffic alert systems etc.
- Aircraft visual conspicuity, including size.
- Weather, including the occurrence of IMC, storm activity, visibility (haze, sun glare) and other weather events which may influence conflict detection, management, and collision avoidance.

A next step in this study will be to understand in more detail the links between these factors and the underlying barriers. This may be done through influence models, or Bayesian belief networks. It is not yet clear whether a quantified analysis can be performed; i.e. determining the percentage effectiveness for each factor.

Whilst the studies in Annex C mention many of these elements, it is the aim of this analysis to base any findings "bottom-up" – i.e. from the data available in the reports and individual occurrences.

4 A methodology for data analysis

4.1 Overview

This section outlines the methodology for the analysis of the airprox reports and ancillary material made available to the study for UK Class G airspace risk.

It builds on the overview shown in section 3 above, by identifying the key elements of information which will be identified as the reports are reviewed.

4.2 Main questions to be answered

The study will analyse existing data only, focusing on Airprox Reports from the database provided by the UKAB. For this reason, the findings and recommendations will rely heavily on the quality of the existing data. The airprox data will be used “as-is”, without further validation of individual reports.

The study will look to identify the contributing factors - including contextual, environmental and human factors - to occurrences and incidents and assess the effectiveness of the existing barriers. In doing so, we will carry out a ‘neutral investigation’, whereby we will assess the contributing factors without attributing blame and will focus on what barriers were effective in order to prevent an actual collision.

By saying that a “neutral investigation” will be carried out, the intention is that if a pilot error appears to lead to an airprox, the analysis will look beyond that error to understand why it occurred, and which contextual and systemic factors led to it.

By their very nature, the airprox reports involve incidents which did not result in an actual collision. This will allow us to assess the effectiveness of the barriers, and note which barriers were effective in order to prevent the collision, as well as understanding the factors which led to the airprox.

The objectives of the analysis to be assessed are:

- What barriers work
- What barriers fail
- The contributing factors (focusing on contextual and systemic factors) to the barriers’ effectiveness
- How effective barriers are when they are introduced

4.3 Approach

In the airprox reports, the following categories of risk are assigned:

- Risk A. Actual risk of collision.
- Risk B. Safety not assured.
- Risk C. No risk of collision.
- Risk D. Insufficient information to make an assessment.
- Risk E. Non-event.

It is the initial intention to focus on Categories A to C and E. Cat C shows no risk of collision and Cat E indicates a non-event but these may still include valuable information on barriers and their effectiveness.

The Airprox board reports classify the causal factors of each airprox. The common causal factors of GA airprox in 2011 are listed below as an example:

- Did not see traffic (48)
- FIR conflict (26)
- Flew too close (20)
- Late sighting of traffic (17)
- Late or no traffic info (9)
- No clearance to enter CAS/ATZ (8)
- Pilot did not adhere to procedures (7)
- Sighting report (6)
- Flight over glider or para site (6)
- Conflict in other airspace (5)
- Did not obey ATC Instructions (4)
- Poor Airmanship (4)

These airprox board assigned causal factors will act as our top level causal issues. We will then ascertain the contributory factors, the ‘why’, through reading individual reports in detail.

For example, for the causal factor classification of ‘did not see traffic’, we will read the individual reports to answer ‘why’ the pilot did not see the traffic. This could be because:

- the pilot was distracted - by equipment, map reading, or passengers;
- the pilot was looking in the other direction - due to other traffic, ATC instructions, or lack of;
- visibility was reduced – by the weather, angle of manoeuvre, plane, etc.

As mentioned earlier, a “no-blame” approach will be adopted to help understand the factors which lead to errors.

4.3.1 Grounded Theory

We are taking a Grounded Theory Approach to the development of our methodology for the analysis of the Airprox reports.

Grounded Theory is a research method where the theory is developed from the data as opposed to validating an existing hypothesis. The primary objective is to describe the key elements of risk in Class G airspace.

We analysed an initial sample of the reports in order to develop key words to identify and categorise each report according to the contributory factors that lead to the Airprox.

4.4 Sample investigation

Task 1 has outlined the barriers currently identified, and indicated the possible contributing factors. Using a Grounded Theory Approach, a first look at a sample of the airprox reports allowed us to develop our own taxonomy for categorising the contributory factors.

These categories were then validated and the terminology adjusted to reflect ICAO's Common ATC taxonomy [35].

The taxonomy has been developed specifically for analysis of MAC in Class G airspace and is comprised of a three tier structure:

- Domains
- Disciplines
- Elements

The high-level domains are as follows:

- Individual/Human factors
- Organisational Factors
- Equipment Factors
- Operating Environment

Each of the domains is subdivided into the relevant disciplines. Where required, disciplines are further divided into individual elements. A full description of the disciplines and the elements contained within them will be provided as part of the report for Task 2.

The draft taxonomy in Table 4 below will be updated throughout the analysis to accommodate additional contributory factors identified, in line with Grounded Theory.

Domains	Individual/Human Factors	Organisational Factors	Equipment Factors	Operating Environment
Disciplines	**Experience level** **Knowledge** Currency Qualification Understanding of procedures	**Oversight** Supervision (ATC) Supervision (CRM) Staff allocation	**Aircraft Systems** Communication (availability) Communication (serviceability) Transponder (availability) Transponder (serviceability) TCAS (availability) TCAS (serviceability) Conspicuity Internal radar (availability) Internal radar (serviceability) GPS	**Infrastructure** Airspace design Airspace complexity Airspace availability Traffic Density Aircraft speed ATC service availability (General) ATC service availability (LARS) Field of view Terrain

	Perceptual Situational awareness Conflict assessment	**Ops Planning** Route Planning Resources	**ANSP Systems** Communication (availability) Communication (serviceability) PSR (availability) PSR (serviceability) SSR (availability) SSR (serviceability) STCA (availability) STCA (serviceability) Maintenance	**Weather** Light conditions Visibility Precipitation Wind Temperature VMC IMC
	Physical limitations **Sensory** Health/Fitness	**Policy Procedures** ATSOCAS TCAS Quadrantal/semi-circular Rules of the air Updates/Communication		**Special Events** Military exercise Flight check Emergency services Air policing Parachute Balloon Low flying Pipeline inspection Civil event Airshow
	Procedural/task perform Planning (pre-tactical) Equipment utilisation (general) Equipment utilisation (altimeter) Equipment utilisation (transponder) Equipment utilisation (Navigation/GPS) Scan (Environment) Scan (ATC equipment) Scan (Aircraft equipment) Workload Priorities Coordination (ATC) Traffic Information (ATC-ATC) Traffic Information (ATC-Pilot) Teamwork (CRM) Violation (General) Violation (TCAS) Action/inaction (non-intentional) (General) Action/inaction (non-intentional) (TCAS) Action/inaction (non-intentional) (Altitude)	**Culture (safety)** Culture (working practices)		**Emergencies**

	Action/inaction (non-intentional) (Navigation) Action/inaction (non-intentional) (Airmanship) Action/inaction (non-intentional) (Readback) Action/inaction (non-intentional) (Communication) Action/inaction (non-intentional) (Phraseology)			
	Psychological Distraction (ATC) Distraction (Pilot) Cognitive limitation Information Processing Assessment of risk Emotional state Personality/attitude	**Training (ATC)** **Training (Pilot)**		
	Fatigue (ATC) **Fatigue (Pilot)**	**Record Keeping** Document accuracy		
		Enforcement Assurance		
		Safety Programme		

Table 4: Taxonomy for coding the Airprox database

4.5 Pilot study

We will carry out a pilot study (2012 reports only) in order to verify our taxonomy and develop it further. We will use this pilot study to update the list of barriers and contributory factors identified in task 1, and verified by the sample investigation, and to gain an indication of any patterns in the combinations of contributing factors leading to an effective or ineffective barrier.

For each report we will note:

- The barrier(s) that failed
- The UKAB classified ‘causal factor’
- The contributory factors, the ‘why’
- The barrier(s) that were successful

We will then code the database in order for us to categorise the reports according to failed and successful barrier(s) and the contributory factors identified.

4.6 Main Study

- Reports back to 1999
- Category A-C and E

The database will be coded further as the study progresses in order to add in new contributory factors that are identified.

4.7 Methodology diagram

See Figure 12 for a diagrammatic representation of the methodology.

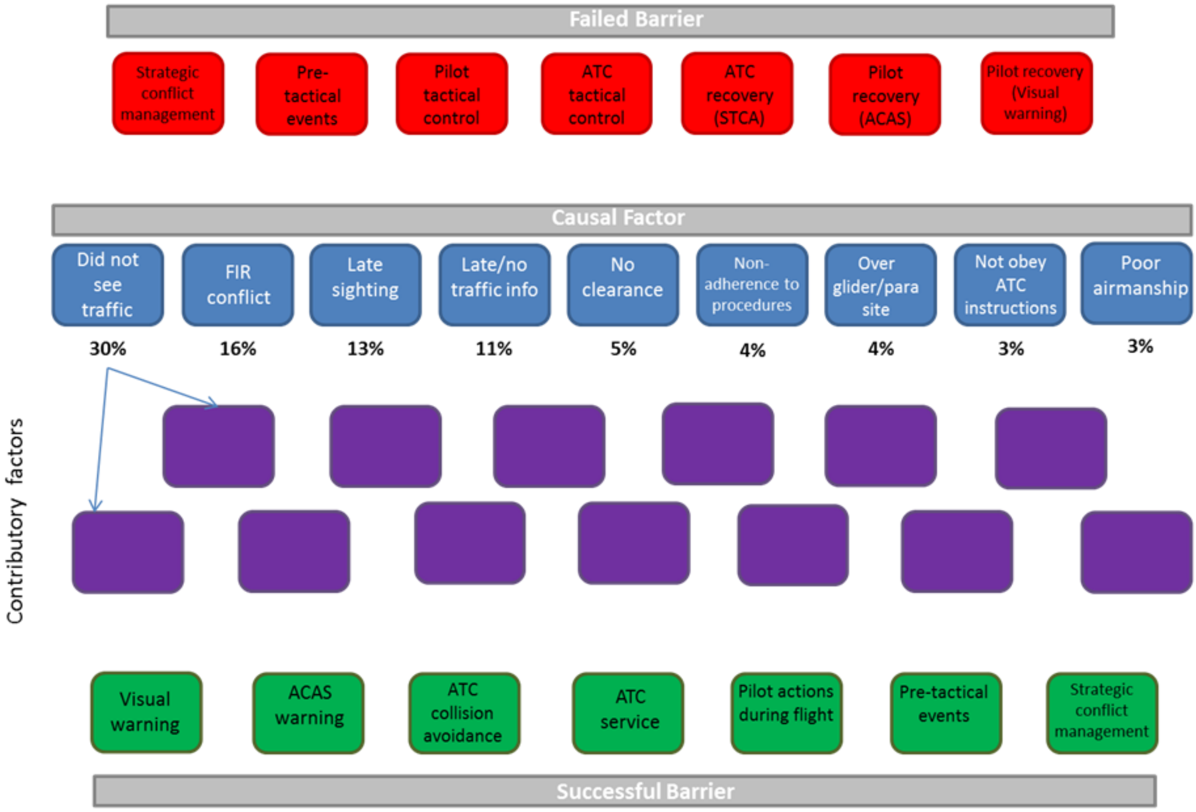

Figure 12: Methodology

4.8 Analysis

The analysis will:

- Identify the barriers that fail/are successful the most
- Identify the contributory factors for each causal factor (there may be some contributory factors which are commonly associated together)
- Identify the contributory factors for each barrier (when they fail and are successful)
- Identify the contributory factors that lead to the most airprox (we may want to link this to risk category)
- Compare the date of introduction of the barriers to the number of airproxes and MACs arising

We will try to look for patterns in the combinations of contributing factors leading to an effective or ineffective barrier.

<u>The outcome:</u>

- Quantified analysis (frequency and effectiveness for each factor)

It is hoped that statistical significance can be gained by the volume of contributory factors and airprox reports

A Acronyms and abbreviations

ACAS	Airborne Collision Avoidance System
ACC	Air Traffic Control Centre
ADS-B	Automatic Dependent Surveillance - Broadcast
AFIS	Aerodrome Flight Information Service
A/G	Air-Ground Service
AIP	Aeronautical Information Publication
AIWG	Airspace Infringement Working Group
AIS	Aeronautical Information Service
AMC	Acceptable Means of Compliance
ANO	Air Navigation Order
APP	Approach Control Service
ATC	Air Traffic Control
ATCO	Air Traffic Control Officer
ATIS	Automated Terminal Information Service
ATS	Air Traffic Service
ATSOCAS	Air Traffic Service outside Controlled Airspace
ATZ	Air Traffic Zone
ASI	Airspace Safety Initiative
BA	Business Aviation
BASP	British Aviation Safety Partnership
BCPL	Basic Commercial Pilots Licence
CAS	Controlled Airspace
CAT	Commercial Air Transport
CFIT	Controlled Fall into Terrain
CRC	Communication & Reporting Centre
CRM	Cockpit (occasionally Crew) Resource Management
CTA	Control Area
GA	General Aviation
GASCo	General Aviation Safety Council
FAS	Future Airspace Strategy

FIR	Flight Information Service
FIS	Flight Information Service
FISO	Flight Information Service Officer
IFR	Instrument Flight Rules
LAPL	Light Aircraft Pilot’s Licence
LARS	Lower Airspace Radar Service
MAA	Military Aviation Authority
MAC:	Mid-Air Collision
MATZ	Military Air Traffic Zone
MoD	Ministry of Defence (UK)
MTOW	Maximum Take Off Weight
NOTAM	Notice to Airmen
NPPL	National Private Pilot’s Licence
PPL	Private Pilot’s Licence
RoA	Rules of the Air
RPAS	Remotely Piloted Airborne System
SMS	Safety Management System
SSP	State Safety Programme
SSR	Secondary Surveillance Radar
STCA	Short Term Conflict Avoidance
TI	Traffic Information
TMZ	Transponder Mandatory Zone
TSAA	Traffic Situational Awareness with Alerts
TWR	Aerodrome Control Service
UAS	Unmanned Aerial Systems
UIR	Upper Information Region
UKAB	UK Airprox Board
UK CAA	UK Civil Aviation Authority
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions

B References

ID	Title	Year of publication
1.	CAA Class G airspace for the 21st Century	March 2012
2.	CAA ATM Class G airspace modelling (feasibility study) – final report including survey data report	Sept 2011
3.	CAA LDLCA Scoping Study	Dec 2013
4.	Australian Transport Safety Bureau – Investigation of Class G	Nov 1999
5.	UKAB - Analysis of airprox in UK airspace – Jan 12 – Dec 12	2013
6.	UKAB - Analysis of airprox in UK airspace – Jun 11 – Dec 11	2012
7.	UKAB - Analysis of airprox in UK airspace – Jan 11 – Jun 11	2012
8.	UKAB - Analysis of airprox in UK airspace – Jul 10 – Dec 10	2011
9.	Eurocontrol airspace infringement presentation	April 2008
10.	Australian CAA aero-study of Class E airspace	August 2011
11.	LAA - Safety in Class G airspace – A Review of Mid-Air Collisions Involving UK Registered Civil Aircraft 1975-2011	Feb 2012
12.	LAA – Managing risk in Class G airspace	Feb 2012
13.	LAA presentation – estimates of GA transponder penetration	Nov 2013
14.	RAF FS mid-air collision risk analysis and feedback	Oct 2012
15.	The Risk of Mid-Air Collision to Commercial Air Transport Aircraft Receiving a Radar Advisory Service in Class F/G Airspace	2003
16.	CAA paper: Application of providence box method for estimating mid-air collision risk in UK airspace	2005
17.	CAA Airborne Conflict Action Group: visual circuit procedures sub-group	June 2013
18.	GAO note: additional FAA efforts could help identify and mitigate safety risks	Oct 2012
19.	LPAT – various presentations to UK fora	2013
20.	BEA (France) safety study on MAC 1989-1999	n/a

21.	AOPA Air Safety Foundation – Collision Avoidance: Strategies and Techniques	n/a
22.	ICAO circular 213 – AN/130 CAA safety sense No.13 EASA EGAST GA 1	1989 2013 2013
23.	GAPAN – discussion paper on sense-and-avoid safety level requirements for UAS	2012
24.	MITRE analysis of MAC and reporting data for TSAA application development in RTCA	2012
25.	UK CAA registered aircraft statistics (from website)	2014
26.	UK CAA Strategic Review of General Aviation	2006
27.	MAA Bow-Tie models for key risks (from website)	2014
28.	CAA Future Airspace Strategy	June 2011
29.	CAA SN 2013-009	2013
30.	CAA Register of Civil Aircraft Statistics	2013
31.	Australian Transport Safety Bureau Limitations of the see and avoid principle	1991
32.	S. M. Moore – Comparison of alerted and visually acquired airborne aircraft in a complex air traffic environment	June 1998
33.	Colvin, Dean, & Dismukes – Is pilots visual scanning adequate to avoid mid-air collisions?	2005
34.	NATMAC Information Notice – LARS Review	2014
35.	ICAO Common Taxonomy - Air Traffic Causal and Contributory Factors	February 2014
36.	CAA Guide to visual flight rules	2011
37.	ASI ATSOCAS Interactive Guide	March 2009
38.	CAP 774 UK Flight Information Services	October 2013
39.	UK AIP ENR 6-1-6-3	May 2014

C Summary of literature

C.1 This section summarises results of our literature review. The table below provides summary of the key references covering the following:

- Purpose of the document;
- Time range of analysed data;
- Geographical region;
- Scope;
- Airspace classes covered;
- Key accident statistics;
- Safety risk factors;
- Mitigations / interventions; and
- Leading indicators

C.2 The review covers documents referred to by the ITT as well as other identified studies.

1. CAA Class G Airspace for the 21st Century (March 2012)

Purpose of the document:
To identify the work required to support the achievement of the CAA's Future Airspace Strategy

Time range of analysed data:
n/a

Geographical region:
UK

Scope:
All traffic in class G airspace

Airspace classes covered:
G

Key accident statistics:

- Powered aircraft A/C predominantly collide with other powered aircraft, gliders with gliders
- Whilst 47% of powered aircraft collisions occur in cruising flight, only 3% of glider collisions (with powered aircraft) were in the cruise. No gliders have collided with other gliders in cruising flight. Collisions appear to be closely related to traffic density with 53% of powered aircraft collisions occurring over or near an airfield and glider collisions being divided 80% over or near the launch site and 20% in cross country thermal or cruise. All of the above must be viewed in the context of overall risk; collisions have thus far accounted for only 1% of all GA accidents and 6% of fatalities/
- Statistical evidence shows that the risk of collisions is relatively low in the FIR generally but is significant in the vicinity of busy GA airfields and flying sites as detailed in the paper on Managing Risk in Class G Airspace.
- Aircraft operating some form of traffic alerting system have found they help to increase pilot situational awareness thereby reducing collision risk.
- Visual search is not 100% effective and even in ideal conditions there is no guarantee that a conflicting aircraft will be sighted in sufficient time to avoid a collision. Studies show that, in essence, a visual search is more likely to be effective when the searcher knows there is a target to find and approximately where to look for that target.
- Visual search is aided by listening for specific instructions or information from ATC or for transmissions from other aircraft. Pilots develop detailed mental models to assist in deciding where to visually search.
- There is a lower probability of seeing traffic if it is not where it is expected to be. There are limitations inherent in a system that ultimately relies on see-and-avoid for collision prevention.

Safety risk factors identified:

- Traffic density, usually over and around busy GA airfields
- Low effectiveness of see-and-avoid

Mitigations / interventions identified:

- Increased effectiveness of see-and-avoid through:
  - Provision of ATS
  - Enhanced electronic conspicuity
  - Traffic alerting systems

Leading indicators identified: n/a

2. ATM Class G modelling feasibility study survey data report (Sept 2011)

Purpose of the document:
Summary of an on-line pilots' survey providing information from individual pilots about the type of flying undertaken, the number of hours flown and the nature of activities conducted.

Time range of analysed data:
2010-2011

Geographical region:

UK

Scope:
All traffic in class G

Airspace classes covered:
G

Key accident statistics:
n/a

Safety risk factors identified:
n/a

Mitigations / interventions identified:
n/a

Leading indicators identified:
n/a

3. LDLCA Scoping Study (Dec 2013)

Purpose of the document:
A study setting out the potential options and possible way forward for Low Density Low Complexity Airspace in the UK and Ireland. It included consultations with stakeholders including GA and the military, and although not specific to safety issues, included consideration of these in the report.

Time range of analysed data:
n/a

Geographical region:
North West of Scotland (not including the central belt), Northern Ireland (excluding Belfast) and Ireland (excluding Dublin)

Scope:
Low Complexity Low Density Airspace in the UK and Ireland

Airspace classes covered:
Mainly Class G

Key accident statistics:
n/a

Safety risk factors identified:
n/a

Mitigations / interventions identified:
Several mitigations for risk in LDLCA were noted by the study

- Use of ADS-B for electronic conspicuity (subject of a working group in the UK CAA)
- Use of Radio Mandatory Zones (RMZ), Transponder Mandatory Zones (TMZ), and Surveillance Mandatory Zones (either Mode S transponders or ADS-B transceivers)
- Appropriate application of ATSOCAS
- Future potential use of enhanced information to enable situational awareness (e.g. notification of business jet arrival at smaller aerodrome in Class G)

Leading indicators identified:
n/a

4. Australian Transport Safety Bureau – Investigation Class G (Nov 1999)

Purpose of document:
A systemic investigation into changing the operation in Class G airspace, with regards to the implementation of a national advisory frequency; provision of a conditional radar information service; and cessation of directed traffic information.

Time range of analysed data:
52 days

From 22 October 1998 To 13 December 1998

Geographical region:
Australia

Scope:
Class G airspace in Australia

Airspace classes covered:
G

Key accident statistics:
Forty-five of the 133 incidents notified to BASI during the demonstration dealt primarily with SAR related issues. Other issues involved in the 133 incidents were:

- education and training (87 incidents)
- frequency management issues, including workload (57 incidents)
- congestion on the national advisory frequency (6 incidents)
- radar information service limitations (5 incidents)

Safety risk factors identified:

- education and training
- frequency management issues, including workload
- congestion on the national advisory frequency
- radar information service limitations
- effective management of policies and procedures for changes to the aviation system

Mitigations / interventions identified:
n/a

Leading indicators identified:
n/a

5. Analysis of airprox in UK airspace – UKAB – Jan '12 – Dec '12

Purpose of document:
Report by the UK Airprox Board: Analysis of Airprox in UK Airspace

Time range of analysed data:
From January 2012 to December 2012

Geographical region:
UK

Scope:
Commercial Air Transport, General Aviation, Military

Airspace classes covered:
All classes covered

Key accident statistics:

- UK Airprox Board investigated 161 Airprox in 2012; there was a reduction from 2011 in risk-bearing airprox (from 37% to 28%)
- In common with previous years, Class G airspace is where most Airprox occur because this is where the greatest variety of aircraft can be found, where pilots are ultimately responsible for avoiding collisions through 'see and avoid' and where a great deal of training takes place.
- 57% were in Class G (35% below 3000ft, 14% between 3001ft and FL79, 8% over FL80)
- 22% occurred within an ATZ/MATZ.
- There has been a reduction in the number of Airprox occurring when pilots operate under a Deconfliction Service compared with the old Radar Advisory Service, but for the lower levels of service there have been significant increases in Airprox numbers under the new ATSOCAS.
- Comparing the previous Flight Information Service (FIS) with a the new Basic Service (BS) and comparing the old Radar information Service with the new Traffic Service (TS) shows increases of 40% and 91% respectively

Safety risk factors identified:

- Not applicable (error in book meant 2011 data was repeated for GA)

Mitigations / interventions identified:

- Minimise flight time below 3000ft is mentioned in the report.
- The issues contributing to airprox in Aerodrome Traffic Zones (ATZs) are being addressed through the CAA Visual Circuit Working Group.

Leading indicators identified:

n/a

6. Analysis of airprox in UK airspace – UKAB – Jun ’11 – Dec ‘11

Purpose of document:

Report by the UK Airprox Board: Analysis of Airprox in UK Airspace

Time range of analysed data:

2011

Geographical region:

UK

Scope:

Commercial Air Transport, General Aviation, Military

Airspace classes covered:

All classes covered

Key accident statistics:

- 161 airproxes in 2011. Around 70% involved GA (and possibly higher, given many designated “unknown” such as gliders and other light aircraft were likely to be civil)
- Category A airprox involving GA higher than any point in the past 10 years (19 in total)
- 60% occurred in Class G (43% below 3000ft, 14% from 3001ft – FL79, 3% above FL80)
- A further 24% occurred in ATZ or MATZ
- Airprox rates per 100,000 hours flight continued to fall (from approx. 2.47 to 1.50)

Safety risk factors identified:

- Many of the airprox in Class G airspace (including MATZs) involve aircraft marshalling for instrument approaches. Common threads include poor lookout while flying on instruments and an incorrect expectation by pilots operating under IFR that VFR traffic will avoid instrument patterns
- Did not see traffic (73)
- Late sighting of traffic (45)
- Inadequate avoiding action / flew too close (40)
- FIR conflict (36)
- Sighting report (or TCAS for CAT) (29)
- No clearance to enter CAS/ATZ (15)
- Controller did not separate / poor judgement (12)
- Late or no traffic info (12)
- Pilot did not adhere to procedures (11)
- Conflict in other airspace (11)
- Climbed / descended through assigned level (9)
- Did not obey ATC instructions (7)
- Flight over glider or para site (6)
- Poor Airmanship (4)
- Inappropriate ATC instructions / invalid FL (3)
- Misinterpretation of ATC message (3)
- Controlled airspace conflict in VMC (2)

- Undetected readback error (2)

Mitigations / interventions identified:
n/a

Leading indicators identified:
n/a

7. Analysis of airprox in UK airspace – UKAB – Jan ’11 – Jun ‘11

Purpose of document:
Report by the UK Airprox Board: Analysis of Airprox in UK Airspace

Time range of analysed data:
From January 2011 to June 2011

Geographical region:
UK

Scope:
Commercial Air Transport, General Aviation, Military

Airspace classes covered:
All classes covered

Key accident statistics:

- 63 airproxes in the 6 months – maintaining the long term average of around 30-35% risk bearing (Cat A or B);
- Civil vs Mil airprox fell compared to similar six month period in 2010 (noting that the 2010 figure was a sharp rise against 2009)
- 40% in Class G below 3000ft, a further 20% in Class G from 3001ft – FL79
- A further 20% occurred within ATZ or MATZ

Safety risk factors identified:
From a combination of CAT, Military and GA:

- Did not see traffic (29)
- Inadequate avoiding action (flew too close) (15)
- FIR conflict (15)
- Late sighting (14)
- Failure to pass or late passing of traffic information (6)
- Penetration of CAS/ATZ without clearance (5)
- Controller perceived confliction (4)
- Not obeying orders or following advice from ATC (3)
- Sighting report (3)
- Poor airmanship (3)
- Controller did not separate / poor judgement (2)
- Flying close to, or over, glider, microlight or paradrop site (2)
- Conflict in other type of airspace (2)

Mitigations / interventions identified:
n/a

Leading indicators identified:
n/a

8. Analysis of airprox in UK airspace – UKAB – July ’10 – Dec ‘10

Purpose of document:
Report by the UK Airprox Board: Analysis of Airprox in UK Airspace

Time range of analysed data:
From July 2010 to December 2010

Geographical region:

UK

Scope:
Commercial Air Transport, General Aviation, Military

Airspace classes covered:
All airspace classes covered

Key accident statistics:

- The UK Airprox Board investigated 167 Airprox events that occurred in UK airspace during 2010
- Majority of Airprox occur in Class G (uncontrolled) airspace where late and non-sightings by pilots are the predominant causes.

Safety risk factors identified:
A total of 29 different causal factors were assigned to the 102 GA Airprox. Following factors are the top 12 factors:

- Did not see conflicting traffic (36)
- Late sighting of conflicting traffic (25)
- FIR conflict (20)
- Inadequate avoiding action/flew too close (14)
- Flying close to/over glider, paradrop or microlight site (8)
- Penetration of CAS/ATZ without clearance (7)
- Did not pass or late passing of traffic info (6)
- Conflict within or on boundary of ATZ/CTR/CTA/AAA (5)
- Did not adhere to prescribed procedures (5)
- Did not separate/poor judgement (4)
- Sighting report (4)
- Inappropriate ATC Instructions, use of invalid FL (4)

Sighting issues were again the most common cause of Airprox involving GA aircraft and the top 4 causes in 2010 were all in the top 5 for 2009. The 8 Airprox involving over-flights of glider, paradrop or micro-light sites are a particular concern when the hazard is exacerbated by the risk of collision with the winch cable. Other scenarios that regularly feature in Airprox reports include pilots join airfield circuits without regard to aircraft already established in the pattern; training flights and especially IF training flights; and aerial survey work.

Mitigations / interventions identified:
n/a

Leading indicators identified:
n/a

9. Eurocontrol Airspace Infringement presentation (April 2008)

Purpose of document:
General & Business Aviation Forum, EUROCONTROL, Brussels, 4 April 2008

Time range of analysed data:
2001-2006

Geographical region:
Europe

Scope:
General Aviation

Airspace classes covered:
All classes

Key accident statistics:
Infringement Causal Factors:

- Unfamiliar airspace 6%
- Bad weather 10%
- Misread map 10%
- Distraction 11%
- Complex airspace 9%
- Navigation failure 15%
- Inadequate clearance 7%
- Other 32%

Safety risk factors identified:

- Aeronautical information
- Airspace and navigation
- ATC and FIS
- Environment (weather)
- Human factors
- Pilot skills (airmanship)

Mitigations / interventions identified:

- Pilot navigation and communication skills
- Airspace design and management
- Aeronautical information provision
- FIS
- Safety awareness

Leading indicators identified:

n/a

10. Australian CAA aero-study of Class E airspace between Port Macquarie and Ballina (August 2011)

Purpose of document:

To review the Class E airspace classification currently in place between Port Macquarie, New South Wales (NSW) and Ballina, NSW.

Time range of analysed data:

From January 2008 to December 2010

Geographical region:

Australian

Scope:

Emphasis is placed on the safety of Passenger Transport (PT) operations.

Airspace classes covered:

Class E and G

Key accident statistics:

n/a

Safety risk factors identified:

- Airspace and frequency congestion around the Port Macquarie and Taree area occur during times of stable weather. Frequency congestion is experienced on the Common Traffic Advisory Frequency (CTAF) for the area
- Frequency congestion compounded due to poor and inappropriate use of VHF communications Airspace and frequency congestion more noticeable during times of stable VFR weather patterns.
- Mandatory carriage and use of transponder without dispensation would enhance safety.
- Certain restricted areas impact on airspace efficiency particularly when activated without notice.
- Evans Head restricted airspace is difficult to avoid during times of thunderstorm activity.

- Provision of a Class E or C service to lower altitudes would be operationally beneficial.
- Promulgation of an additional danger area as discussed in section 5.4 restricts the implementation of Class E services to lower levels without further consultation.
- Current surveillance levels would only support minor potential for the provision of Class E services to lower levels.

Mitigations / interventions identified:

- Dispensation for the carriage and use of transponders in Class E airspace has a perceived safety implication.
- Current surveillance coverage would only support minor potential for the provision of Class E services to lower altitudes.
- Lower level Class E airspace would reduce the available time for crews to communicate their intentions on CTAF and Class G frequencies.
- Lowering Class E airspace could result in a marginal increase in risk.
- The high percentage of Airspace Infringements (previously known as Violations of Controlled Airspace) indicates that a certain amount of confusion exists with pilots with regards to the airspace design.
- Stakeholder feedback was positive towards a lowering of Class E airspace when supported by aeronautical studies and appropriate cost benefit analysis.

Leading indicators identified:

n/a

11. Safety in Class G airspace – A Review of Mid-Air Collisions Involving UK Registered Civil Aircraft 1975-2011 (Feb 2012)

Purpose of document:

In order to better understand the safety risks in Class G airspace, a study was conducted by the LAA as input to the Class G in the 21st Century activity. The data was extracted from the CAA MORS database and merged with the BGA accident database.

Time range of analysed data:

From 1975 to 2011

Geographical region:

UK

Scope:

Data on mid-air collisions within the UK FIR involving UK registered civil aircraft

Airspace classes covered:

Class G

Key accident statistics:

There is no recorded collision involving a commercial air transport aircraft in Class G airspace. In the 37 years since 1975 a total of 218 aircraft have been involved in 108 mid-air collisions of which 45 involved 86 fatalities. Disregarding hang gliders and the events which are irrelevant to the analysis of airspace safety leaves 178 aircraft involved in 89 collisions, 38 of which involved 74 fatalities.

Of the 178 aircraft involved, 72 were powered aircraft, 6 were glider tugs, 96 were gliders, and 4 were military. The military aircraft were 2 Tornados, 1 Tucano and 1 A-10.

Safety risk factors identified:

Collisions appear to be closely related to traffic density with 56% of powered aircraft collisions occurring over or near an airfield and glider collisions being divided 91% over or near the launch site and 9% in cross country thermal or cruise

Collisions account for approximately 1% of all GA accidents and 6% of fatalities.

Mitigations / interventions identified: n/a

Leading indicators identified: n/a

12. Managing Risk in Class G airspace – A note by the LAA (Feb 2012)

Purpose of document:

Uses data from the previous study, 'Safety in Class G airspace – A review of Mid-Air Collisions Involving UK Registered Civil Aircraft', and considers how the risk is distributed and considers how and where that impacts on FAS policies for Class G airspace.

The paper was written to use the data collected to propose inputs from an LAA perspective to the "Class G in the 21st Century" activity.

Time range of analysed data:

From 1975 to 2011

Geographical region:

UK

Scope:

Data on mid-air collisions within the UK FIR involving UK registered civil aircraft

Airspace classes covered:

Class G

Key accident statistics:

- Collisions in the open FIR, including those in choke points and densely utilised areas, constitute 22% of the total.
- It appears that collision risk is not increased when flying close to controlled or restricted airspace but could be reduced, even without the benefit of radar services.

Safety risk factors identified:

- The highest risk of collision for GA occurs around busy GA airfields and flying sites (71%), with 29% spread over the FIR broadly in line with traffic density.
- Risk to gliders is with other gliders in and around the launch site. But the risk to aeroplanes and helicopters is 55% around airfields and 45% in cruise.

Mitigations / interventions identified:

- The provision of an ATS service at an airfield does not appear to prevent collisions occurring. Strong pilot skills in understanding the situation and the likely intentions of other aircraft combined with well-practised lookout skills could help reduce this risk.
- Technical solutions are not well adapted to deal with any of the GA issues discussed.
- ADSB (out) is presently beyond the means of GA because of the requirement for the GPS and the installation to be certified. ADSB (in) is available but without ADSB (out) or an ADSB TIS it cannot function. FLARM works for gliders and some GA aircraft but is not certified.

Leading indicators identified:

n/a

13. GA Transponder Penetration presentation (Nov 2013)

Purpose of document:

Information on GA Transponder coverage in the UK

Time range of analysed data:

Presented 18/11/2013

Geographical region:

UK

Scope:

UK Aircraft

Airspace classes covered:

n/a

Key statistics:

- Of registered aircraft transponders are fitted to 51% aeroplanes, 35% microlights and 10% gliders.
- Of unregistered aircraft transponders are fitted to 27%.

14. RAF FS Mid-Air Collision Risk Analysis and Feedback (Oct 2012)

Purpose of document:

Overview of current mitigations (prevent, detect, avoid) and identifies potential areas for improvement

Time range of analysed data:

1980-2008

Geographical region:

UK

Scope:

RAF MAC statistics

Airspace classes covered:

All

Key accident statistics:

- 10 Cat A airprox occur for every random collision. The RAF rate was nearer 30, said to indicate a better rate of reporting culture.
- A GAPAN analysis of the risk of MAC from random collisions found that the risk per flying hour for GA traffic was twice that for military ac. This may be due to better military training, lookout skills, cockpit visibility and equipment specifications. It is a strong indicator that the much higher levels of regulation, training, supervision and risk management for military operations in an environment shared with GA traffic, produces the expected benefits.
- The paper also found that the risk was higher by day, below 3000ft in uncontrolled airspace, and near airfields. Operations in Controlled Airspace (CAS) were assessed to be 400 times safer than other operations, but this does not suggest that wider use of CAS is required or practicable.

Safety risk factors identified:

- Most dangerous = uncontrolled airspace below 3000ft, due to unknown, mixed and relatively uncontrolled traffic environment, and around airfields due to concentration of traffic.
- Airprox data indicates that the airfield environment and visual circuits are still a live risk that requires attention.
- See-and-avoid is limited by cockpit design, ac relative speed, visibility, lighting levels and conspicuity
- Avoiding action can be taken by pilots based on TI without a visual sighting, but weakness includes poor assimilation of TI or an unwillingness to act on TI alone, even when notified by ACAS.
- Airprox reports indicate that pilots may not always be fully aware that they hold responsibility for collision avoidance in uncontrolled airspace, even when operating an Air Traffic Service.
- The key factors are the speed and density of traffic, and the time in the airspace.
- Not all ac have large radar cross-sections, and radar clutter and filtering may lead to conflicting ac not being visible to radar. In addition, not all ac are fitted with IFF transponders so may not appear on SSR displays. Moreover, controllers may just not see, assimilate or report conflicts in a timely of accurate enough manner.
- Over-reliance on ATC services and other safety aids, over time, may reduce the effectiveness of crews' lookout scans. Whilst systems are imperfect, and uncontrolled, low conspicuity, non-squawking ac such a microlights share the operating environment, lookout skills must be reinforced at every opportunity.
- The limitations of lookout are determined in part by eye physiology, including effects such as fatigue, hydration level, and cockpit obscuration in addition to the environmental conditions.

Mitigations / interventions identified:

- Detection could be aided by pre-flight planning
- Resourcing issues with service provision can affect risk. Need to ensure regulation is robust and that controllers and aircrews understand their services and responsibilities
- Minimising time spent in high-risk areas, or avoiding them all together where possible, is a primary means of reducing MAC risk.
- Establishing and complying with sound deconfliction procedures is essential in controlling the risk when exposure to busy airspace, such as around airfields in general and near approach

and departure lanes in particular, holding points, transit routes, range entry and exit points and in the UK LFS.

- Understanding the traffic density is fundamental to being able to manage MAC risk, and operators need to be cognisant of changes to this element of their operating environment.
- Where lookout may be compromised by the exercise or activity being undertaken, NOTAMs may be issued to warn other users of the heightened risk, either causing them to intensify or focus their lookout or encouraging them to avoid the area completely.
- TS/DS Utility. However, once the instructional element of the sortie commences, a very busy control service can become a distraction, may provide limited reduction in MAC risk, and may actually increase other risks through distraction and overload of the crew if they do not prioritise their ATS accordingly.
- Historic conspicuity trials identified dark colour schemes as the most effective for visual detection resulting in their adoption for the majority of military training ac.

Leading indicators identified:

- There are many Airprox cases where a controller has seen a clear conflict on a Radar screen but the communication of the hazard has failed to prevent a near-miss. This may be due to controllers not communicating the degree of conflict sufficiently well to alert the crew, or providing TI that is not accurate enough
- Other possible reasons for the lack of effective avoiding action being taken by pilots are: lack of assimilation of clear TI by the pilot; inability to decide on appropriate avoiding action; or a preference to 'stand on' and hope to get visual. Indeed, it may be that most called traffic is sighted in good time resulting in a confidence that this will always be the case.
- This suggested a perverse presumption that offering a service when not all traffic could be detected was worse than offering none at all, and that aircrew reduced their lookout when under a TS, even when warned of the limitations of their service by controllers

15. The Risk of Mid-Air Collision to Commercial Air Transport Aircraft Receiving a Radar Advisory Service in Class F/G Airspace (2003)

Purpose of document:

Discusses the quantification of the risk (chance) of mid-air collision to commercial air transport aircraft receiving a Radar Advisory Service in UK Class F/G airspace.

Time range of analysed data:

1999 - 2001

Geographical region:

UK

Scope:

Risk of MAC for CAT aircraft receiving a radar advisory service

Airspace classes covered:

Class F/G

Key accident statistics:

- Airprox rate for CAT aircraft receiving a RAS in Class F/G is 11.2Airproxes per 100,000 flying hours exposure.
- Annual Hours exposed for all CAT aircraft receiving a RAS in Class F/G are 107,000.
- The Airprox for this type of service is about 50% greater than that for CAT aircraft generally (7.13 in 2000), and CAT Airproxes in controlled airspace are probably more likely to be reported.

Safety risk factors identified:

n/a

Mitigations / interventions identified:

n/a

Leading indicators identified:

Probabilities would need to be estimated for such risk components as controller perceptual or judgement error, attention failure, memory lapse, etc.

16. Application of providence box method for estimating mid-air collision risk in UK

airspace

Purpose of document:
Explaining the application of the providence box method (a method for apportioning target levels of safety).

Time range of analysed data:
n/a

Geographical region:
n/a

Scope:
It measures the probability of a mid-air collision given that a ‘close encounter’ event has occurred. This is achieved by using the concept of a ‘providence box’, which is a volume of airspace with the commercial air transport aircraft in the middle and it is assumed that if another aircraft enters this box then providence is all that prevents a collision. The probability of the providence box being breached is provided empirically by historical data such as Airprox (thus removing the most difficult task of modelling the probability of two or more aircraft being in the same place at the same time).

Airspace classes covered: All

Key accident statistics: n/a

Safety risk factors identified: n/a

Mitigations / interventions identified: n/a

Leading indicators identified: n/a

17. Airborne Conflict Action Group: Visual Circuit Procedures Sub-Group (24th Sep 2013)

Purpose of document:
Report of Visual Circuit Procedures Sub-Group meeting (26th June 2013); it recommended that AMC Guidance (a “skyway code”) be applied to the Rules of the Air. This meeting discussed in greater detail the suggested content of that guidance. The effectiveness of the Barriers (now called Controls) discussed in previous meetings was reviewed.

Time range of analysed data:
n/a

Geographical region:
UK

Scope:
UK airspace, and regulatory guidance

Airspace classes covered:
n/a

Key accident statistics:
n/a

Safety risk factors identified:

- Why does lookout fail:- distraction, human factors aspects, limitations of the human eye, may not have enough time (2 x PA28 head to head gives 12-15 seconds to see and react whilst CAA states that 10 seconds is required to see and avoid whilst the FAA states 12.5 secs) not appropriate in poor visibility or whilst ‘heads-in’ during instrument training
- Making appropriate use of ATS – ATCOCAS: Pilots may expect a service which they do not get
- Most pilots are pretty poor at listening out and building a picture of the traffic around them (therefore not a good mitigation)
- Takes significant amount of time to do a lookout (30s) therefore chance of seeing an a/c at the 10-15 second point are low

Mitigations / interventions identified:
A ‘Skyway Code’, this would include:

- General CAA Guidance on Circuit Joining Procedures

- Having a ‘Plan B’, in case of diversion, change in weather, radio failure, contingency plans (orbit, hold)
- Encouragement to ask in clear language if unsure of instructions
- Emphasis on good lookout
- Understanding VFR rules – clear of cloud by 1,000ft
- Utilise a/c lights as much as possible
- Discourage orbits in the circuit unless specifically instructed
- Risks and danger involved
- High speed a/c don’t have right of way over low speed

Currently this information is scattered and reading an AIP can detail much information that is not required.

Also required:

- Development of basic, affordable electronic conspicuity for light a/c

Leading indicators identified:

n/a

18. GAO Additional FAA Efforts Could Help Identify and Mitigate Safety Risks (October 2012)

Purpose of the document:

Review of general aviation safety.

Time range of analysed data:

1999 - 2011

Geographical region:

USA

Airspace classes covered:

All GA

Key accident statistics:

- Aircraft, particularly single engine piston, flying personal operations most involved in accidents
- The annual number of GA accidents decreased 1999-2011

Safety risk factors identified:

- Most accidents attributed to pilot errors (70%) a loss of control was most common in fatal accidents and a loss of engine power was most common in non-fatal accidents.
- 44% of pilots in accidents had less than 100 hrs.
- Experimental - Amateur Built (E-ABS) were the second most common a/c involved in accidents.
- Pilot flying for pleasure and practicing manoeuvres and take-off and landings are the phases of flight when most accidents occur.

Mitigations / interventions identified:

- The collection of GA a/c flight-hour data, safety improvement goals and performance measures.
- Outreach and engagement
- Training
- Funding to reduce accidents in Alaska
- Funding university research on GA issues
- Funding to develop a system from reporting a/c issues
- Technology (air bags, ballistic parachutes, weather in the cockpit, angle-of attack indicators, terrain avoidance equipment
- Define equipage requirements

Leading indicators identified:

- Aircraft malfunction, human performance
- Loss of control in flight (31%) – the number 1 causal factor
- Pilot decisions, actions or cockpit management (70%)
- Combination of the pilots actions and failure to properly attain/maintain a performance

parameter e.g. airspeed or altitude (34%)

- In experience in make and model (40%)

19. Low Power ADS-B Transceiver – various material

Purpose of the material:

Provides an initial high level assessment of the safety and performance requirements, and associated certification approach, for a low cost, Low Powered ADS-B Transceiver (LPAT) for use by General Aviation (GA) in uncontrolled airspace. NATS have briefed on this as several GA fora.

Time range of analysed data:

n/a

Geographical region:

UK

Airspace classes covered:

n/a

Key accident statistics:

n/a

Safety risk factors identified:

- mid-air collision
- loss of control (e.g. unnecessary avoiding action)
- Controlled Flight into Terrain (CFIT) or obstacles.

Mitigations / interventions identified:

- faster visual acquisition of traffic in the vicinity of own aircraft freeing up pilot time for other activities (including scanning horizon for other targets)
- detection of traffic that would otherwise be hard to visually acquire (e.g. because of the relative positions of aircraft or aircraft characteristics such as speed)
- Display of relative range information on detected targets as well as target type.

Leading indicators identified:

n/a

20. BEA safety study – MAC 1989-1999

Purpose of the document:

Understanding mid-air collisions in France, the main contributory factors and characteristics

http://www.bea-fr.org/etudes/abordageseng/midair.htm

Time range of analysed data:

1989-1999

Geographical region:

France

Airspace classes covered:

All

Key accident statistics:

Seventeen mid-air collisions were noted in the time-period under analysis.

- Three involved mid-air collisions between a transport plane and light aircraft (two cases) or a glider (one case),
- Three involved a collision between a light aircraft and a glider,
- Eleven collisions occurred between light aircraft,
- Nine flights were instruction flights with the instructor on board,
- Two mid-air collisions occurred while one of the two planes was flying IFR

The majority of the collisions occurred below 3000ft, where most VFR flights exist. Twelve of the collisions occurred in uncontrolled airspace. All collisions occurred in daytime in good weather conditions.

Safety risk factors identified:

- Discussion of efficacy of visual acquisition, given limitations of eye and human perception (e.g. constant bearing, dead angles).

- Knowledge of airspace (leading to infringement, and lack of awareness of where other traffic may be.

Mitigations / interventions identified:

- faster visual acquisition of traffic by using all available means to be spotted (e.g. lights during day) and acquiring traffic e.g. cleaning windshield, systematic use of radio and transponder, and adherence to notified procedures
- enhanced training of pilots in outside monitoring, assisting pilots in how to search and detect (rather than solely glance at the sky).
- pilots should be trained to appraise the relative movement of another aircraft and to conceive and quickly execute the correct avoidance manoeuvre.

Leading indicators identified:

n/a

21. AOPA Air Safety Foundation – Collision Avoidance: Strategies and Techniques

Purpose of the document:

To disseminate information on the history of mid-air collision risk and to teach pilots how to visually identify potential collision threats and adopt procedures that can lessen the risk of an in-flight collision.

Time range of analysed data:

n/a

Geographical region:

USA

Airspace classes covered:

All

Key accident statistics:

Several quoted in the report (source: AOPA Air Safety Foundation):

- Half of MACs occur within five miles of an airport in the USA
- 96% occur at or below 3000ft AGL
- 40% occur at or below 500ft AGL (e.g. traffic pattern)
- Head-on collisions only account for 14% of all MACs
- 39% occur whilst converging in a side impact
- 47% occur as one aircraft overtakes another
- Flight time / experience does not appear to be a major risk factor

Safety risk factors identified:

- Lack of visual acquisition of traffic
- Incorrect procedures applied in the cockpit

Mitigations / interventions identified:

- Awareness of human perception and visual acquisition abilities, leading to improved scanning techniques in the cockpit
- Awareness of design issues with individual aircraft limiting visibility
- Awareness of environmental issues (e.g. haze, sun, etc.) limiting visibility
- Appropriate time taken for scan – experiments with military pilots suggests 17 seconds outside and 3 seconds on the panel are necessary for an effective scan (also referenced in ICAO Circular 213 – AN/130 (see below)
- Appropriate CRM (sterile cockpit, programming GPS on the ground etc.)
- Use of electronic conspicuity and collision avoidance technology
-

Leading indicators identified:

n/a

22. ICAO Circular 213 – AN/130 AND CAA Safety Sense No. 13 AND EASA EGAST GA 1

Purpose of the document:

Each of these documents (ICAO 1989, CAA 2013, EASA 2013) focuses on mid-air collision causes and methods to reduce the risk, in particular visual conspicuity and effective “look-out”. They are grouped in this table since each document builds on and references the other.

Time range of analysed data:
n/a

Geographical region:
n/a

Airspace classes covered:
n/a

Key accident statistics:
Summaries provided of general trends in mid-air collisions (as per many of the sources above)

Safety risk factors identified:

- Lack of visual acquisition of traffic
- Environment
- Inappropriate procedures

Mitigations / interventions identified:

- Improved visual acquisition through applying scanning patterns, ensuring windshield is clean, understanding limitations of the eye, using a time-sharing plan for scanning, using CRM with another pilot (if present), and using proper planning.

Leading indicators identified:
n/a

23. GAPAN – discussion paper on sense-and-avoid safety level requirements for UAS/RPAS

Purpose of the document:
GAPAN commissioned a study which analysed the 32 million hours of flying carried out by British registered aircraft in the 10 year period 1st January 1999 – 31st December 2008 in order to assess the actual risk of an aircraft being involved in a mid-air collision (MAC) in UK airspace.

Whilst the purpose was focused on UAS/RPAS, the underlying research into risk of MAC was a useful input for this study.

Time range of analysed data:
1999-2008

Geographical region:
UK airspace

Airspace classes covered:
All

Key accident statistics:
The volumes of airspace that carried the highest risk of mid-air collision were Class G airspace, especially below 3000ft, and around airfields, both inside and particularly outside controlled airspace.

Formally reported Category A airprox events occurred 10 times as frequently as MACs. A separate survey of GAPAN members showed that “very near misses” (subjectively assessed by survey respondents as Category A events) occurred on average 40 times as often as they were reported.

Over 70% of the events occurred in Class G, particularly below 3000ft, and in areas around aerodromes.

Safety risk factors identified:

- n/a

Mitigations / interventions identified:

- The paper proposed tailoring the sense-and-avoid solution to fit the operational environment, although this was limited to discussion of controlled vs uncontrolled airspace.

Leading indicators identified:
n/a

24. MITRE analysis of MAC and reporting data for TSAA application development

Purpose of the document:
To assess the risk of MAC and airproxes as an input to the design and development of the “Traffic Situational Awareness with Alerts” application utilising ADS-B in RTCA SC-186

Time range of analysed data:

January 2000 – June 2010

Geographical region:

USA

Airspace classes covered:

All

Key accident statistics:

59% of MACs occurred in the airport vicinity (with 45% occurring in the traffic pattern).

54% of MACs occurred between aircraft heading in the same direction, primarily due to the number occurring on finals, short finals, or over the runway. Only 8% were head-on collisions.

For accidents away from the aerodrome, and excluding flights in formation for any reason, the most common angle of incidence was “side-on” (near perpendicular), accounting for 29% of those MACs (sun-glare or blind spots from window struts or wings were mentioned as potential contributory factors here). All other angles were roughly equal in probability.

Safety risk factors identified:

- n/a

Mitigations / interventions identified:

- n/a

Leading indicators identified:

n/a

D Class G airspace supplementary information

D.1 Airspace Classification

The UK has two Flight Information Regions (FIR): London FIR and Scottish FIR. The airspace above the two FIRs is known as the Upper Flight Information Region (UIR). The airspace within the FIRs and the UIR is broken down into types of airspace classified using the ICAO Airspace Classification System.

The UK currently utilises six classifications of airspace depending on the requirement to control activity within the airspace, with Classes A to E being controlled and Classes F and G uncontrolled. In order to maximise access to airspace for all users the CAA's policy is for Class G airspace to be the default classification. Other classifications are only introduced where required to provide a safe operating environment for specific activities [36].

D.2 Regulatory requirements

Class G airspace is uncontrolled to the extent that any aircraft can use it in accordance with the Rules of the Air (RoA) and the Air Navigation Order (ANO) which apply to all aircraft within the UK [36]. Instrument Flight Rules (IFR) and Visual Flight Rules (VFR) are both permitted within Class G airspace.

It is not mandatory for a pilot to file a flight plan, carry a transponder, or to be in receipt of an Air Traffic Service (ATS).

If receiving an ATS, instructions issued by controllers to pilots within Class G airspace are not mandatory. However, compliance is advisable to enhance the safety of the operating environment. Pilots are responsible for collision avoidance and terrain and obstacle clearance, regardless of whether they are in receipt of an Air Traffic Control (ATC) service [36].

The speed limit for all flights within Class G airspace is 250kt IAS below FL100, unless instructed by ATC or published in procedures.

D.3 Requirements for flights in Class G

Required Separation and ATS Compliance

As per all VFR flights, the pilot in command is responsible for maintaining the required separation from other traffic and terrain in Class G airspace. IFR flights are also responsible for separation from other traffic and terrain. Pilots of VFR and IFR flights may request an ATC service (see section 2.8) to assist in achieving separation but they ultimately remain responsible for safe separation from other air users. It is not mandatory for a pilot to be in receipt of an ATS [37].

Due to the existence of traffic within Class G which may not be in receipt of an ATS, the flight details and intentions of all traffic may not be known by the controller. This unknown traffic environment requires pilots to consider the ATS provision to be limited by the uncertain nature of the airspace and the unpredictable workload of the controller. In addition, the nature of traffic within Class G airspace may result in sudden and unpredictable behaviours of traffic even when receiving an ATS, hence the service provided may be constrained [37]. Outside Controlled Airspace an aircraft receiving a service from an ATC Unit is expected to comply with ATC instructions unless the pilot advises otherwise.

D.4 Air Traffic Zones (ATZ)

Where an Air Traffic Zone (ATZ) exists inside Class G airspace, aircraft are required to comply with Rule 45 of the Rules of the Air regulations. For aerodromes covered by Rule 45, during ATZ notified hours, a pilot shall obtain permission of the air traffic control unit if available to enable safe flight within the ATZ, obtain information from the Flight Information Service (FIS) if available or otherwise from the air to ground communication service [36].

The pilot must also maintain watch on the ATZ frequency or, if this is not possible, stay alert for visual instructions from the aerodrome. If the aircraft is fitted with a means of transmitting by radio to the ground, aircraft within Class G airspace should report their position and height on the appropriate frequency when entering and exiting ATZs in order to comply with Rule 45.

D.5 Military Air Traffic Zones (MATZ)

Similarly to ATZs, a pilot is required to contact a notified open ATZ within a Military Air Traffic Zone (MATZ) to comply with Rule 45 of the Rules of the Air.

The MATZ is an extended area of protection beyond a standard ATZ for military aircraft operating the critical stages of circuit, approach and climb-out at military airfields.

Pilots in Class G airspace flying through a MATZ are not required to contact the aerodrome ATS to comply with Rule 45, but they must respect the ATZ within the MATZ during opening hours. It is, however, good airmanship to contact the MATZ to request a transit (known as a MATZ penetration) to improve flight safety, efficiency and the situational awareness of the controllers and traffic within the zone. The UK CAA heavily encourage this recognition of a MATZ, and pilots are requested to contact the controlling aerodrome when 15nm or 5 minutes flying time from the boundary (whichever is greater) [36].

With many military aerodromes accommodating either high numbers of aircraft and/or fast moving aircraft, a controller is often established to manage transit traffic in order to increase the safety of station based and visiting aircraft. By providing a service to military and civilian transit aircraft in the vicinity, ATC are able to increase their situational awareness and coordinate movements with arriving and departing traffic. This is particularly beneficial when aircraft without transponders utilise a service. Their altitude and intentions can be requested if required to enable the safe separation of aircraft. Furthermore it facilitates the accurate passing of traffic information as the altitude of the non-transponder equipped aircraft is now known [36].

Part of the transit service may include flight through the MATZ (including the ATZ) which provides a layer of protection to aircraft operating in the visual circuit. However, aircraft may elect to fly through a MATZ (outside of the ATZ) without being in receipt of an ATC service.

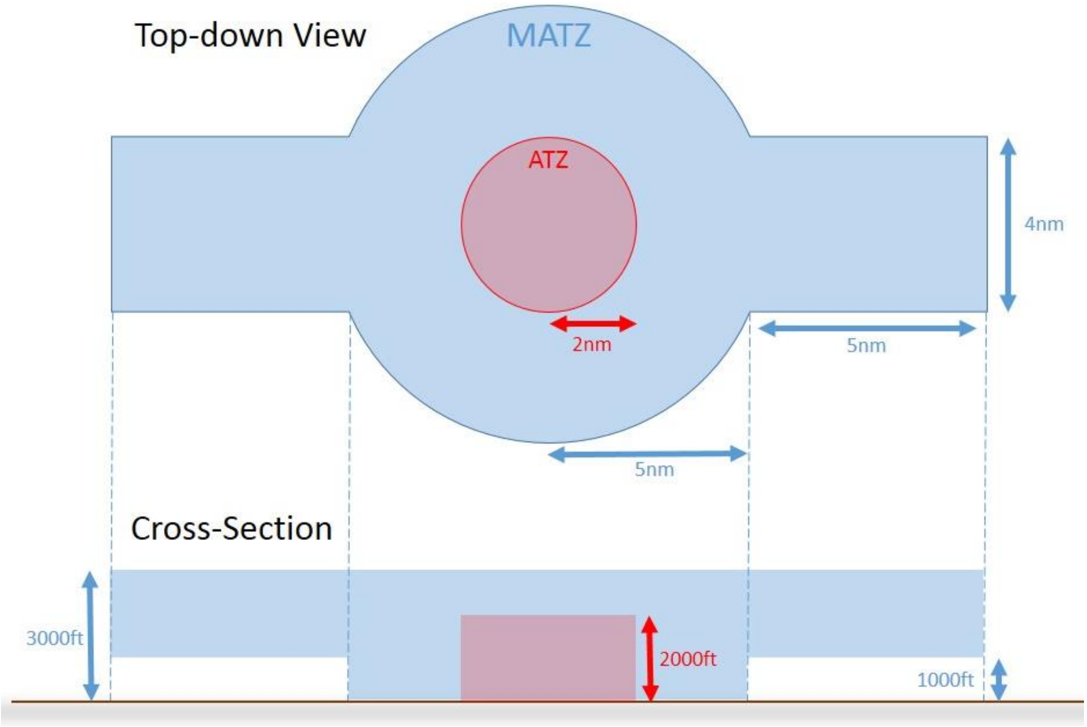

Figure 13: Top-down and Cross-sectional view of a typical MATZ

D.6 Flight Restrictions and Hazards

As within all other airspace, aircraft within Class G airspace are required to comply with the rules for airspace which is restricted or deemed hazardous.

Prohibited Areas: Pilots in Class G airspace are required to avoid all prohibited areas where flight of an aircraft is outlawed.

Restricted Areas: Pilots in Class G airspace are required to avoid all restricted areas where flight of an aircraft is outlawed with certain specified conditions.

Danger Areas: Pilots in Class G airspace are required to avoid all danger areas where flight of an aircraft is outlawed when notified. This is due to dangerous activities occurring in the area at certain times.

D.7 Conditions for IFR and VFR Flight

VFR flight is permitted in Visual Meteorological Conditions (VMC) by day within UK Airspace.

The VMC minima are determined by class of airspace, altitude and airspeed; however, the pilot licence privileges notified at Schedule 8 of the UK Air Navigation Order (ANO) may impose more stringent requirements on the following licence holders:

- National Private Pilot Licence (NPPL)
- Private Pilot Licence (PPL)
- Basic Commercial Pilot Licence (BCPL)

For Class G airspace, the VMC Minima are stated below.

At or above FL100:

- 8km flight visibility; and
- 1500m horizontal and 1000ft vertical separation from cloud.

Below FL100:

- 5km flight visibility; and
- 1500m horizontal and 1000ft vertical separation from cloud.

Or, at or below 3000ft AMSL:

- Aircraft:
  - 5km flight visibility; and
  - Clear of cloud and with the surface in sight.
- Aircraft (except helicopters) at 140KIAS or less:
  - 1500m flight visibility; and
  - Clear of cloud with the surface in sight.
- Helicopters at a speed which is reasonable given the visibility:
  - Clear of cloud with the surface in sight; and
  - Flight visibility of at least 1500m.

Separation from other traffic is the responsibility of the pilot in command of a VFR flight [36].

For flights in conditions other than within these minima, flights must be operating under IFR. IFR flights are permitted in any weather conditions within Class G airspace, subject to the performance and safety limitations of the aircraft.

D.8 Users of Class G airspace

The range of uses of uncontrolled airspace combined with a broad spectrum of users makes for a diverse and complex operating environment.

Three broad groups were defined during the Future Airspace Strategy (FAS) [28]: Commercial Air Transport (CAT), the General Aviation (GA) Community and the Military.

CAT is the transport of passengers, cargo or mail for remuneration or hire.

GA is civil aircraft operation other than CAT, operating fixed-wing aircraft, helicopters, gliders, self-launched motor-gliders, microlights, hang gliders, paragliders, para motors and parachutes.

The military covers the Army, Royal Navy, Royal Air Force and Visiting Forces aviation activity, ultimately falling under the responsibility of the Ministry of Defence and Secretary of State for Defence.

CAT operates in Class G airspace if there is no other option or where it is commercially advantageous to do so. For the latter, the operating airline must balance any increase in risk against the economic advantage.

GA is a diverse sector and represents 96% of UK civil aircraft [1]. The UK CAA stated in their document 'Class G Airspace for the 21st Century' study that the vast majority of GA activity currently takes place in Class G airspace. GA activity is expected to continue to grow in the period to 2030 and with it the public demand for continued access to Class G airspace.

Precise figures for the amount of GA VFR and IFR traffic are not known.

Military activity in Class G airspace includes a wide range of operational training and missions covering all aspects of aviation. There is a wide range of aircraft types from fast jets to rotary aircraft to heavy transport aircraft, as well as training aircraft.

The establishment of danger areas and restricted areas for military and defence activities restricts the amount of UK airspace available to other users. However, the flexible use of such areas is improving which reduces the impact on other airspace users.

D.9 Airspace Users Statistics

The UK CAA's Strategic Review of GA (2006) reported that there were an estimated 27000 civil aircraft in the UK, which is largely dominated by GA aircraft.

In 2006 there were 47000 pilots licenced to fly, of which 19000 had professional licences, 28401 had private licences with a current medical and 3400 had the basic NPPL licence.

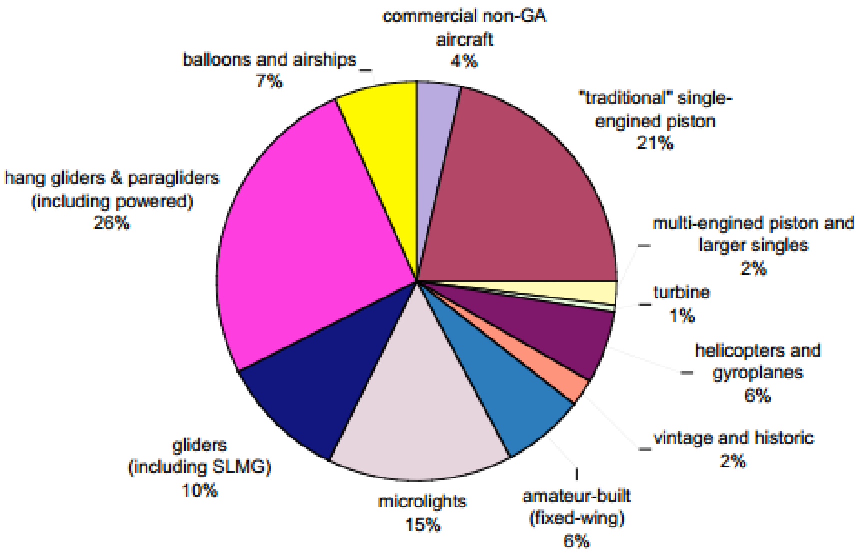

Figure 14: Make-up of UK GA, 2006 [26]

According to the Light Aircraft Association, a total of 19940 General Aviation aircraft were on the register in 2013. Of these, 8080 were aeroplanes, 4045 microlights and 2248 were gliders [26].

Of these aircraft, 60% were not equipped with transponders. Inclusive of approximately 7000 unregistered aircraft, 73% of UK General Aviation aircraft are not equipped with a transponder [26].

D.10 Airspace Users Trends

The majority of GA sectors have experienced growth in both numbers and hours flown in the last decade. Microlights, self-built aircraft, and balloons have shown particularly strong growth, partly at the expense of more traditional single engine light aircraft. Recreational helicopter usage has also grown primarily due to the introduction of smaller and cheaper aircraft. Glider activity has remained relatively static, although there has been a gradual increase in the number of self-launching motor gliders [30].

Business aviation (BA) has shown strong growth, although the numbers of aircraft on the CAA register have declined. This reflects a shift away from turboprop aircraft towards foreign-registered business jets based in the UK, which are estimated to be growing in numbers.

D.11 Location of Class G Airspace

All airspace not defined as any Class A to Class F, including airspace above FL660, is designated as Class G airspace. Full details are contained in the UK AIP ENR 6-1-4-1, 6-1-4-2, 6-3-2-1, 6-3-2-2.

D.12 Air Traffic Services Outside Controlled Airspace (ATSOCAS)

Within G airspace, regardless of the ATS being provided, pilots are ultimately responsible for collision avoidance and terrain clearance. Any ATS is constrained by the unpredictable nature of the environment and particularly by aircraft that are not transponder equipped [37].

The conditions for the provision of services in Class G airspace are not predicated on flight rules. Therefore, the pilot of a VFR flight may request any of the ATS.

Controllers will make all reasonable endeavours to provide the ATS that a pilot requests. However, due to finite ATS provider resources or controller workload, tactical priorities may influence ATS availability or its continued provision. Therefore, a reduction in traffic information and/or deconfliction advice may have to be applied, and in some circumstances an alternative ATS may have to be provided in order to balance overall ATS requirements [36].

Instructions issued by controllers to pilots operating outside controlled airspace are not mandatory; however, the ATS rely upon pilot compliance with the specified terms and conditions so as to promote a safer operating environment for all airspace users [38].

There are four distinct service levels available within uncontrolled airspace: Basic Service, Traffic Service, Deconfliction Service, and Procedural Service.

Basic Service [38]

The Basic Service allows the pilot maximum autonomy and therefore collision avoidance with traffic or terrain remains entirely the pilot’s responsibility. A controller is under no obligation to provide traffic information.

The controller can provide the pilot with relevant safety information such as weather, serviceability issues, aerodrome conditions and general activity within the area.

A surveillance system is not necessary to provide this ATS.

A pilot and controller can establish an agreement to restrict an aircraft to a level or band of altitude, heading, route or area of operation.

Traffic Service [38]

A Traffic Service provides the pilot with traffic information derived from ATM surveillance equipment, however no deconfliction advice is given and the pilot remains entirely responsible for collision avoidance.

The controller will alert the pilot to any traffic anticipated to pass within 3nm laterally and 3000ft vertically, unless the traffic is deemed irrelevant by the controller (e.g. passing behind). Controllers will repeat traffic information upon pilot request, or if it remains in hazardous proximity.

Due to the limitations on controllers outside controlled airspace, for example unpredictable flight profiles, inadequate surveillance coverage and high controller workload, a Traffic Service may not provide complete traffic information or it may be of late notice. Thus the pilot must maintain a good lookout at all times to see and avoid other airspace users.

When in receipt of a Traffic Service, pilots should not change their routing or level band without first advising the controller, as their flight profile may have been sequenced with other airspace users.

Deconfliction Service [38]

A Deconfliction Service provides traffic information as with a Traffic Service, but also gives deconfliction advice to the pilot. The avoidance of other airspace users remains the responsibility of the pilot.

Due to the limitations on controllers outside controlled airspace, for example unpredictable flight profiles, unpredictable manoeuvres by autonomous aircraft and high controller workload, the deconfliction minima may not always be achieved. See and avoid remains an important component of collision avoidance regardless of the prevailing weather conditions.

Pilots who decide not to follow deconfliction advice must inform the controller and accept responsibility for deconfliction. If a heading or level is not acceptable for a pilot, the controller shall be informed. Controllers may offer further traffic advice until a situation is resolved.

Procedural Service [38]

This non-surveillance service assures deconfliction minima with other aircraft in receipt of a Procedural Service from the same controller. Separation with other aircraft and terrain is the pilot’s responsibility.

Controllers will expect the pilot to accept instructions which may require flight in instrument metrological conditions.

Controllers will pass traffic information on those aircraft he is providing a service and any other flights he has been made aware of which he considers to be in confliction.

Aerodrome ATS [36]

Within Class G airspace, aerodromes are still able to provide one of three services. At aerodromes that require air traffic control, an Aerodrome Control Service (TWR) is provided. Elsewhere, an Aerodrome Flight Information Service (AFIS) or an Air-Ground Service (A/G) may be provided. An Automated Terminal Information Service (ATIS) provides broadcasts for routine arrival and departure information if available.

Aerodromes within Class G may also provide an Approach Control Service (APP), although there is no requirement in Class G for pilots flying IFR to comply with APP instructions unless they are within the ATZ. Nor are pilots required to notify the APP controller of their presence in the area. Hence APP in Class G airspace is regarded as advisory only. The APP will provide separation between aircraft in receipt of its service until they are transferred to either aerodrome controller or released to a control centre.

D.13 Requirements to receive services

The purpose of the specific service definitions is to provide services to cater for a wide range of airspace users, which is a feature of uncontrolled airspace such as Class G.

To receive a traffic or Deconfliction Service, the ATCO must be equipped with an ATS surveillance system. The aircraft must be identified to the controller which may require the issuance of a transponder code.

To receive a Deconfliction Service or a full Traffic Service, the aircraft is required to remain within the limits of the surveillance system. Thus, if descending below ATC terrain safe levels, the pilot will be made aware by the controller and should expect a reduction in surveillance performance and is responsible for terrain clearance. If already in receipt of a Traffic Service, the pilot should be aware of the reduced coverage below ATC terrain safe level.

A Deconfliction Service is not available below ATC terrain safe levels unless departing from an aerodrome climbing into the safe level. Until reaching the safe level, or if descending below the safe level, a Traffic Service with no deconfliction advice will be provided.

To provide a Procedural Service, ATC units are required to gain regulatory approval.

To receive a Procedural Service, where a high reliance is placed on aircraft following precise track, radial and time allocations, in some instances pilots will require instruments to navigate to a higher degree of accuracy than possible using visual references. This is particularly true in low airspace availability or high controller workload.

D.14 Service providers [36]

There is a diverse range of providers of ATSOCAS inside Class G airspace such as:

- Area Control Centre – civil sector Air Traffic Control Officer (ATCO)
- Area Control Centre – Flight Information Services Officer (FISO)
- Area Control Centre – Military ATCO
- Area Control Centre – Alerting & Fixing Cell (Distress & Diversion)
- Airfield – Civil ATCO
- Airfield – Civil FISO
- Airfield – Military ATCO
- Air Weapons Range – Military or civil ATCO
- Communication & Reporting Centre (CRC) – Military Aerospace Battle Manager

- Air Surveillance & Control Systems Aircraft - Military Aerospace Battle Manager or Royal Navy Fighter Controller
- Royal Navy Ship – Royal Navy ATCO

Many of the above service providers are established to provide services to specific user groups. However, some ATS units offer a Lower Airspace Radar Service (LARS) to aircraft operating below FL95 in areas outside Controlled Airspace within the limits of radar and radio coverage. The service is usually available within approximately 30nm of the ATS unit.

Unless the ATS Unit is open 24 hours, standard opening hours for LARS are weekdays 0800-1700 in winter and 0700-1600 in summer. Some units remain open for weekend and night flying.

At some ATS units, LARS is provided as a secondary task and therefore the service may be unavailable if ATCOs are fully engaged with primary tasks.

ATS units providing a LARS are published in the UK AIP ENR 6-1-6-3 and comprise both civil and military units as follows:

Culdrose; Newquay; Plymouth Military (West and East); Exeter; Yeovilton; Bournemouth; Bristol; Cardiff; Boscombe Down; Brize Norton; Farnborough (North, West and East); Southend; Manston; Shawbury; Valley; Marham; Norwich; Coningsby; Waddington; Humberside; Warton; Linton-on-Ouse; Leeming; Durham Tees Valley; Newcastle; Leuchars; Lossiemouth.

Some non-LARS ATS units are also able to provide ATSOCAS to various degrees. The Air Traffic Control Centres (ACC) of London Information and Scottish Information are able to provide a Basic Service through a FISO. FISOs are also available at participating aerodromes within an aerodrome operating area or ATZ, and are able to provide a Basic Service only.

Above FL95 and outside CAS, pilots are able to contact military ATCOs at the Swanwick ACC who will provide ATSOCAS subject to capacity.

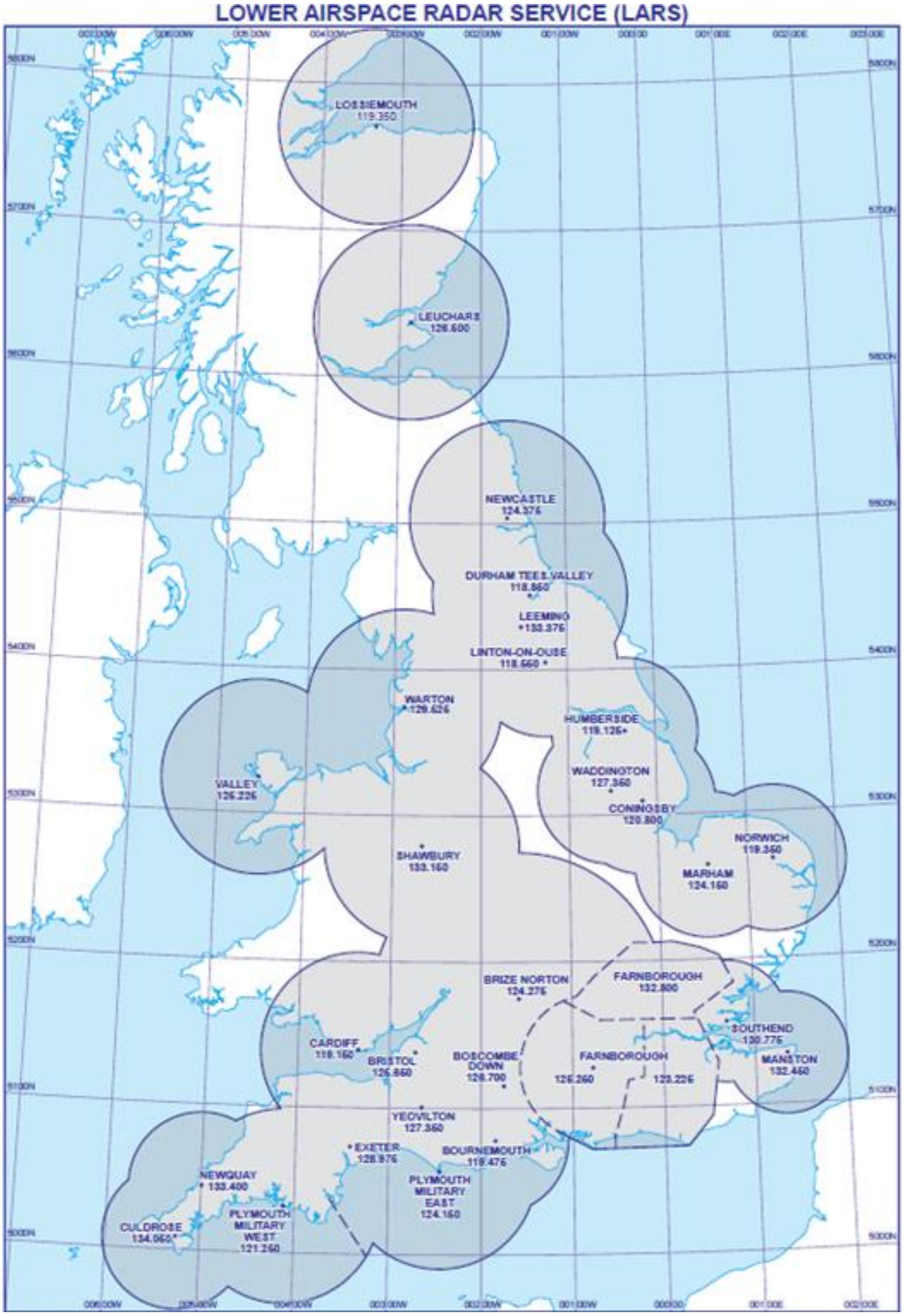

Figure 15: LARS cover in the UK [39]

D.15 Changes affecting Class G Airspace

Changes to Controlled airspace

The UK airspace is constantly evolving with numerous airspace change proposals being considered each year. The growth in regional airports and CAT as a whole over the last two decades has led to the requirement for additional controlled airspace. The resultant trend has been a steady reduction in the availability of Class G airspace at a time when recreational flying has increased.

The following changes impacting Class G airspace are a sample of the type of changes that have or are being introduced.

- Introduction of CAS between Aberdeen and Newcastle (P18)
- Introduction of CAS between Newcastle and Pole Hill (P18)
- Expansion of CAS around Belfast and IOM
- Expansion of CAS between Liverpool and Dublin (L70, L975)
- Expansion of CAS between the Scottish TMA and Manchester TMA (N615, N864, and associated fillets of airspace)
- Expansion of CAS south of the Humber (Y70, L603)
- Expansion of Newcastle CTA
- Introduction of CAS between NOTRO and RISLA (N862, N90)
- Expansion of CAS west of Brize Norton (N14)
- Expansion of CAS between Manchester TMA and London TMA (L151, N601)
- Introduction of CAS at Norwich
- Expansion of the London TMA and surrounding areas and proposed changes as part of London Airspace Consultation
- Proposed introduction of Cardiff/Bristol ‘Severn’ and additional ‘Cotswold’ control areas
- Proposed introduction of Class D airspace in the vicinity of Farnborough reclassified from Class G. This is an area of high intensity GA traffic already funnelled into narrow corridors by the London TMA
- Proposed Class E airspace at Aberdeen
- Removal of Class F airspace within the UK
- Proposed introduction of CAS at Southend Airport

Service provision

The names and definitions of ATSOCAS were changed on 12 March 2009 to their current form. The change was primarily instigated to standardise the application and understanding of ATSOCAS. Whilst incident rates have improved under Deconfliction Service, they have worsened under Traffic Service. The reasons for these variations are not fully understood and cannot necessarily be attributed to the change in service definitions [37].

The CAA is currently considering the following amendments:

In order to provide a stronger argument that the provisions of a Basic Service comply with the ICAO definition of a FIS, it is proposed that pilots should receive generic traffic information and warnings of collision hazards from controllers/FISOs.

Additional guidance has been provided to highlight that deconfliction advice is not available under a Traffic Service and to emphasize a pilot's responsibilities toward collision avoidance when allocated levels by ATC.

It is proposed that Deconfliction & Procedural Services are limited to IFR aircraft only.

Unmanned Aerial Systems (UAS)

The impact of the forthcoming entry of this new airspace user group to Class G airspace is as of yet unknown. The UK CAA is, however, aware that Class G airspace may need to evolve in the future to accommodate such new users to facilitate their needs whilst accommodating the requirements of present users. Once the regulatory and technical hurdles have been overcome, this particular user group is likely to add significantly to the number of airspace users. See and avoid will become sense and avoid and the implications for mitigating the risks of a MAC will need to be fully understood [1].

Aircraft performance [26]

There has been a growth in the use of microlight aircraft as technology improves their performance and reduces their cost to buy and own.

The Light Aircraft Pilots licence (LAPL) has reduced the cost barrier of entry to general aviation, as well as the requirements for licensing, making recreational flying more accessible. Understandably, a reduced training syllabus focuses on aircraft handling as opposed to knowledge of the specific risks present in Class G airspace.

The average age of GA aircraft has been steadily increasing, with single and multi-engine piston aircraft averaging 19-20 years in 2006. Market trends indicate that sales of traditional GA aircraft such as the Cessna are still some way behind the 2007/8 peak but sales of very light jets such as the Gulfstream are increasing.