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Class G airprox reports analysis

Results and conclusions

an egis company

Document information

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Executive Summary

Introduction

An airprox is defined as *"a situation in which, in the opinion of a pilot or air traffic services personnel, the distance between aircraft as well as their relative positions and speed have been such that the safety of the aircraft involved may have been compromised"*. Airprox Reports are one method of monitoring where aviation safety may have been compromised and combined with mandatory occurrence reports and voluntary reports help provide a broader picture of aviation safety.

The Civil Aviation Authority (CAA) contracted Helios to investigate and document, using UKAB Airprox Reports and supporting data, the specific contributory risk factors that increase the likelihood of a mid-air collision (MAC) within Class G airspace. The purpose of which is to develop an improved understanding of how safety in Class G airspace can be enhanced.

The study was divided into 3 tasks as follows:

Task 1 [2] included a review of key existing studies relating to the Class G concept of operation and resulted in the development of a 'barrier' model that depicts the key mitigations in Class G airspace that prevent a MAC.

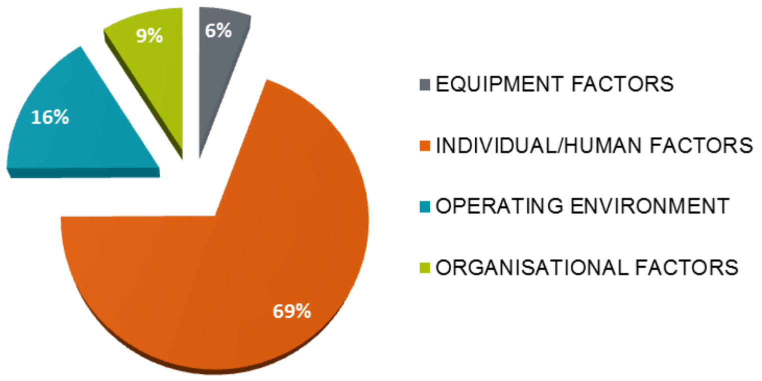
Task 2 (detailed in this document) included the development of a taxonomy for coding the causal and contributory factors present and then a full analysis of all airprox reports occurring in Class G airspace from 2000-2013, using a grounded theory approach. Each report was coded for the contributory factors involved in the incident. This 'bottom-up' approach was complimented by a top down analysis of the barrier model by recording which barrier components were either successful or unsuccessful.

Task 3: Having established a prioritised list of safety risk factors the final part of the study (also captured in this document) suggested a set of leading indicators that can be used to monitor performance in key areas in the future.

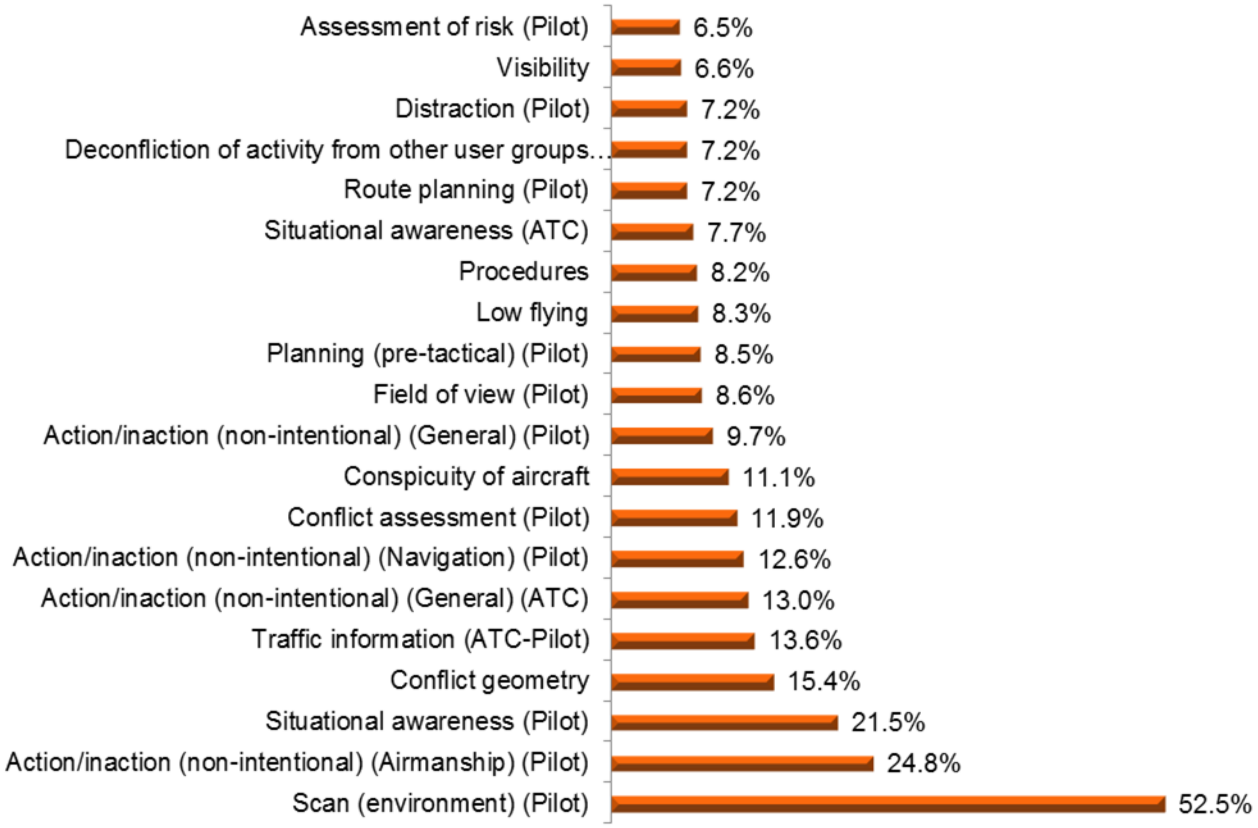
It is worth noting that the Airprox Report data was never intended to be used for this purpose, it is incomplete and only reflects those incidents actually reported. There will also be incidents that go unnoticed or are unreported. Due to the relatively small sample size and broad spectrum of elements in the taxonomy, it was difficult to obtain a high degree of statistical significance and so a degree of professional interpretation was required in delivering the analysis.

Analysis – Contributory Factors

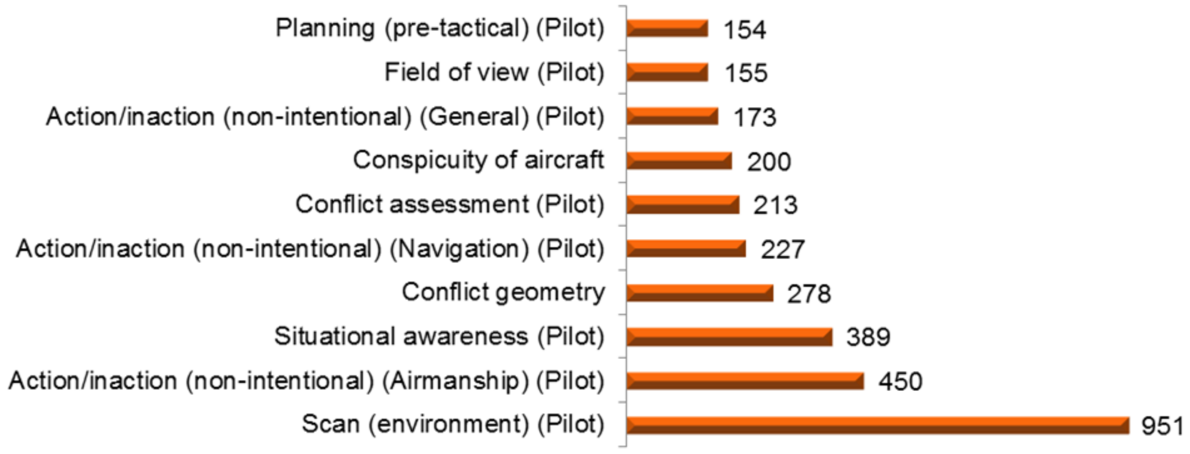
The taxonomy contained four high-level domains with individual/human factors accounting for 69% of the total (see pie chart below).



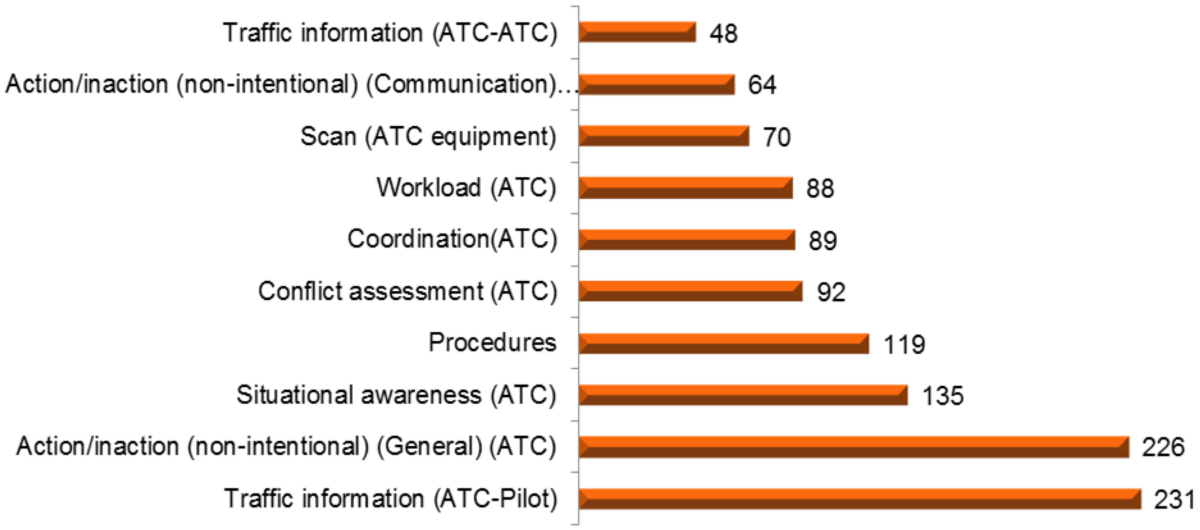
A total of 137 different contributory factors were coded into the database. The figure below provides a percentage of the total number of reports.



The top 10 contributory factors associated with pilots are depicted in the figure below.



The top 10 contributory factors associated with ATC are depicted in the figure below.



The 5 most prevalent contributory factors for each of the main user groups are depicted in the table below. The percentages relate to the proportion of the individual user groups total contributory factors.

GA	Military	CAT
Scan 20.4%	Scan 20%	Scan 16.1%
Airmanship 7.7%	Low flying 7.4%	Situational Awareness (Pilot) 9.6%
Conflict Geometry 6.9%	Situational Awareness (Pilot) 6.4%	Conflict Assessment (Pilot) 9.1%
Situational Awareness (Pilot) 6.8%	Conflict Geometry 6.3%	Visibility 5.7%
Navigation 3%	Airmanship 4.6%	Conflict Geometry 5.2%

Pilot scan

The element most closely associated with see and avoid in the taxonomy was pilot scan and this was the main factor which contributed to the airproxes and was ineffective in 52.5% of the incidents. However, *this wasn't just attributed to scan technique* but more commonly a number of additional contributory factors reduced the likelihood of a pilot visually acquiring another aircraft. In order to investigate this further, the factors which commonly occurred with ineffective pilot scan were analysed.

The key factors found to impact a pilot's ability to visually acquire another aircraft were as follows (% concurrence):

- Pilot situational awareness 25.3%
- Conflict geometry 22.1%
- Conspicuity of aircraft 17.0%
- Field of view 14.5%
- Traffic information (ATC-pilot) 13.0%
- Distraction 12%

Situational awareness

As with pilot scan, a lack of situational awareness did not necessarily infer that the pilot's actions were not fully effective. Instead there were other influences which may have been outside the pilot's control that also impacted their ability to maintain full situational awareness.

Pre-tactical planning

The analysis found that a strong influence on pilot situational awareness occurred even before the pilot became airborne. Pre-tactical (or pre-flight) planning (18.3% concurrence with situational awareness), which included activities such as effective route planning and cognisance of any other user activity (including applicable NOTAMs) was an important process in building a comprehensive understanding of potential hazards along the intended route. Poor navigation in the taxonomy (17% concurrence with situational awareness) was often a result of failing to plan the route effectively to account for glider sites, busy military and civil airports, and approach and departure lanes. It was evident from the aircrew reports that when they were aware of another user who was utilising a similar area, there was a conscious effort to scan for it in order to deconflict their activities.

Airmanship (position reporting- circuit / en-route)

Once airborne, and particularly in and adjacent to the visual circuit, a lack of timely and accurate position reporting impacted the situational awareness of other airspace users. A lack of position information passed to adjacent aerodromes along the intended route, particularly those operating without surveillance equipment, was found to impact the situational awareness of both controllers and pilots. Within the visual circuit where no Air Traffic Service (ATS) was provided it was evident that missed, late or inaccurate calls quickly degraded the situational awareness of others and meant pilots were not always looking in the optimum location to acquire other aircraft.

A third of pilots chose not to make contact with a service provider or utilise a ‘common frequency’. More common, particularly within the General Aviation user group, was the practice of pilots ‘listening out’ on a frequency but not actually transmitting their location or intentions. Whilst it is not mandatory to be in radio contact (except for specified areas) with an ATS provider or to utilise a common frequency, there is a direct impact on the situational awareness of other pilots (and potentially ATC).

Traffic information

For those in receipt of an ATS the timeliness and accuracy of traffic information also influences pilot situational awareness (17.5% concurrence) and ultimately effective scan (13% concurrence). Furthermore, it was often the absence of additional information that could have been included with the traffic information that reduced situational awareness such as stating the aircraft in confliction was established on the ILS or was conducting aerobatics.

It was evident in the reports that when faced with difficulty acquiring other aircraft or in areas of high traffic density, pilots were often slow to upgrade the ATS, even temporarily. This was particularly the case for those operating on a Basic Service (BS). Recognising that meteorological conditions may influence the level of ATS requested prevailing risks, such as traffic density or high workload, should also attract a similar response.

Distraction

Distraction often occurred at the same time as issues with pilot scanning (88% concurrence), and was attributed to a range of things such as navigating in complex airspace, focusing attention on the ground during final approach, and operating equipment inside the aircraft. Where tasks do require frequent heads in time, it would be beneficial to have other barriers in place such as some level of ATS (if available) or automated alerting systems.

Conflict geometry

Conflict geometry occurred in 15.4% of the airprox reports and 75% of these occurred at the same time as issues with the pilot scanning effectively. Aircraft approaching on a constant bearing was noted as being a particular issue.

Field of view

A restricted field of view was a contributory factor in 8.6% of the airprox reports and 89% of these occurred at the same time as issues with the pilot scanning effectively. Strategies to counter limitations in a pilot’s field of view were frequently evident; however, some conflicts developed very quickly which left minimal time to detect the threat, particularly if it was screened by a section of the airframe.

Low-flying was a contributory factor in 8.3% of the airprox reports and in a third of these terrain-screening was also a contributory factor.

Conspicuity

Problems with visual conspicuity occurred in 11.1% of the airprox reports and 81% of these occurred at the same time as issues with the pilot scanning effectively. Small aircraft that had a poor contrasting colour against the prevailing background proved particularly challenging to detect.

Significantly, it appears that conflict geometry, field of view, and conspicuity tended to occur together (31.2% concurrence) making it even more challenging to acquire the other aircraft. *This could be interpreted as when these factors occur together it is more likely to result in an airprox.*

Airmanship

Following pilot scan, poor airmanship was the second most common contributory factor (24.8% of reports). Common themes were pilots flying close enough to another to the extent that it caused them alarm or ineffective integration into the visual circuit. Poor airmanship was also associated with ineffective navigation skills (23.3% concurrence) such as not paying due regard to active glider sites, particularly those conducting winching, as opposed to someone getting lost.

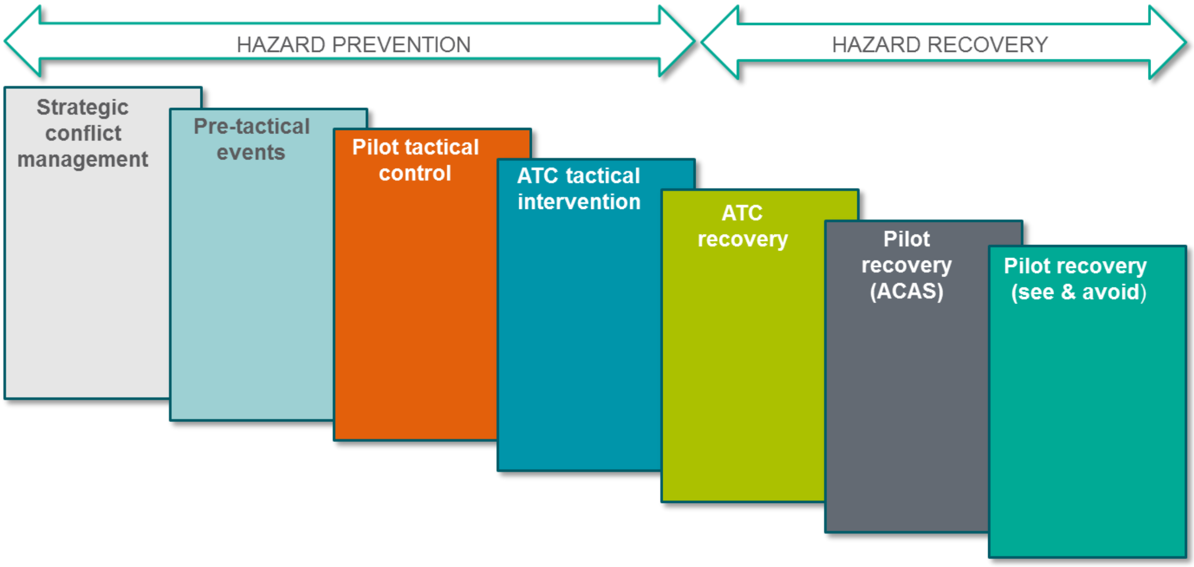
Risk categories

Using the three main risk categories it was also possible to gain a better understanding of the relative impact of the contributory factors within each risk classification (A-C). There appears to be little difference between the contributory factors and the level of risk between categories A and B. However, there are some noticeable differences in risk category C.

Where poor scan is a contributory factor, there is a significant increase in the level of risk regarding the outcome (the incident is more likely to be classed as A/B). Likewise, poor pilot situational awareness, distraction, conflict geometry and visual conspicuity all impact the level of risk of the incident. Conversely, whilst poor airmanship is a significant factor in terms of airprox contributory factors, it doesn't appear to influence the level of risk across the categories to the same extent as scan and situational awareness. The same can be said for traffic information passed from ATC to the pilot.

Analysis - Barrier Model

As the barrier model only contained 36 components compared to the 135 in the taxonomy, the results from this analysis of successful and unsuccessful barriers couldn't provide the same granularity. It was also uncommon for all barriers to be referenced in each report as either successful or unsuccessful as the data was never intended for this purpose.



Successful barriers

Due to the nature of the airprox reports and their understandable focus on the level of risk, there tended to be less explicit information about what went right and therefore the data in this particular area is by no means complete or necessarily a true reflection of the importance of each barrier. Where recorded, 52% of the successful barriers resulted from pilot recovery (see and avoid). This was often at a very late stage but still sufficient to avoid a MAC. At least one of the flight crew was able to view the other aircraft in time on 70% of occasions and at least one aircraft initiated effective avoiding action 62% of the time. It should be noted that some form of avoiding action was not necessarily required on every occasion. The other significant barrier (24% of successful occasions) was ATC tactical intervention which was the application of UK FIS.

Unsuccessful barriers

Pilot tactical control

In 49% of recorded unsuccessful events, pilot tactical control was the key barrier impacting risk which was largely attributable to see and avoid and situational awareness. At this tactical stage the barrier relates to visually acquiring a potential confliction in sufficient time to prevent the situation developing into a conflict. Within this barrier two components stand out as being particularly significant. A lack of effective situational awareness and/or see and avoid occurred in 68% of the airproxes and effective airmanship skills occurred in 31%.

ATC tactical intervention

Except for notified areas, it is not mandatory for a pilot to be in contact with an air traffic service provider and, importantly, ATS is not available in some portions of the UK's airspace due to radio and radar coverage limitations. Therefore an ATS is not universally available as a barrier. Almost a third of the pilots involved in the airprox sample were not in receipt of any form of ATS rendering this barrier and ATC recovery ineffective on a significant number of occasions. Where an ATS was provided it accounted for 18% of unsuccessful barriers. This was due, in part, to human factor incidents (226 occasions) where the controller did not perform as well as may have been expected. This included the provision of UK FIS such as poor coordination, planning or late avoiding action. Whereas the pilot tactical control above is present for all airproxes, ATC tactical control is not and therefore the two sets of figures for the number of airproxes in which the components occur cannot be compared equally.

Pilot recovery (see and avoid)

The pilot recovery barrier relates to visual acquisition once a conflict has occurred in sufficient time to take avoiding action to prevent a MAC. This barrier accounted for 18% of unsuccessful barrier events. In 16% of the reports (288 occasions) a pilot failed to observe the other aircraft at any stage in the event. In 19% of the reports (374 occasions) the pilot failed to observe the conflicting aircraft in time to take effective action to avoid a collision.

Strategic conflict management

The ability to fully understand this barrier is limited due to the fact that strategic issues tend not to be captured in the airprox reports. This barrier, alongside pilot tactical control, is one of only three that may be present in the prevention of a MAC and so it is vital that it is as effective as possible and that we gain a greater understanding of its impact going forward. The analysis showed that strategic conflict management accounted for 6% of the failed barriers with the majority of issues being weaknesses in local procedures to deconflict activities of different user groups.

Pre-tactical events

Although pre-tactical events only accounted for 4% of the total unsuccessful barrier events, it is worth noting that pilot briefing occurred in 9% of reports as being less effective than was ideal.

Pilot recovery (ACAS)

In the data sample 77% of aircraft were not equipped with ACAS rendering this barrier largely unavailable, although this is an improving situation as more aircraft become fitted. For this barrier to be effective, the conflicting aircraft needed to be equipped with a serviceable transponder that was switched on, not terrain masked, and not subject to airframe blanking or multi-path effects. However, the Airprox Board only made specific reference to a lack of transponder being a factor impacting risk in 2.5% of the reports.

ATC recovery

ATC recovery accounted for just 2% of unsuccessful barriers. This can be attributed, in part, to the low number of aircraft in the data set (3.2%) that have an airprox whilst in receipt of a Deconfliction Service (DS). It is likely that even if ATC avoiding action doesn't achieve the prescribed separation minima, the action is likely to prevent an airprox from occurring.

Availability of the barriers

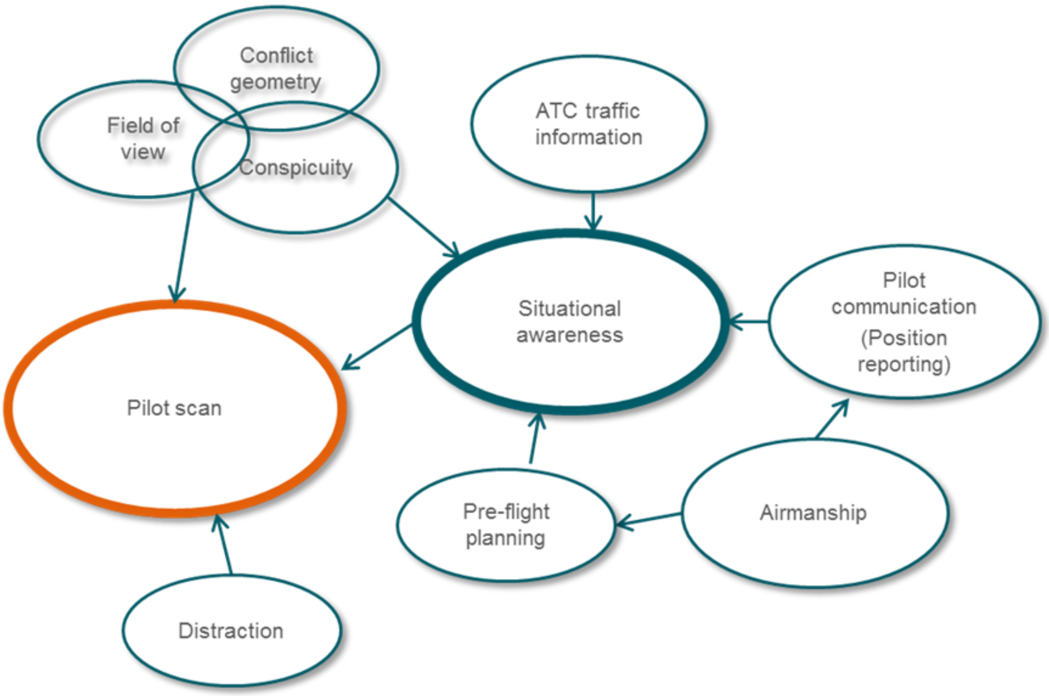
Aircraft equipped with ACAS and in receipt of a DS have 7 barriers that help prevent the occurrence of a MAC. Receipt of a DS adds an ATC recovery barrier in addition to ATC tactical intervention. At 2013 rates, 60% of aircraft involved in an airprox were not fitted with ACAS resulting in this barrier not being present on a significant number of occasions. Furthermore 96.8% of aircraft were not in receipt of a DS either by choice or because it was not available or appropriate severely limiting the application of this barrier. Therefore the majority of aircraft involved in the airprox were relying on a single recovery barrier (pilot see and avoid).

Of the barriers available to prevent a confliction developing in the first place, 30% of pilots were not in receipt of an ATS which reduced the frequency the ATC tactical intervention barrier was available. Once airborne many pilots were therefore reliant on see and avoid to both prevent a conflict from developing and to prevent a MAC should one occur.

Using the analysis

Under existing regulations [5, 6] an aircraft does not have to be equipped with a radio, transponder, or ACAS to operate in Class G airspace. Therefore see and avoid remains the prime means of collision avoidance and the findings from this study will naturally lead to increased focus on pilot scan. However, it is not sufficient to tackle pilot scan in isolation as there is a complex interaction between other contributory factors that influence a pilot's ability to see other aircraft.

The barrier model is useful to illustrate the components and their relative strengths and availability but it has its limitations in that it depicts a linear combination of failures. However, the events did not develop in any pre-defined sequence such as those used in event and fault trees. Instead the airprox occurred due to unexpected combinations of factors that occurred in a non-linear sequence as depicted below.



A more systemic view of the interaction between the contributory factors is required as *it is the combination of factors occurring together that leads to an incident*. A greater appreciation for both pilots and controllers of the system as a whole will have more of an impact than focusing on a specific contributory factor. A greater understanding of how their actions influence the number and strength of the barriers is likely to prove more beneficial than targeting education in a few selected areas.

Leading Indicators

The method of determining the "possibility of harm" has traditionally focused on extrapolating trends for metrics of harm being caused or nearly caused (accidents or serious incidents). However, the relatively small amount of airprox reports makes it difficult to assess, with any statistical significance, the impact of any safety initiatives whilst relying on this data alone. Another issue in determining which safety initiatives are best to implement is that it is rare (1.7% of airprox) for a single factor to lead to an incident. In this study there was an average of 5 contributory factors for each incident.

This data also shows us where barriers were successful in preventing the incident becoming any more serious, thus reducing the possibility of harm. Rather than focusing on a specific occurrence where a barrier was unsuccessful, the emphasis proposed is to ensure key indicators reach a certain level more of the time and that as a result, there are fewer dips in human performance levels. This is a conscious shift in focus from what goes wrong (incident data) to what goes right during routine day-to-day performance. It is in our understanding and monitoring of day-to-day activities (work-as-done) where leading indicators are of value.

There are several sources of information that further our understanding of 'work-as-done'. Currency and standards checks provide excellent information on work-as-done and the monitoring and sharing of lessons identified is a powerful tool. The use of safety surveys that consider a specific area of operations is also of benefit to increasing our understanding of why routine activities go well. However, a safety survey that looks at extant procedures must look at *how* they are actually being applied in addition to assessing how robust the actual procedures are.

Leading indicators can be objective or subjective measures and consider positive or negative actions. In order for the metric to be of value there must be a direct traceable link between the leading indicator and the function it is monitoring. The value of a leading indicator is how close it relates to the barrier that it is monitoring. Individual leading indicators can be identified by looking at the combinations of contributory factors both causing and successfully preventing an incident. These contributory factors are built into a model in this study, and it is the performance (or effectiveness) of this model which can then be assessed by leading indicators.

The analysis demonstrates that safety risk is not a series of individualistic cause-effect chains, but a complex inter-related system where one factor impacts others, and many factors operate on a performance continuum rather than merely being a success or failure, in particular human performance. Furthermore, procedures are not always followed, but the flexibility of human performance can be the mitigating element preventing a more serious incident, meaning we are particularly interested in a greater understanding of operational reality as opposed to procedure design.

The effective measurement of leading indicators is complicated in the Class G environment by the wide variety of users. In the field of human performance, it necessarily leads to some form of self-assessment, which is inherently subjective. However, interventions can be defined to ensure a more objective assessment, either through training provision or monitoring/testing and this study suggests a number of areas which could be targeted based on the causal factor data.

Whilst targeted intervention in human behaviour through training and on-going education can have significant benefits in improving performance, they can only influence the strength of the barriers if the barriers themselves are present. For some of the barriers, this starts with the availability of equipment, and the measurement of uptake over time.

The recommendations made within this paper are summarised in the table below:

General	
1	It is recommended that, following some adjustments to the taxonomy (see Annex E), it continues to be used to categorise contributory factors for all classifications of airspace.

2	Having developed a database containing the specific contributory factors for each airprox between 2000 and 2013 it is recommended that this database continues to be used to capture the contributory factors from incident data on an ongoing basis.
3	There is an opportunity to conduct further analysis in specific areas. The database contains all the information from the Joint Airprox Reporting System (JARS) and so cross comparison of the data can be completed.
Leading Indicators	
4	Expert assessment of priority areas for improvement (in terms of effectiveness of barrier components) is required.
5	For the key areas to be monitored, they need to be translated into equipment, procedure or human performance outcomes. If the latter, it is recommended to phrase as 'learning outcomes' in the same way as a Training Needs Analysis. The aim is to ensure coherency with other objectives of training, so the knowledge, awareness and applied practice on reducing risk levels in Class G is strategically designed to fit into the wider training picture (e.g. initial examinations, refresher training, online training etc)
6	Assessment of the cost of measurement is recommended. For some leading indicators, some design is necessary to be able to capture the metrics (e.g. online surveys etc.). If the benefit is not likely to be high, the value of capturing the metric in the first place must be assessed.
7	Think innovatively. In overcoming the inherent context of operations in Class G airspace, namely a diverse user base with many individual operators, new techniques may be necessary to capture the data. Whilst in large organisations, over-the-shoulder surveys such as day-to-day surveys are used; for individual operations, self-assessment is likely to be the answer for wide data collection. This could be achieved by, for example, mobile phone applications being used to collect data at the end of each flight.
Incident reporting	
8	The current list of causal factors assigned by the UKAB does not necessarily promote a broader understanding of the airprox itself or enable meaningful trend analysis. It is recommended that the list of causal factors is updated, in line with the terms used in a common taxonomy such as the one developed by EASA - European Co-ordination Centre for Aviation Incident Reporting System (ECCAIRS).
9	Consideration could be given to developing the barrier model further and linking occurrences to barriers in the future. This would provide an indication of the number of barriers available and which ones were unsuccessful or successful. This would promote a greater understanding of risk and could complement the existing risk classification scheme. It would also aid analysis of the effectiveness of safety initiatives.
10	It is recommended that the airprox reporting system endeavours to capture the barriers that are available along with which components were successful or unsuccessful.
11	Consideration should be given to utilising additional methods to assess risk. Use of the Risk Analysis Tool (RAT) developed by EUROCONTROL would aid the assessment of severity and risk and improve on the current risk descriptions. It would also allow the analysis of a single event in order to understand the factors involved and then place the event in context with other events.
12	As part of the UKAB assessment process of each incident, it is recommended that they consider the probability that it could occur again. The UKAB currently make recommendations aimed at preventing reoccurrence of some events but the likelihood of reoccurrence is not currently documented and monitored.
13	In addition to recording serious incidents such as an airprox there may be added value in recording more minor events in the same database, or at least within the same

	department, to enable trend analysis and risk management across a broader spectrum of events.

Contents

List of figures

List of tables

1 Introduction

1.1 Background

The Civil Aviation Authority (CAA) 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) was 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 contributory risk factors that increase the likelihood of a mid-air collision (MAC) within Class G airspace. The UKAB is already acutely aware of many of the issues present in the airprox reports. Indeed the CAA has been proactive in establishing a number of working groups to tackle issues such as visual conspicuity and visual circuit procedures. This study aims to provide additional evidence and statistical rigour to build on the CAA’s existing understanding of risk.

The study has been divided into three distinct tasks as follows:

Task 1: This task conducted a review of key existing studies relating to the Class G airspace concept of operation. The review material was used to construct a ‘barrier’ model that depicts the key mitigations in Class G airspace that prevent a MAC from occurring. An outline methodology for analysing the airprox database was also included in the report. The report from Task 1 [2] was provided to the Project Steering Group on 20th June 2014.

Task 2: Task 2 (this document) refined the methodology outlined in Task 1 and developed a detailed taxonomy for coding causal and contributory factors in a database. The significant findings from the data are presented. Some suggestions on the future management of airprox reports are also made.

Task 3: Having established a prioritised list of safety risk factors, the final part of this study (also captured in this document) suggests a set of leading indicators that can be used to monitor performance in key areas in the future.

1.2 Scope

This document sets out the methodology employed in the analysis of the airprox reports and presents the results. The analysis considers the effectiveness of existing barriers along with the key causal and contributory risk factors. The report concludes with recommendations for the future and a suggested set of leading indicators.

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.

1.3 Structure of this document

The structure of the document is as follows:

Section 2: Provides guidance on interpreting and using the data;

Section 3: Describes the methodology used to analyse the reports;

Section 4: Analyses the data to understand the relationships and present the findings;

Section 5: Discusses the key findings from the analysis;

Section 6: Provides guidance on the use of leading indicators.

2 Interpreting the data

2.1 Definition

"An Airprox is a situation in which, in the opinion of a pilot or air traffic services personnel, the distance between aircraft as well as their relative positions and speed have been such that the safety of the aircraft involved may have been compromised" [3]

2.2 Data Sample

The data represents all airprox reports where at least one of the aircraft was inside Class G airspace from the start of 2000 to the end of 2013 (1813 reports).

2.3 Interpretation of the data

Airprox reports represent one method of monitoring where aviation safety may have been compromised. These combined with mandatory occurrence reports and voluntary reports help provide a broader picture of aviation safety.

As with any statistics, it is important to understand the context within which they are viewed. The number of airproxes reported represents a fraction of the total number of flights and so the information is a sub-set of the overall statistics (see Figure 1 below).

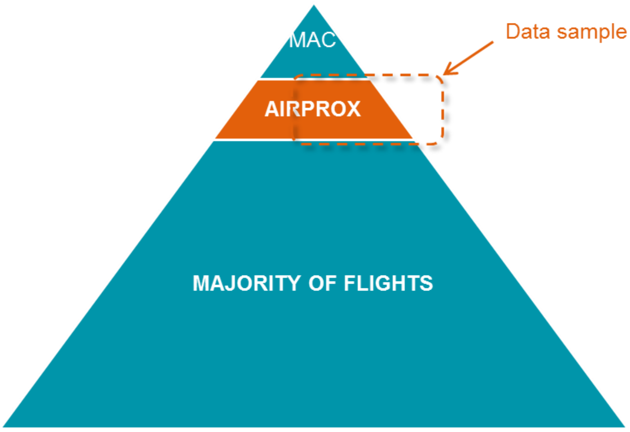


Figure 1: Illustration of data sample

There are undoubtedly incidents that occur that go either unnoticed or are not reported, whilst improvements in safety culture and education have likely had an impact on reporting rates. Reporting rates within user groups have also changed over time with an increase in reports from microlight pilots particularly noticeable over the past 4 years. This is not necessarily because they are having more incidents than before, but could be a reflection on improved reporting of incidents. Due to the relatively small sample size and broad spectrum of elements in the taxonomy, it was difficult to obtain statistical significance in much of the data and so a degree of professional interpretation gained from reading the reports was required in delivering the results and analysis. Due to the small sample size and lack of definitive flying rates inside Class G airspace, any trends or findings should be treated with an element of caution.

It is worth noting that the fact that a particular element in the taxonomy has been applied to a particular aircraft or ATC doesn't infer any level of blame is being apportioned. The elements may be applied for a variety of reasons many of which may be outside the individual's control.

It is also worth noting that the Airprox Report data was never intended to be used for this type of retrospective analysis. There is little reference to the broader strategic factors that influence safety or a systemic view of the individual elements of the system in place at the time of the airprox.

2.4 Obtaining the results

Retrospectively analysing thousands of airprox reports is an obvious challenge. The experts involved have attempted to ensure a robust and consistent process, but two elements should be noted when reviewing the results:

- The experts were evidently not the equivalent of the full UKAB. The full Board is convened for a reason; each expert present brings a different perspective. Even with the full Board, there are often disagreements and subsequent voting as to causes of individual airproxes. With one expert reviewing each report in this study, the potential for varied interpretations was present. Nevertheless, each of the experts reviewing had excellent understanding of Class G operations from a variety of perspectives, and shared their insights as they evaluated the airproxes. A taxonomy was agreed beforehand, and a pilot study conducted to test the categories' comprehensiveness. Finally, the 4 step grounded theory (see Annex A) was applied to cross-check interpretation and ensure the consistent application of the taxonomy.

- The experts were limited by the information presented in the UKAB reports. In particular, subjective opinion (e.g. in the individual pilot or controller reports) had to be treated very cautiously. Also, the UKAB reports did not always give the full background information on effective barriers such as reasons why the airprox did not lead to anything more severe.

Many of the contributory and causal factors presented in the airprox reports are well documented and widely published. The issues themselves are not new. Nevertheless, the results obtained from the analysis do provide a more granular set of information into the contributory factors, based on UKAB findings, and can help determine the factors impacting the evolution of the airprox.

3 Methodology

3.1 Method of analysis

A combination of bottom-up and top-down approaches were used to analyse the content of 1813 airprox reports which had been filed between 2000 and 2013. This data sample contained only those airproxes where at least one of the aircraft was inside Class G airspace. The bottom-up method used a grounded theory approach to build a series of hypotheses based on the raw data. The top-down method uses the hypotheses (Barrier model) developed in task one to assess the effectiveness of the key mitigations preventing a MAC in Class G airspace.

3.2 Grounded theory approach

Our approach to understanding why incidents occur has been based on a 4 step grounded theory approach. This is a ‘bottom-up’ approach that looks to formulate a series of hypotheses based on the content of the data as opposed to using the data to prove/disprove an established hypothesis.

Whilst the Joint Airprox Reporting System (JARS) database contains a causal factor for the majority of the reports, the description used did not always provide a full understanding of what occurred. In addition, the reports contained valuable statements on additional causal, contributory, and environmental factors that enabled a greater understanding of risk to be captured. To do this, it was necessary to develop a taxonomy which could be used to categorise the statements which could then be recorded in a spreadsheet for further analysis.

3.2.1 Developing the taxonomy

The Helios team developed a comprehensive taxonomy for coding airprox reports based on an initial sample investigation and the findings from the review of Class G airspace risk. This taxonomy was validated by cross checking it against the Commercial Aviation Safety Team (CAST)/International Civil Aviation Organisation (ICAO) Common Taxonomy Team Air Traffic Taxonomy (CICTT AT taxonomy) for aviation accident and incident supporting systems, and ‘Air Traffic Causal and Contributory Factors; Definitions and Usage notes’, which is a high level categorisation of factors that contribute to incidents or accidents. The CICTT AT taxonomy took account of ECCAIRS during its development which should aid the transfer and interpretation of data in the future should it be required.

The taxonomy has been developed for the UK concept of operation in Class G airspace. However, only minor modification would be required to capture the full range of causal factors in other classifications of airspace or alternative concepts of operation.

Our taxonomy was distributed for broader review by the CAA, UKAB, and Class G stakeholders for comments and updated accordingly. In line with the CICTT AT taxonomy, this taxonomy consists of a three-tier structure:

- High-level domains;
- Disciplines;
- Individual elements.

There are four high-level domains:

- Individual/human factors;
- Organisational factors;
- Equipment factors;
- Operating environment.

The full taxonomy can be found in Table 1 below, and a full description of each item in the taxonomy is provided in Annex **Error! Reference source not found.**.

Domains	Disciplines							
Individual / Human Factors	**Experience Level / Knowledge**	**Perceptual**	**Physical / Sensory**	**Procedural / task performance**	**Psychological**	**Fatigue**		
	Currency (Pilot) Currency (ATC) Qualification (Pilot) Qualification (ATC) Understanding of procedures (Pilot) Understanding of procedures (ATC)	Situational awareness (ATC) Situational awareness (Pilot) Perception bias (ATC) Perception bias (Pilot) Conflict assessment (ATC) Conflict assessment (Pilot)	Sensory (ATC) Sensory (Pilot) Health/Fitness (ATC) Health/Fitness (Pilot)	Planning (pre-tactical) Equipment utilisation (general) Equipment utilisation (altimeter) Equipment utilisation (transponder) Equipment utilisation (Navigation/GPS) Equipment utilisation (Radio) Scan (Environment) Scan (ATC equipment) Scan (Aircraft equipment) Workload (Pilot) Workload (ATC) Priorities (ATC) Priorities (Pilot) Coordination (ATC) Traffic Information (ATC-ATC) Traffic Information (ATC-Pilot) Pilot ATS Selection Confusion with level of service provided Teamwork (CRM) Violation (General) Violation (ACAS)	Distraction (ATC) Distraction (ATC Handover) Distraction (Pilot) Cognitive limitation (Pilot) Cognitive limitation (ATC) Information Processing Assessment of risk (Pilot) Assessment of risk (ATC) Emotional state (ATC) Emotional state (Pilot) Personality /attitude (Pilot) Personality /altitude (ATC)	Fatigue (ATC) Fatigue (Pilot)		

Domains	Disciplines							
				Action/inaction (non-intentional) (General) Action/inaction (non-intentional) (ACAS) Action/inaction (non-intentional) (Altitude) Action/inaction (non-intentional) (Navigation) Action/inaction (non-intentional) (Airmanship) Action/inaction (non-intentional) (Readback) (ATC) Action/inaction (non-intentional) (Readback) (Pilot) Action/inaction (non-intentional) (Communication) (ATC) Action/inaction (non-intentional) (Communication) (Pilot) Action/inaction (non-intentional) (Phraseology) (ATC) Action/inaction (non-intentional) (Phraseology) (Pilot)				

Domains	Disciplines							
Organisational Factors	**Oversight** Supervision (ATC) Supervision (CRM) Staff allocation	**Ops Planning** Route Planning Deconfliction of activity with other groups Resources	**Policy Procedures** UK FIS ACAS Quadrantal/semi-circular Procedures Rules of the air Updates/Communication	**Culture (safety)** Culture (working practices)	**Training** Training (ATC) Training (Pilot)	**Record Keeping** Document accuracy	**Enforcement** Assurance	**Safety Programme** Safety Programme
Equipment Factors	**Aircraft Systems** Communication (availability) Communication (serviceability) Transponder (availability) Transponder (serviceability) ACAS (availability) ACAS (serviceability) Collision Warning System – TAS (availability) CWS – TAS (serviceability) Conspicuity	**ANSP Systems** Communication (availability) Communication (serviceability) PSR (availability) PSR (serviceability) SSR (availability) SSR (serviceability) STCA (availability) STCA (serviceability) Maintenance Visual display						

Domains	Disciplines							
	Internal radar (availability) Internal radar (serviceability) GPS							
Operating Environment	**Infrastructure** Airspace design Airspace complexity Airspace availability Traffic Density Aircraft speed ATC service availability (General) ATC service availability (LARS) Field of view Conflict Geometry Terrain	**Weather** Light conditions Visibility Precipitation Wind Temperature VMC IMC	**Special Events** Military exercise Flight check Emergency services Air policing Parachute Balloon Low flying Pipeline inspection Civil event Model Flying Airshow	**Emergencies** Emergencies				

Table 1: Class G Contributory Factor Taxonomy

3.3 Top down approach

As well as the bottom up approach taken to assign the contributory factors to each Airprox report, we also took a top down approach to assess the barriers present in each incident. The review of existing research in Task 1 was used to develop the barrier model in Figure 2 below:

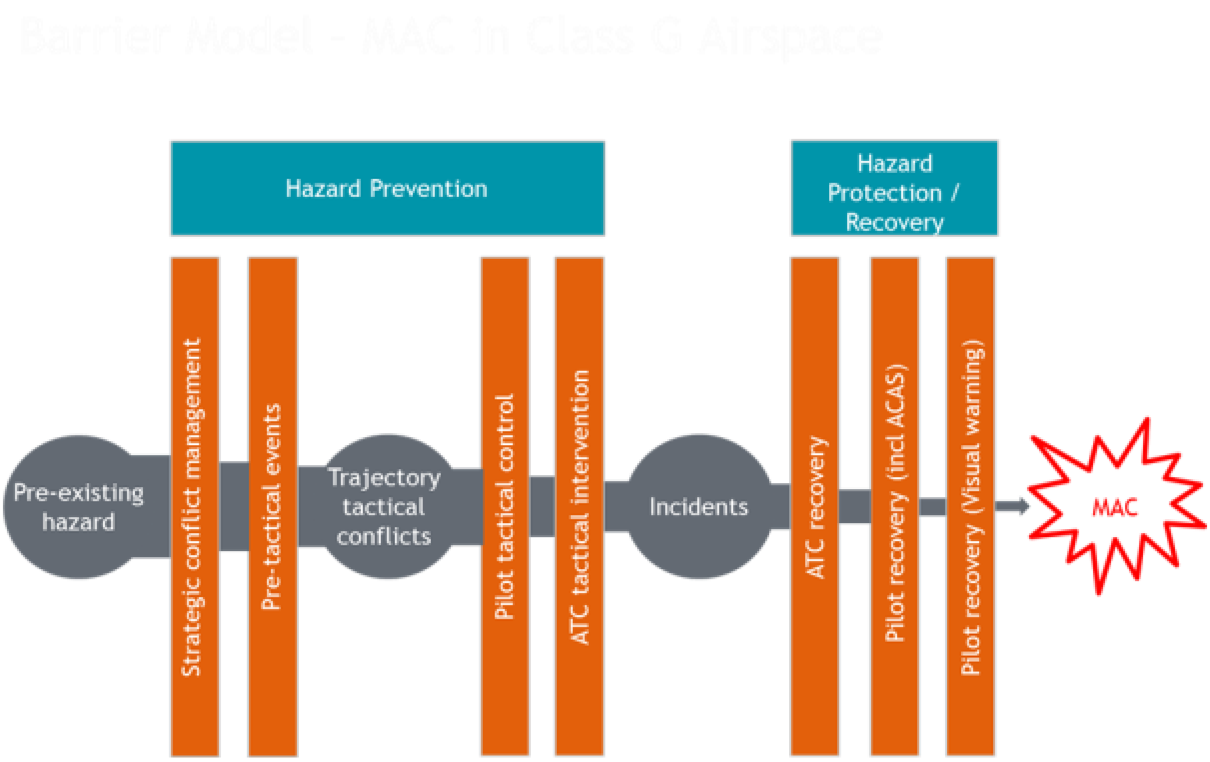


Figure 2: Key barriers mitigating risk in Class G airspace

The model is essentially split into those mitigations that help prevent a hazard from occurring (hazard prevention) and those which aid the recovery (hazard protection/recovery) should an incident occur. A full description of each of the barriers is contained in Annex B, along with the components of each barrier. The equipment and behaviours underpinning each component are contained within the safety functional map in Annex C. The number of components within each barrier was kept deliberately low to prevent it morphing into a second taxonomy.

For each report, the incident was assessed for which barrier(s) were unsuccessful and failed to prevent the Airprox. Also, as an Airprox by definition has not led to a MAC, the barrier(s) that were successful in preventing the incident developing into a MAC were also recorded. For clarity, the elements under ATC recovery include the provision of avoiding action regardless of whether a short-term conflict alert (STCA) had been triggered.

3.4 Pilot study

Once the taxonomy of contributory factors was developed, a pilot study was performed. The pilot study consisted of a full analysis of all 2012 Class G airprox reports with a risk category rating of A, B, C or E, explained in Table 2 below.

Risk		Definition
A	Risk of collision	An actual risk of collision existed
B	Safety not assured	The safety of the aircraft was compromised
C	No risk of collision	No risk of collision existed
D	Risk not determined	Insufficient information was available to determine the risk involved, or inconclusive or conflicting evidence precluded such
E	Normal safety standards	Normal safety standards were maintained.

Table 2: Risk Category Ratings

The purpose of the pilot study was to verify whether the taxonomy could be applied to the analysis of airprox reports and develop it further, adding any additional contributory factor categories required. It was also necessary to determine whether the successful and unsuccessful barriers could be determined through reading the reports, and whether the barriers identified in Task 1 were comprehensive or additional barriers could be identified. The pilot study was successful in doing this. However, in line with grounded theory some additional contributory factors were added to tailor the taxonomy further.

The results of the pilot study were presented at a workshop consisting of CAA, UKAB and Class G stakeholder attendees. This gave stakeholders the opportunity to provide their input on the methodology being applied, allowing it to be adapted before the main study. Some contributory factor categories were amended, and here it was decided that it was important to be able to attribute the contributory factors to the individual pilots involved in the incident, rather than the incident as a whole. An indication of the type of analysis possible was presented, allowing stakeholders to provide input on what analysis they would like to see. This has been reflected in the results and analysis.

3.5 Main study

The main study consisted of a full analysis of all class G airprox reports from 2000-2013 with a risk category rating of A, B, C or E.

For each report we coded the database with:

- The contributory factors;
- The barrier(s) that were unsuccessful;
- The barrier(s) that were successful.

3.5.1 Applying the taxonomy

The contributory factors were assigned to the individual pilots concerned, and also ATC. ATC for the purposes of this analysis includes all those providing services or information to airspace users such as ‘air defence’ controllers, Forward Air Controllers and other personnel charged with the responsibility for the deconfliction of air activities. On some occasions, such as a ‘sighting report’, no contributory factors were identified and so the entry in the database was left blank.

During the analysis two minor issues arose with regard to the taxonomy. Firstly, the crew resource management (CRM) elements within human factors and organisational factors had some elements of overlap. Secondly, there was an inconsistency in how the impact of those under training was recorded. Some were mistakenly coded under Training ATC as opposed to ATC supervision which included the supervision of trainees by instructors. The number of instances where this impacted the outcome of an airprox was low and therefore this was not found to significantly impact the overall results.

Having completed the analysis, it was felt that some new elements could be added to strengthen the taxonomy for use in the future. These are detailed in Annex D.

3.6 Assessing the Barriers

Whilst the assessment of the barriers didn't provide the range and depth of data available compared to the taxonomy, it was sufficient in capturing the main barriers that were either successful or unsuccessful.

As each report was assessed, a note was made in the database as to which components of the barriers were either effective in mitigating the risk involved along with which barriers were unsuccessful.

It became clear that the analysis would be able to code any successful or unsuccessful barriers explicitly stated, but would not be able to work as a tick box exercise and judge whether or not each barrier was present or not for each incident, as the detail required to do that was not contained in each report. This was particularly the case for successful barriers where little reference may have been made in the report as to what may have mitigated the level of risk.

In order to provide impartial evidence, the barriers were only captured as having a positive or negative effect when they were explicitly recorded as facts or where the UKAB explicitly made reference to them. The views and opinions of the pilots, controllers, aircraft owners, managers, instructors, flying clubs, and other organisations associated with the airprox were not recorded.

Within each barrier, some components may have been successful whilst others were not, rather than simply being a case of all components in the barrier either being effective or not. Furthermore, the barriers are not completely distinct from each other. Different components within one barrier can impact the success of those in another. For example, the receipt of traffic information (ATC tactical intervention) aids the pilot's situational awareness thus making pilot tactical control more effective. This was less true for the recovery barriers where if they were available then there was less fluctuation across the individual components.

Ultimately each barrier was either successful or unsuccessful but those successful components within an unsuccessful barrier help mitigate the level of risk to a varying extent.

4 Analysis

The full results can be found in Annex E. This includes the top contributory factors by user group, over time, by aircraft category, altitude and phase of flight. Below you will find a highlight of the key results and an analysis of these.

4.1 High-level Domains

As described in Section 2, the taxonomy contained four high-level domains. Figure 3 below depicts the split between Individual/Human Factors, Organisational Factors, Equipment Factors, and Operating Environment Factors.

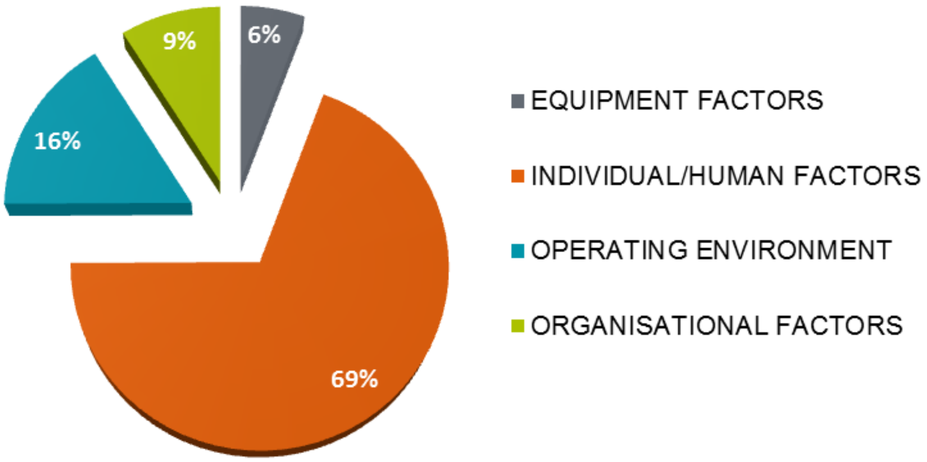


Figure 3: High-level Domains

4.2 Contributory Factors

A total of 137 different contributory factors were coded into the database. The top 20 most prevalent contributory factors are depicted in Figure 4 below:

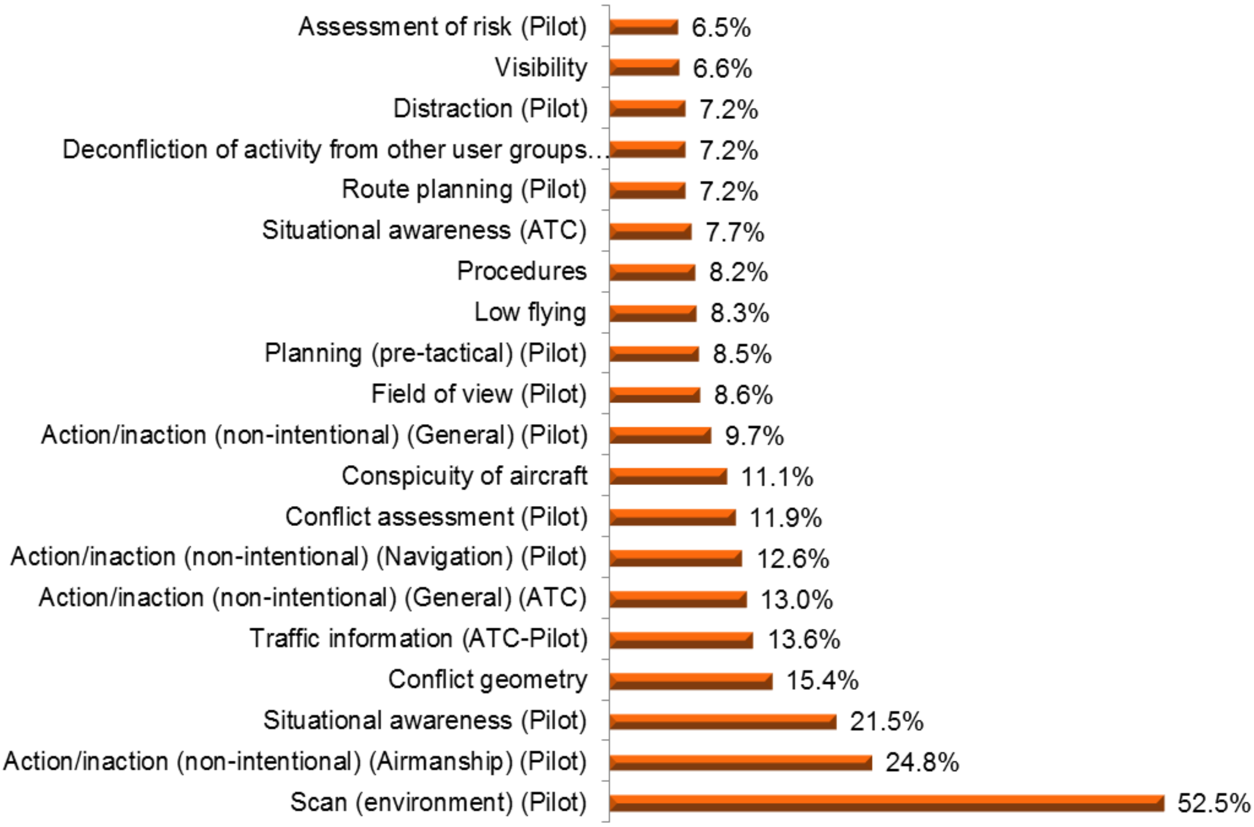


Figure 4: Top 20 Contributory Factors (% of total airprox)

4.2.1 Contributory Factors – Pilot

The top 10 contributory factors associated with pilots are depicted in Figure 5 below. A full description of each of the top 10 factors can be found in Annex E.

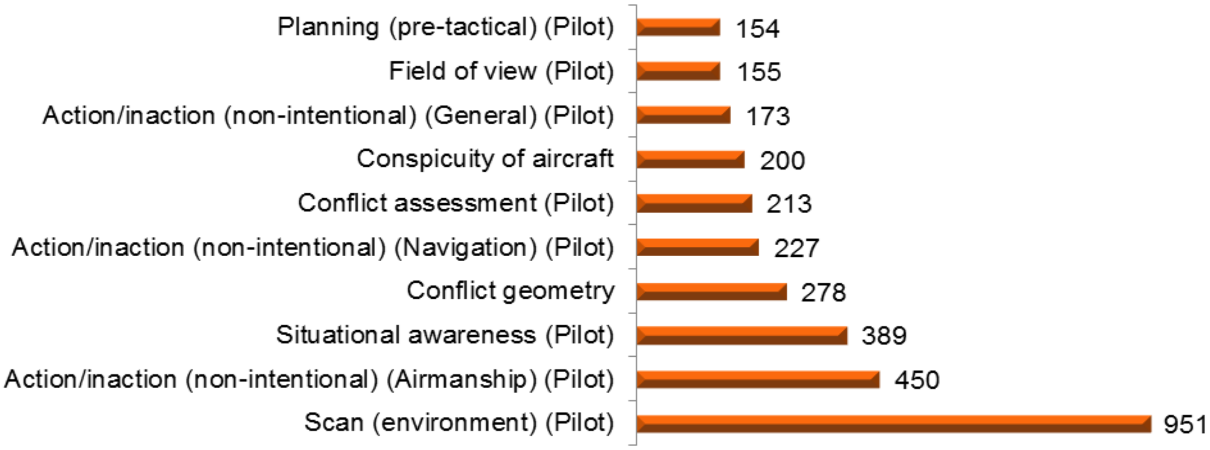


Figure 5: Top 10 Contributory Factors – Pilot (sample size 1813 reports)

4.2.2 Contributory Factors – ATC

The top 10 contributory factors associated with ATC are depicted in Figure 6 below. A full description of each of the top 10 factors can be found in Annex E.

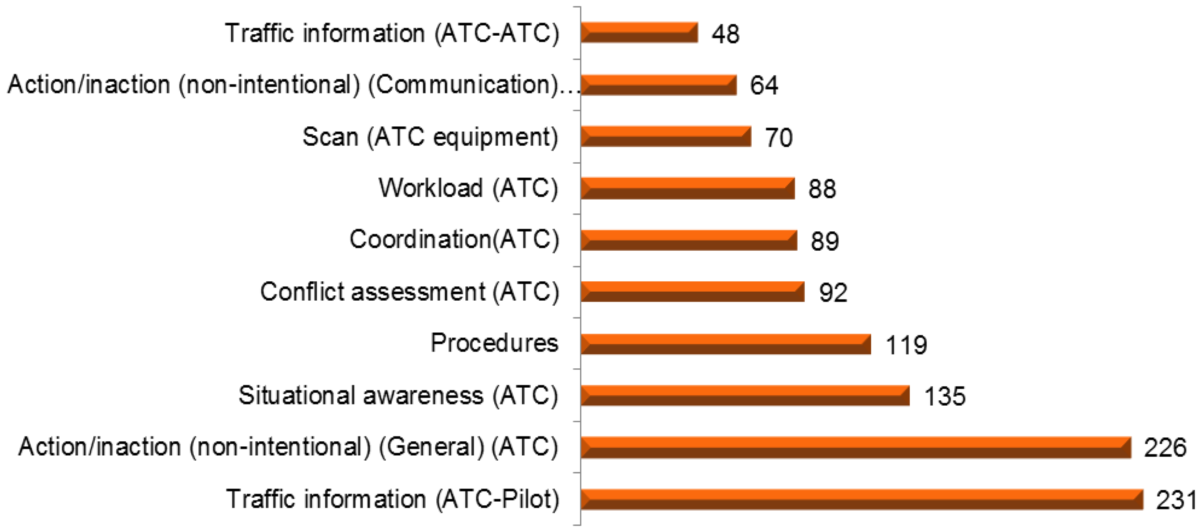


Figure 6: Top 10 Contributory Factors – ATC (Sample size 1813 reports)

4.3 Grounded theory

In order to complete the grounded theory process, it was necessary to analyse the data in order to identify any common relationships and occurrences between the contributory factors. The fact that another element occurred at the same time didn't necessarily mean that there was a direct relationship between the two, but using the knowledge gained during the coding process it was possible to interpret the results in a meaningful way. This process enabled us to create a series of hypotheses which were largely data driven but due to the low levels of statistical significance a degree of interpretation was required.

4.4 Factors affecting pilot scan [Scan (environment) (Pilot)]

In accordance with CAP 774 [4], regardless of the ATS being provided (if any), pilots are ultimately responsible for collision avoidance. Whilst ATC services and electronic aids like ACAS and Traffic Avoidance Systems (TAS) may assist pilots in avoiding collisions, the primary method in Class G airspace is 'see and avoid'. Furthermore, the rules of the air can only be implemented successfully if pilots are able to see each other in sufficient time to implement the rules safely.

The element most closely associated with see and avoid in the taxonomy was Scan (environment) (Pilot) and this was a contributory factor in 52.5% of all airprox reports, twice as frequent as the next most common factor (Airmanship 23.8% of reports). Figure 7 below depicts the frequency that other contributory factors occurred at the same time as an ineffective scan. For example, pilot situational awareness was a factor on 25.3% of the occasions when scan (environment) (Pilot) was recorded.

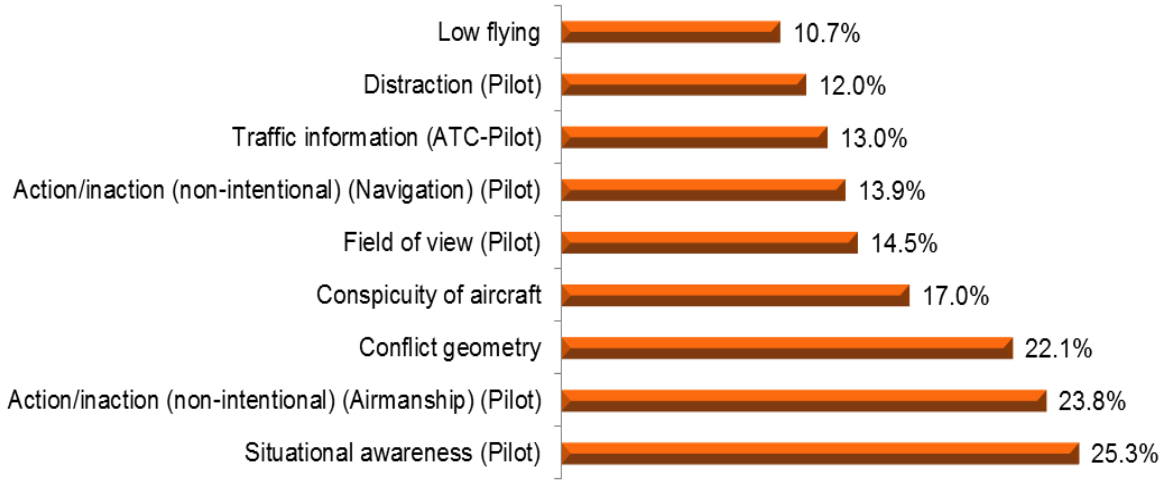


Figure 7: Factors occurring with Scan (environment) (Pilot)

Analysing the data in Figure 7 above, it is clear that there are a number of factors that may impact a pilot's ability to maintain an effective scan. Most prevalent (25.3%) was the impact of reduced situational awareness. Pilots were more likely to visually acquire another aircraft in good time if they were aware of its presence either via an ATS or electronic device such as internal surveillance or ACAS. The main factors occurring with situational awareness (pilot) are depicted in Figure 8 below.

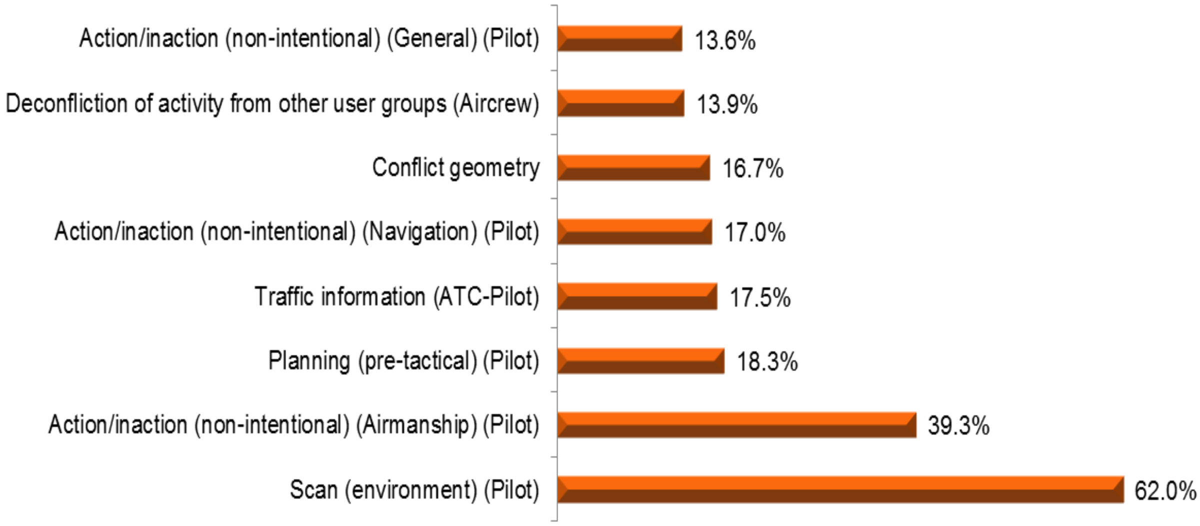


Figure 8: Factors occurring with Situational Awareness (Pilot)

Situational awareness

Pilot scan aside, the greatest influence on situational awareness (39.3%) is poor airmanship and this is discussed in more detail in Section 4.5 later in this chapter. Other key factors impacting situational awareness are as follows:

Planning (pre-tactical) (Pilot)

Some influences on situational awareness occurred even before the pilot became airborne. Planning (pre-tactical) (Pilot) occurred in 18.3% of reports where situational awareness was a contributory factor. This included activities such as effective route planning and cognisance of any applicable NOTAMs. An example for military aircrew was a lack of awareness of other users in the low flying system; something which the MOD has been addressing over recent years. However, this was not just about awareness of other military activities. Effective briefing relied on other user groups notifying activity via the Pipeline Inspection Notification System (PINS) or Civil Aircraft Notification Procedures (CANP). It was evident from the aircrew reports that when they were aware of another user who was utilising a similar area, there was a conscious effort to scan for it in order to deconflict their activities.

For GA pilots, poor briefing tended to concern a lack of awareness of other airspace users and their activities, and this subsequently impacted on their route selection. Poor navigation in the taxonomy (17% occurrence with situational awareness) was often a result of failing to plan the route effectively to account for glider sites, NOTAM activity, busy military and civil airports, and approach and departure lanes. This meant that pilots were not necessarily aware of the activity and flight profiles and therefore flew in close proximity to other airspace users. It is acknowledged that in many cases there was no requirement to avoid a specific area per se but pilots should have been aware of the various hazards that were present along their intended route.

Traffic information

Another influence on a pilot’s situational awareness (17.5%) and ultimately effective scan (13%) was the timeliness and accuracy of traffic information passed by providers of UK FIS. Whilst timeliness and accuracy were fundamental in providing effective traffic information, it was often a failure to pass some additional pertinent information which reduced situational awareness. Typical examples of situations where additional information could have assisted situational awareness were:

- Descending/climbing rapidly;
- Fast/slow moving contact;
- Number of aircraft in formation
- Conducting GH or aerobatics;
- Established on the ILS.

The passing of pertinent traffic information is not limited to those providing a Traffic or Deconfliction Service. Whilst it is important not to blur the lines between the various UK FIS it was apparent that those agencies providing a BS also played an important role in the passing of information which aided pilot situational awareness and ultimately visual scan. Examples were details of known activity in the vicinity, such as gliding, military radar patterns, and additional aircraft on frequency.

Visual circuit

Visual circuits where no aerodrome service was available tended to impact pilots' situational awareness as they were reliant on timely and accurate communication from those both in the circuit as well as arrivals and departures. It was evident that missed, late or inaccurate calls quickly degraded the situational awareness of others and meant pilots were not always looking in the optimum location to acquire other aircraft.

Where an aerodrome service was available, the dual use of UHF and VHF frequencies sometimes resulted in reduced situational awareness for those operating on different frequencies if they were not cross-coupled. For example, an aircraft departing on UHF may be unaware of an aircraft joining the circuit on VHF. It is worth noting that the use of dual frequencies was a factor influencing controller workload; however, controller workload was not found to be a significant contributory factor in the airprox reports (1.1% of reports).

Conflict Geometry, Field of View, and Conspicuity

The conflict geometry between the aircraft involved in the airprox had an impact on effective scan (22.1% occurrence with scan, 16.7% occurrence with situational awareness). Typical examples were where the aircraft were 'belly up' to each other or one descending on top of another. However, the conflict geometry also impacted visual acquisition when the aircraft were on a constant bearing which resulted in little discernible movement of the other aircraft making them harder to detect. The pilot's field of view also had a similar impact on visual scan (14.5% occurrence with scan) as it also limited the pilot's ability to see in all directions. However, field of view was also impacted by IFR 'screens' and night vision devices. Some night vision devices had the potential to make depth perception and field of view more challenging.

An additional factor linked with effective scan was the conspicuity of aircraft (17% occurrence with scan). Significantly, it appears that conflict geometry, field of view, and conspicuity tended to occur together (31.2% occurrence) making it even more challenging to acquire the other aircraft. This could be interpreted as when these factors occur together it is more likely to result in an airprox and for the incident to end up in this dataset.

4.5 Action/inaction (non-intentional) (Airmanship) (Pilot)

Following pilot scan, poor airmanship was the second most common contributory factor in the reports (24.8%). Common themes where poor airmanship skills were recorded were pilots flying close enough to another to the extent that it caused them alarm or ineffective integration into the visual circuit. Often the alarm occurred because the pilot had not been aware of the other aircraft prior to the airprox.

Poor airmanship is also a key factor impacting effective scan and situational awareness (23.8% occurrence with scan, 39.3% occurrence with situational awareness). A third of pilots chose not to make radio contact with a service provider or to utilise a 'common frequency'. More common was the practice of pilots 'listening out' on a frequency but not actually transmitting their location or intentions. Whilst it is not mandatory to be in radio contact (except for specified areas) with an ATS provider or to utilise a common frequency, there is a direct impact on the situational awareness of other pilots (and potentially ATC) as they may be unaware of a potential conflict.

This was most evident around aerodromes providing a Procedural Service (PS) or where the aircraft not in radio contact was also not transponder equipped.

In addition to the relationship between airmanship and situational awareness, there is also a link (23.3% occurrence) with ineffective navigation skills. This primarily manifested itself through aircraft not paying due regard to active parachuting and glider sites (particularly those conducting winching) as opposed to someone getting lost.

A failure to follow the rules of the air was a common theme under 'Action/inaction (non-intentional) (General) (Pilot)' which had a 19.6% occurrence rate with airmanship. Again, poor integration into the visual circuit often involved poor airmanship and inaction (General) occurring together. Another example of airmanship and inaction (General) occurring together was a tendency for pilots to 'stand on' if they had right of way even though the other pilot may not have seen them. This led to late avoiding action. Conflict assessment was a factor in 19.3% of the reports where airmanship was also a factor. This was due in part to differing opinions between pilots of what distance between aircraft is acceptably safe. What was deemed acceptable by one was determined as being too close by another.

4.6 Comparison with UKAB causal factors

It was possible to analyse the top 10 (UKAB attributed) causal factors between 2000 and 2013 to see which contributory factors occurred for each. The results are in Table 3 below.

UKAB Causal Factor		Top 3 contributory factors		
1	Failure to see conflicting traffic	Scan pilot	Situational awareness pilot	Conflict geometry
	653 airprox	18.6%	5.8%	5.5%
2	Late sighting of conflicting traffic	Scan pilot	Conflict geometry	Situational awareness pilot
	553 airprox	20.3%	6.2%	5.4%
3	FIR conflict	Scan pilot	Airmanship	Situational awareness pilot
	403 airprox	13.5%	4.5%	4.2%
4	Inadequate avoiding action/flew too close	Airmanship	Scan pilot	Conflict assessment
	291 airprox	12.7%	8.5%	7.6%
5	Failure to adhere to prescribed procedures	Airmanship	Situational awareness pilot	Scan pilot
	122 airprox	10.7%	8.5%	8.5%
6	Sighting report	Conflict assessment pilot	Airmanship	Scan pilot

UKAB Causal Factor		Top 3 contributory factors		
	119 airprox	9.2%	5.5%	5.2%
7	Poor Airmanship	Airmanship	Scan pilot	Situational awareness pilot
	108 airprox	12.3%	11.1%	7.6%
8	Failure to pass or late passing of traffic info	Traffic information ATC-Pilot	General inaction ATC	Scan pilot
	100 airprox	11.4%	8.2%	6.7%
9	Failure to separate/poor judgement	Inaction general ATC	Traffic information ATC-Pilot	Conflict assessment ATC
	83 airprox	13.0%	7.0%	7.0%
10	Flying close to/over glider or paradrop site	Navigation pilot	Scan pilot	Airmanship
	83 airprox	14.5%	12.2%	12.0%

Table 3: Top 3 contributory factors for each of the top 10 UKAB causal factors

Rather than adding anything of significant value in terms of understanding, the comparison with UKAB causal factors provided useful validation that the taxonomy and methodology were consistent with the findings in the UKAB database.

4.7 Barrier Model Analysis

As the barrier model only contained 36 components compared to 135 elements in the taxonomy, the results do not provide the same granularity obtained via the grounded theory approach. However, comparison between the findings provided useful validation of the value of the barrier model results.

4.8 Successful Barriers

Due to the nature of the airprox reports and their understandable focus on determining the level of risk and causal factors, there tended to be less explicit information about what went right as opposed to what went wrong. Whilst it was possible to identify a number of successful barriers in the majority of the reports, there are gaps in the data due to some barriers, such as strategic conflict management, not being referenced in the reports. The successful barriers that were referenced are depicted in Figure 9 below.

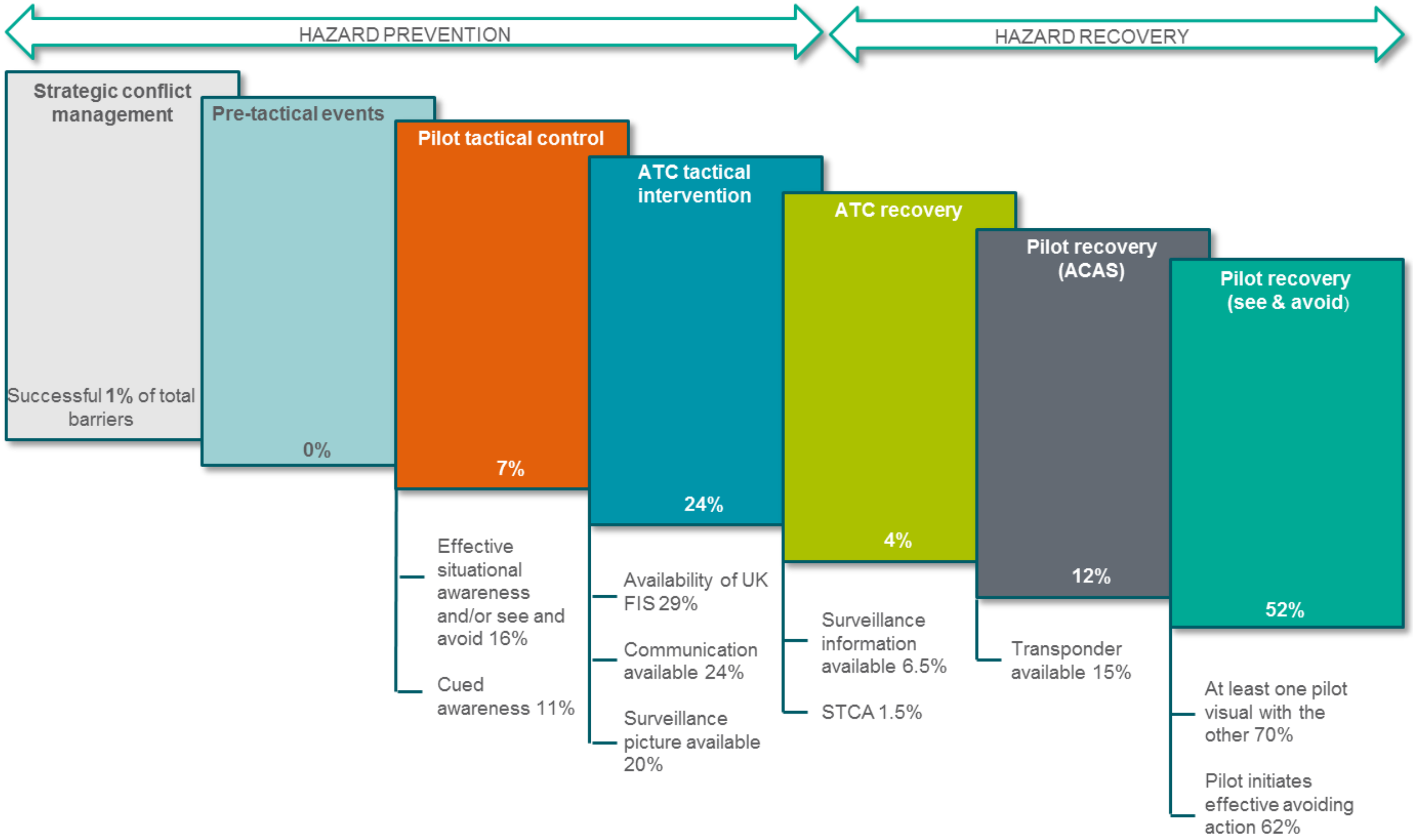


Figure 9: Successful Barriers

Pilot recovery (see and avoid)

Unsurprisingly, given that an airprox had occurred, the most successful barrier was on the 'recovery' side of the barrier model as opposed to 'tactical control/intervention'. Where recorded, 52% of the successful barrier components resulted from pilot see and avoid. This was often at a very late stage but still sufficient to avoid a mid-air collision (MAC). At least one of the flight crew was able to view the other aircraft in time on 70% of occasions and at least one aircraft initiated effective avoiding action 62% of the time. It should be noted that some form of avoiding action was not necessarily required on every occasion.

ATC Tactical Control

Despite almost a third of airproxes occurring when a pilot was not in receipt of an ATC service[1] (30%), ATC Tactical Control accounted for 24% of successful barrier components. However, this does not necessarily imply that all elements within the ATC Tactical Control barrier were successful at any one time, only that some elements helped mitigate the level of risk. For example, the availability of surveillance information (20% of airprox reports), communication (24%), and UK FIS (29%) were recorded as mitigating the level of risk and therefore had a positive impact on the outcome of the airprox.

Pilot Recovery (ACAS)

The use of ACAS and other forms of traffic alerting systems accounted for 12% of the successful barrier components. Whilst there were instances where Resolution Advisories mitigated the level of risk, Airborne Collision Avoidance Systems (ACAS) were also a frequent aid to pilot situational awareness. The presence of a transponder was a factor in mitigating the level of risk 15% of the time. However, this statistic should be viewed with the same caution as with other successful barriers, as there were many occasions where it was clear the use of ACAS would have aided situational awareness but it was not explicitly stated in the report that the availability of ACAS influenced the level of risk.

Pilot tactical Control

Pilot tactical control accounted for 7% of successful barrier components. The key area that was most successful in mitigating risk was effective situational awareness where at least one pilot had effective situational awareness 16% of the time. Also recorded was the frequency (again where stated) of occasions where cued awareness either from ATC or ACAS/TAS enabled the pilot to visually acquire the aircraft on a conflicting trajectory. Cued awareness (where recorded) enabled at least one pilot involved in the airprox to visually acquire the other 11% of the time.

ATC Recovery (STCA)

This barrier encompassed ATC recovery actions regardless of whether STCA was available and accounted for 4% of successful barriers. STCA was only referenced as a positive factor in mitigating risk in 1.5% of the

[1] Pilot was either not in radio contact or was 'listening out'.

reports (26 occasions over 14 years) although its use at area control centres and some civil units was referenced more frequently.

The instances of surveillance information having a positive impact on reducing the level of risk were slightly higher at 6.5% of reports.

Whilst, on initial glance, the success of this barrier appears relatively low, this is due to the low number (3%) of aircraft that are in receipt of a DS within the data set. This could be interpreted as those in receipt of a DS are less likely to have an airprox and therefore this barrier is actually very successful.

Strategic Conflict Management

Strategic conflict management encompassed such things as airspace design, procedures and segregation to protect user groups, and effective management. Understandably, little reference (1% of reports) was made when the 'system' underpinning safety was performing as expected.

4.9 Unsuccessful Barriers

As mentioned in the methodology, it was uncommon for all barriers to be present or indeed referenced in each report or for all the components within each barrier to be referenced as either successful or unsuccessful. However, it was possible to determine the number of unsuccessful events within each barrier which are illustrated in Figure 10 below.

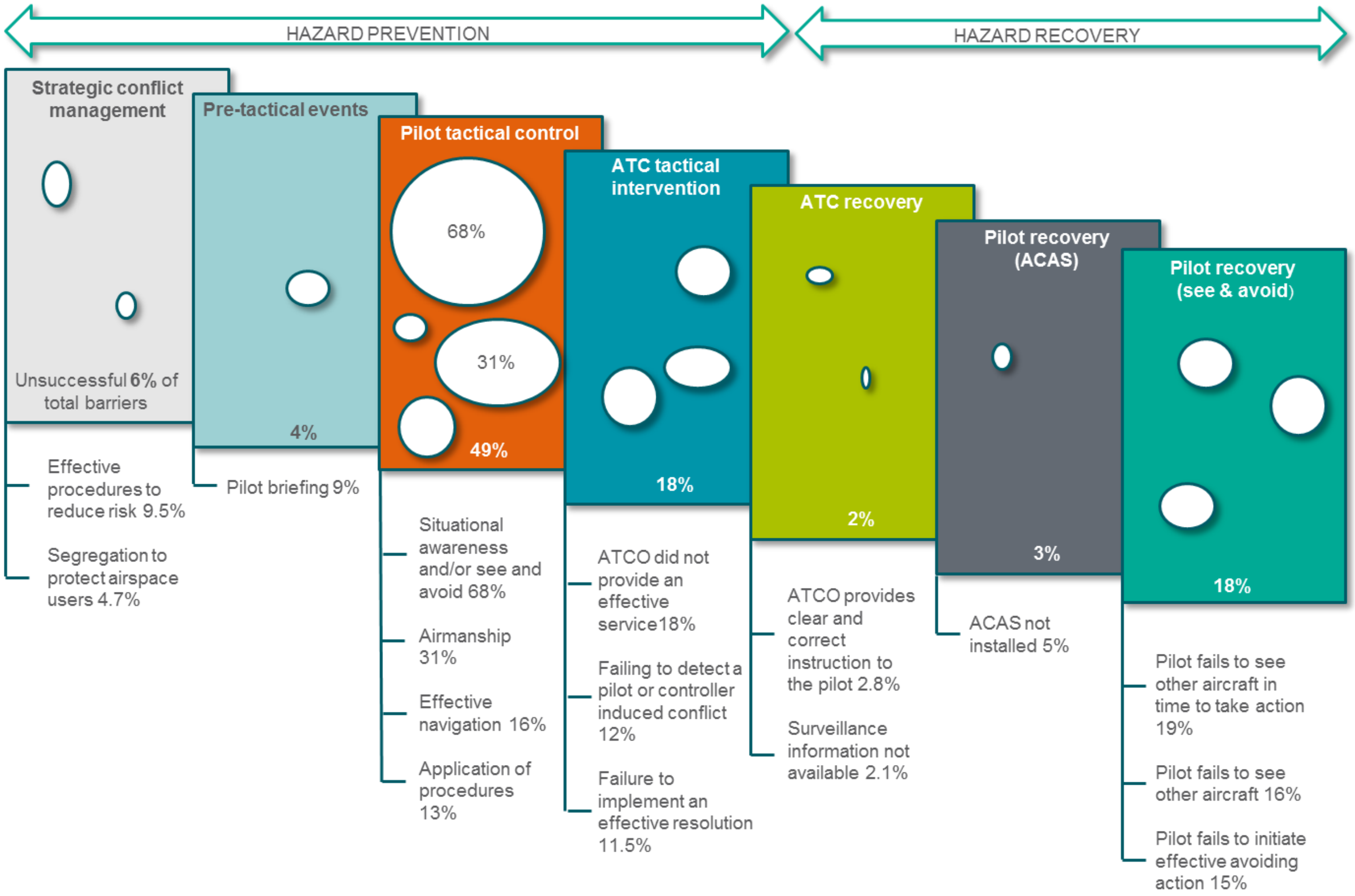


Figure 10: Unsuccessful Barriers

Pilot Tactical Control

Within the barrier model, pilot tactical control contained the following components:

- Effective navigation;
- Effective situational awareness and/or see and avoid;
- Effective airmanship skills;
- Effective reaction to instructions;
- Effective application of procedures;
- Correct readback of instructions;
- Cued awareness enables visual acquisition.

In 49% of recorded unsuccessful events, pilot tactical control was the key barrier impacting risk within the model. See and avoid at this tactical stage (barrier) relates to visually acquiring a potential confliction in sufficient time to prevent the situation developing into a conflict. Within this barrier two particular components stand out as being particularly significant. A lack of effective situational awareness and/or see and avoid occurred in 68% of the airproxes and effective airmanship skills occurred in 31%. Effective navigation (16%) and effective application of procedures (13%) were also worthy of note.

ATC Tactical Control

Within the barrier model ATC tactical control contained the following components:

- Adequate surveillance picture;
- Adequate communication;
- UK FIS are available;
- ATCO provides effective service;
- ATCO detects potential pilot or controller induced conflict;
- ATCO implements effective resolution;
- Avoidance not invalidated by other aircraft.

The component “ATCO detects potential pilot or controller induced conflict” would typically be associated with controllers providing a Traffic or DS. However, it was also applied to those providing a BS or Aerodrome Control Service where it was specifically referenced in the report that there was a missed opportunity to detect a developing conflict regardless of whether the controller was responsible for the separation of aircraft or not.

Except for notified areas, it is not mandatory for a pilot to be in contact with an air traffic service provider. Almost a third of the pilots involved in the airprox sample were not in receipt of any form of ATS[2] rendering this barrier and ATC recovery ineffective on a significant number of occasions. The effectiveness of this barrier is partly dependent on the availability and level

[2] Pilot was either not in radio contact or was ‘listening out’.

of ATS provided and even the use of an Air-Ground service or Basic Service (BS) provides some mitigation against risk. Where an ATS was provided, it accounted for 18% of the unsuccessful barriers with 3 components being particularly significant. The ATCO did not provide an effective service in 18% of the reports along with failing to detect a pilot or controller induced conflict (12%) and failing to implement an effective resolution 11.5%. Whilst the provision of traffic information is generally associated with a Traffic Service (TS) and DS the passing of warnings, where possible, to those in receipt of a BS proved to be equally valuable on occasions.

Whereas the pilot tactical control above is present for all airproxes, ATC tactical control is not and therefore the two sets of figures for the number of airproxes in which the components occur cannot be compared equally.

Pilot Recovery (See and Avoid)

This pilot recovery barrier relates to visual acquisition once a conflict has occurred in sufficient time to take avoiding action to prevent a MAC. This barrier accounted for 18% of unsuccessful barriers events. Specifically, the following components are included in this barrier:

- 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.

In 16% of the reports (288 occasions) a pilot failed to observe the other aircraft at any stage in the event. In 19% of the reports (374 occasions) the pilot failed to observe the conflicting aircraft in time to take effective action to avoid a collision. Additionally, the pilot failed to initiate effective avoiding action, potentially due to the time available, in 15% of the reports.

Strategic Conflict Management

Strategic conflict management includes the national policy and procedures, such as the Rules of the Air, and sets the foundations to minimise risk in each classification of airspace. Areas such as airspace design, effective procedures to manage low flying, and robust training, to name but a few, all underpin the safe conduct of flight.

Strategic conflict management accounted for just 6% of the unsuccessful barrier components and this was predominantly down to effective procedures to reduce risk which occurred in 9.5% of the reports. Typically this related to local procedures as opposed to national and was often a lack of robust inter-unit agreements and coordination between user groups to reduce risk. However, it was evident from the reports that much work had been done over recent years to address these issues.

Pre-tactical Events

Although pre-tactical events only accounted for 4% of the total unsuccessful barrier events, it is worth noting that pilot briefing occurred in 9% of reports as being less effective than was ideal. It was evident that the root cause of some issues in pilot tactical control stemmed from inadequate planning and/or briefing. Examples were a failure to read local aerodrome procedures, NOTAMs, or plan a route that minimised exposure to glider sites, military aerodromes and busy approach and departure lanes.

Pilot Recovery (ACAS)

Pilot recovery as a result of ACAS is a very specific barrier. In terms of what was recorded, it was rare (7 occasions in 14 years) for a pilot not to implement a resolution advisory successfully or for a recovery manoeuvre not to be possible (3 occasions in 14 years). However, these figures should be viewed in the context that in the data sample 77% of aircraft were not equipped with ACAS rendering this barrier largely unavailable[3]. For this barrier to be effective, the conflicting aircraft needed to be equipped with a serviceable transponder that was switched on. The data from the UKAB database recorded that 6% of the aircraft were either not fitted with a transponder or it was switched off/unserviceable. The Airprox Board only made specific reference to a lack of transponder being a factor impacting risk in 2.5% of the reports. It was noted that the MoD made a series of recommendations over the sample years for the mandatory equipage of transponders but this may not have been referenced by the UKAB as being a contributory factor in the incident and therefore may not have been counted.

ATC Recovery (STCA)

ATC recovery accounted for just 2% of unsuccessful barriers. This can be attributed, in part, to the low number of aircraft in the data set (3.2%) that have an airprox whilst in receipt of a DS. It is likely that even if ATC avoiding action doesn't achieve the prescribed separation minima, the action is likely to prevent an airprox from occurring.

4.9.1 Phases of flight

Having looked at the successful and unsuccessful barriers it was possible to assess if there was any variation across the main phases of flight. Table 4 below identifies the top 4 successful barriers across each phase of flight.

[3] Rates for 2013 were down to 60% of aircraft involved in the airprox were not fitted with ACAS.

Flight Phase		Top 4 successful barrier components			
1	Level cruise	Flight crew observes visible aircraft in time	Flight crew initiates effective avoiding action	Other aircraft is visible to the flight crew	Avoidance manoeuvre not invalidated by other aircraft
	2018 successful barriers	14.6%	13.5%	13.2%	10.7%
2	Circuit	Flight crew observes visible aircraft in time	Flight crew initiates effective avoiding action	Other aircraft is visible to the flight crew	Avoidance manoeuvre not invalidated by other aircraft
	855 successful barriers	19.5%	18.7%	17.8%	14.6%
3	Low-level cross country	Flight crew observes visible aircraft in time	Other aircraft is visible to the flight crew	Flight crew initiates effective avoiding action	Avoidance manoeuvre not invalidated by other aircraft
	412 successful barriers	22.8%	21.4%	20.6%	16.7%
4	En-route climb >1500ft	Flight crew observes visible aircraft in time	Other aircraft is visible to the flight crew	Flight crew initiates effective avoiding action	UK FIS are available
	763 successful barriers	10.5%	10.0%	8.1%	7.1%
5	En-route descent to 1500ft	UK FIS are available	Flight crew observes visible aircraft in time	Other aircraft is visible to the flight crew	Flight crew initiates effective avoiding action
	887 successful barriers	9.0%	8.6%	7.8%	7.3%
6	Airfield instrument or radar pattern	Flight crew observes visible aircraft in time	UK FIS are available	Other aircraft is visible to the flight crew	Flight crew initiates effective avoiding action
	942 successful barriers	9.9%	9.7%	9.0%	7.6%

Table 4: Top 4 successful barrier components for each of the main flight phases

What is immediately apparent in Table 4 above is the importance of the pilot see and avoid recovery barrier in mitigating risk across all phases of flight. This recovery barrier is particularly important in the low-level cross country phase of flight where there appears to be less reliance on UK FIS (1.2% of successful barriers) compared to those in the climbing (7.1%), descent (9.0%), and instrument pattern (9.7%) phases of flight[4].

Also worth noting is that an effective ATS reduces risk prior to a conflict developing as opposed to a recovery barrier (late see and avoid) which aims to minimise the impact once an incident has occurred.

Table 5 below identifies the four main unsuccessful components within the barriers across each phase of flight.

Flight Phase		Top 4 unsuccessful barrier components			
1	Level cruise	Effective situational awareness and/or see and avoid	Effective airmanship skills	Flight crew observes visible aircraft in time	Other aircraft is visible to the flight crew
	1063 unsuccessful barriers	27.6%	10.3%	7.4%	6.4%
2	Circuit	Effective situational awareness and/or see and avoid	Effective airmanship skills	Effective navigation	Effective application of procedures
	760 unsuccessful barriers	22.8%	14.9%	9.9%	8.7%
3	Low-level cross country	Effective situational awareness and/or see and avoid	Flight crew observes visible aircraft in time	Flight crew initiates effective avoiding action	Other aircraft is visible to the flight crew
	274 unsuccessful barriers	33.9%	11.3%	10.2%	8.0%
4	En-route climb >1500ft	Effective situational awareness and/or see and avoid	ATCO provides effective service	ATCO implements effective resolution	ATCO detects potential pilot or controller induced conflict
	347 unsuccessful barriers	15.9%	12.1%	9.2%	8.1%
5	En-route descent to	Effective situational awareness	ATCO provides effective	ATCO implements effective	Flight crew observes visible aircraft

[4] Note: The data on successful barriers was more limited in the reports and not all occasions of successful ATC services were recorded.

Flight Phase		Top 4 unsuccessful barrier components			
	1500ft	and/or see and avoid	service	resolution	in time
	334 unsuccessful barriers	19.8	12.3%	10.2%	6.9%
6	Airfield instrument or radar pattern	Effective situational awareness and/or see and avoid	ATCO provides effective service	Effective airmanship skills	Flight crew observes visible aircraft in time
	476 unsuccessful barriers	17.6%	9.9%	9.0%	6.9%

Table 5: Top 4 unsuccessful barrier components for each of the main phases of flight

Consistent with the taxonomy results, where scan was the primary contributory factor (52.5% of airprox) and situational awareness the third (21.5% of airprox), the main unsuccessful barrier across all phases of flight was 'effective situational awareness and/or see and avoid'. In level cruise, the second most common element in the taxonomy 'airmanship' (24.8% of airprox) is also the second most common component in the barrier model to be unsuccessful. In this instance, poor airmanship was often attributed by the UKAB to not paying due regard to other airspace users by flying too close to another aircraft or aerodrome/launch site. When considering the level of risk, it is worth noting that a failure to observe the other aircraft in time accounts for 7.4% of the unsuccessful components in level cruise.

In the visual circuit see and avoid and airmanship are also the most prevalent unsuccessful barriers. In this instance poor airmanship was often linked to poor navigational skill as aircraft flew too close to those operating in a visual circuit. Another common example was poor application of procedure where pilots did not follow the correct joining method for the visual circuit.

In the low-level cross country phase of flight where less use was made of ATS, the top four unsuccessful components were all attributable to the pilot recovery barrier of see and avoid.

In the en-route climb >1500ft, en-route descent to 1500ft, and airfield instrument/radar patterns UK FIS was recorded as being a particularly successful component (4^{th}, 1^{st}, 2^{nd} respectively). However, the ability of the ATCO to provide an effective service was the second most unsuccessful component across these phases of flight. This was due, in part, to human factor incidents (226 occasions) where the controller did not perform as well as may have been expected. This included the provision of UK FIS such as poor coordination, planning or late avoiding action. The other main aspect of service delivery accounting for this unsuccessful component was late, inaccurate, or incomplete traffic information (231 occasions).

4.10 Risk Category contributory factor analysis

Using the three main risk categories (A-C), it was possible to assess the relative impact of the top 15 contributory factors.

Thirteen percent of the airprox reports (238) were assessed as Category A, thirty percent Category B (546), and fifty three percent Category C (964). By normalising the results, it was possible to gain a better understanding of the relative impact of the contributory factors within each risk classification (A-C), the results of which are in Table 6 below. The un-normalised results are depicted in Annex F.

	Risk category		
Contributory factor	**A**	**B**	**C**
Scan (pilot)	79%	75%	35%
Situational awareness (pilot)	29%	25%	18%
Airmanship	21%	25%	27%
Conflict geometry	27%	21%	9%
Conspicuity	16%	17%	7%
Traffic information ATC-Pilot	13%	15%	13%
Field of view	11%	14%	12%
Distraction (pilot)	15%	13%	5%
Inaction (general) (ATC)	12%	11%	4%
Low flying	15%	10%	16%

Table 6: Relative impact of contributory factors for each risk classification (A-C)

From the results there appears to be little difference between the contributory factors and the level of risk between categories A and B. However, there are some noticeable differences in risk category C. This allows us to assess the specific contributory factors which are more likely to result in Risk Category A or B, compared to those which are as likely to result in Risk C, and therefore deduce the contributory factors which, if present, are likely to lead to greater risk.

Where poor scan is a contributory factor, there is a significant increase in the level of risk regarding the outcome. Likewise, but to a lesser extent, when poor pilot situational awareness is a factor, this increases the level of risk. What is particularly noticeable is the impact of conflict geometry and conspicuity on the level of risk. Conflict geometry and visual conspicuity are both linked with an ability to successfully acquire the other aircraft and clearly have a big impact on risk. Pilot distraction also had an impact on pilot scan so again there is a corresponding impact on risk. An error or omission by ATC also appears to have an impact on the level of risk.

Conversely, whilst poor airmanship is a significant factor in terms of airprox contributory factors, it doesn’t appear to influence the level of risk across the categories to the same extent as those factors influencing scan. The same can be said for traffic information passed from ATC to the pilot. Inaccurate, incomplete, or late traffic information may be a contributory factor leading to an airprox, but it does not appear to impact the level of risk to the same extent. Finally, low flying activities may be a contributory factor leading to an airprox but the activity in itself does not influence the level of risk across the categories. This is not to say that these factors don’t, in some situations, lead to incidents of high risk (Risk A or B), just that this contributory factor is as likely to result in Risk C as Risk A/B, and therefore is not as inherently risky as other factors which, if present, are more likely to result in Risk A/B.

5 Key conclusions and discussion points from the analysis

5.1 See and avoid

See and avoid is presently the primary method of preventing a MAC in Class G airspace and its effectiveness is fundamental to the success of the pilot tactical control and pilot recovery (visual warning) barriers.

> *"The Board emphasised that the responsibility to 'see and avoid' remained, no matter what the flight conditions or whether the flight was operating under VFR or IFR" (Extract from Airprox report)*

A failure to see conflicting traffic is the primary causal factor attributed by the UKAB (19.4% of reports) followed by late sighting of traffic (16.4% of reports). There are several areas identified in the taxonomy which may impact a pilot's ability to successfully detect other aircraft and therefore the effectiveness of the pilot tactical control and pilot recovery (visual warning) barriers.

Given that these two barriers may be the only tactical and recovery barriers present and that a failure to visually acquire the conflicting aircraft would lead to a failure of both, it is worth considering the effectiveness of see and avoid in more detail.

Pilot scan is the contributory factor from the taxonomy which most closely associates with 'see and avoid' and a failure in pilot scan was a factor in 52.5% of the airprox reports, twice as frequent as the next most common contributory factor, airmanship (23.8%). This study has found that the ability of a pilot to scan effectively is impacted by a range of factors, including; factors impacting situational awareness, distraction, field of view from the aircraft, the conflict geometry of the encounter, the visual conspicuity of the aircraft involved, terrain screening and environmental conditions. These factors are all explained in more detail below. Interestingly, weather conditions were not found to have a significant impact on pilot scan.

5.2 Situational awareness

Situational awareness was the largest contributory factor (25.3%) occurring in conjunction with pilot scan. This was not just a failure of the pilot to maintain awareness of their surroundings, but also a failure of others to help build a full picture of the dynamic environment.

Effective communication by both pilots and controllers played a significant role in enhancing situational awareness. In the visual circuit where no aerodrome service was available, effective position reporting was crucial in maintaining the safe and orderly flow of traffic. A lack of accurate and timely position information quickly degraded the situational awareness of those in the circuit. Of note was a lack of communication between aircraft when they were unsure of another aircrafts position or intentions.

Away from the visual circuit 30% of those involved in an airprox were either not in any form of radio contact or were 'listening out' on a frequency. Whilst perfectly compliant with the regulations [5, 6], this practice does little to enhance the situational awareness of other aviators or providers of ATS. This was particularly evident when aircraft were not in radio contact when in close proximity to an ATZ or when transiting through airspace where a Procedural Service was being provided. Furthermore, those pilots not in radio contact or listening out did not receive information on other aircraft that may have been in close proximity.

It was noted that many gliders are fitted with radios and that frequencies are allocated by the CAA for glider operational usage. These frequencies are specifically allocated such that an RT licence is not required in order to use them. However, this resulted in the situation where glider pilots had used a radio for a number of years and could be in a position to influence safety of flight, for example by notifying position and intentions on a local Zone frequency, but did not do so because the lack of an RT licence prevented them from legally using a frequency other than those allocated. The UKAB commented that the effort and cost of obtaining an RT licence, when there was no mandated requirement to obtain one, was an effective deterrent to glider pilots.

Even for ATS providers utilising surveillance information, a call on the radio could enhance awareness of position, altitude, and intentions. A pilot does not have to be in receipt of an ATS in order to improve the situational awareness of those around them and could listen out on the frequency following the initial transmission of intentions. Pilots would still need to be clear as to whether they were requesting an ATS or passing information useful for the safe conduct of flight.

Where an ATS was provided, the controller was sometimes able to enhance the situational awareness of the pilot through the provision of timely and accurate traffic information. As mentioned in Section 4.4, additional information that aids the pilot in building a mental picture can prove to be particularly effective. Those providing a BS had no obligation to pass warnings of other traffic [4] other than under a duty of care. However, the timely notification of other aircraft activity in the vicinity plays an equally important role in aiding situational awareness and ultimately facilitating the pilot in the detection of potential conflicts.

It was evident in the reports that when faced with difficulty acquiring other aircraft or in areas of high traffic density, pilots were often slow to upgrade the ATS, even temporarily. This was particularly the case for those operating on a BS. Where meteorological conditions may influence the level of ATS requested, equally the prevailing risk, such as traffic density or high workload may need to have a similar effect. Consideration as to the appropriate ATS for a particular phase of flight or geographical region should take place as part of the pre-flight planning process.

It was apparent that the aircraft operating within Class G airspace had gradually been fitted with ACAS over recent years (Figure 11) and that GA aircraft were more recently adopting traffic alerting systems. These systems may enhance situational awareness prior to a conflict developing although there were some limitations in how the information was presented to the pilot. Nevertheless, their uptake not only ensures that a recovery barrier is present (ACAS), but also aids pilot tactical control through enhanced situational awareness.

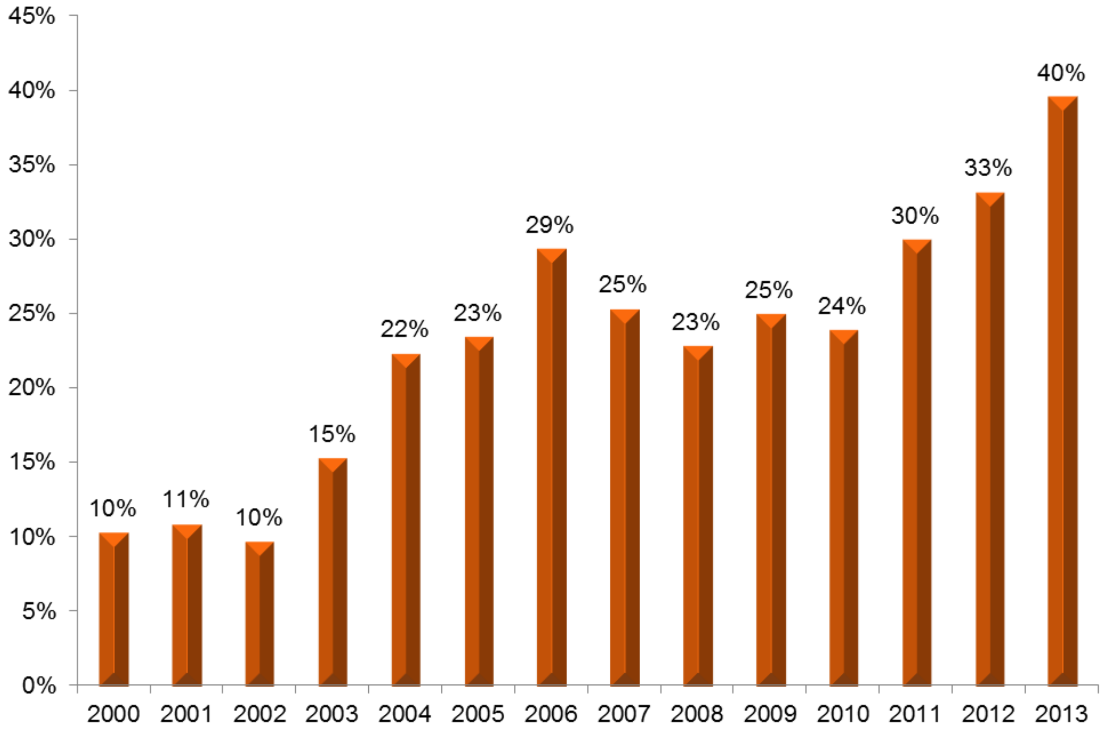


Figure 11: Percentage of aircraft fitted with ACAS[5]

What is interesting about Figure 11 are the three step changes in equipage in 2003, 2007 and 2011. The rise in 2003 may be linked to the initial take-up of ACAS. Then the dip and stabilisation in 2007 may be linked to the recession and pilots not equipping due to the expense of fitting ACAS. Finally there has been an increase in equipage from 2011 onwards which may be due to recovery after the recession and the reduced cost of equipment. Another influence on the statistics is the increase in CAT operating in Class G airspace which are fitted with ACAS.

In sum, anything that enhances the situational awareness of pilots and those providing ATS will strengthen the risk mitigation of those barriers and aid the most important barrier of see and avoid.

5.2.1 Distraction

Distraction often occurred at the same time as issues with pilot scanning (88% concurrence), implying that it was distraction which impacted pilot scan. A pilot can be distracted by a multitude of things, and some of the common examples evident from the airprox reports as impacting effective scanning include:

- Fixating on just one aircraft that is in the vicinity;
- Focusing attention on the ground such as during final approach or conducting photography/surveys;
- Navigation, particularly in complex airspace;

[5] Percentage of aircraft fitted with ACAS in the data sample

- Focusing on instruction within the cockpit;
- Changing frequency, transponder code, or inputs to other flight systems;
- High workload tasks;
- Military training with a requirement to identify a target on the ground or monitor a 'threat' aircraft.

These are all routine activities that create distraction either inside or outside the cockpit. The question is what is a reasonable amount of time between effective scan patterns? It was evident from the reports that some slow aircraft found it challenging to take effective avoiding action against a fast moving aircraft even when sighted with 30 seconds or more before the closest point of approach (CPA). Fast moving aircraft approaching each other head on also left little time to visually detect and react. In one example the pilot sighted the other with 20 seconds to the CPA and still overstressed the aircraft with the avoiding action manoeuvre. Finally, although the number of CAT involved in the airprox sample was relatively low, it was noted that some were limited in their ability to manoeuvre quickly in the event of a late sighting and that some pilots reported disengaging the auto pilot before commencing a turn.

Where tasks do require frequent heads within the cockpit time, it would be beneficial to have other barriers in place such as some level of ATS. This was frequently noted by the UKAB in their assessment and an analysis could be made of the effective uptake of such advice (i.e. what percentage of operations requiring heads-in time use a TS or DS, when available?).

5.2.2 Field of view

A pilot's field of view, and hence scan, may be impacted by the design of the airframe with many operators citing known issues with particular aircraft. This ranged from wing configurations to cockpit design. Some fixed-wing CAT have a particularly limited field of view. Strategies to counter these limitations were frequently evident; however, some conflicts developed very quickly which left minimal time to detect the threat, particularly if it was screened by a section of the airframe.

Use of night vision devices may also impact the pilot's field of view and depth perception and it was noted that some limited their use to during the operational task as opposed to in the transit phase of flight. Additionally, some crews elected to keep one member without any devices to provide an alternative visual perspective.

The use of 'IFR' screens to restrict the field of view of those under training was noted as was the potential for them to limit, to a lesser extent, the field of view of the instructor.

A restricted field of view was a contributory factor in 8.6% of the airprox reports and 89% of these occurred at the same time as issues with the pilot scanning effectively.

5.2.3 Conflict geometry

Conflict geometry occurred in 15.4% of the airprox reports and 75% of these occurred at the same time as issues with the pilot scanning effectively. It was noted that aircraft on conflicting trajectories that had minimal variation in their relative bearings, were more difficult to acquire. This was often due to the relative lack of motion which may be compounded by conspicuity issues. Conflict geometry issues also included aircraft approaching each other on reciprocal headings which significantly reduced the time to detect and react.

5.2.4 Visual conspicuity

Visual conspicuity was a factor in 11.1% of the airprox reports and 81% of these occurred at the same time as issues with the pilot scanning effectively. Furthermore, conspicuity was linked with conflict geometry on more than a third of occasions. Light aircraft and gliders may produce a small cross section to those approaching from head on, behind, and potentially those at the same level. Colour schemes that had little contrast to the background and the lack of lighting on some aircraft also made them more challenging to detect. It was noted that some pilots of aircraft with low conspicuity made deliberate manoeuvres to improve their cross sectional area that was visible when they were aware of others in close proximity. The nose light in the Hawk aircraft was noted as being particularly effective at aiding visual conspicuity including some situations when the aircraft was on a constant bearing.

5.2.5 Terrain screening

Low flying was a contributory factor in 8.3% of the airprox reports and 68% of these occurred at the same time as issues with the pilot being able to scan effectively. In a third of the airprox where low flying was a factor, terrain screening was also a factor. Or to turn it around, when terrain screening was a factor, low flying was also a factor 79% of the time. Terrain screening had the impact of limiting the available area that could be scanned effectively and ultimately reduced the time available to detect and react to a confliction. In an extreme example a Hawk and GR9 were head to head with a closing speed of 840kts; due to terrain the earliest they were able to see each other was about 1nm range. This provided approximately 4 seconds to detect and react. No other tactical or recovery barriers were present at the time.

5.2.6 Environmental conditions

Flying towards the sun makes visual scanning more challenging and there are examples of good airmanship where the pilot had adopted a different heading to improve see and avoid. However, the possibility of a conflicting aircraft being lost in bright conditions remained. Light conditions were a contributory factor in 4.4% of the airprox reports; however, not all of these would necessarily have been attributable to bright conditions.

At night the challenge, particularly at lower levels, was to differentiate aircraft lighting from the ambient lighting on the ground.

5.2.7 Impact of poor weather conditions

What was evident from the data was that poor weather appeared to have little impact on these events with less than 5% of aircraft involved in the airprox reporting flying in IMC. Additionally, the weather elements such as poor visibility and precipitation in the taxonomy appeared to have no correlation with effective scan. From the data it can be deduced that flying in good visibility clear of cloud is not an effective barrier in itself unless an ability to scan effectively is also present. However, as discussed above, there are many reasons that may hinder a pilot's ability to maintain an effective scan. It would seem prudent that the level of ATS should not be based solely on things like in-flight visibility and should take account of things like task complexity, airspace, and level of risk on the projected route.

5.2.8 Collective failure of see and avoid

The issues above are well known across the majority of the aviation community and taken in isolation there are strategies to minimise their impact on see and avoid. For each airprox there were at least two pilots involved[6] so as long as at least one was able to maintain an effective scan then some mitigation was in place to reduce risk. However, on 55% of the occasions where an ineffective scan contributed to an airprox, it was attributed to both pilots. Of these, 27% were linked to conflict geometry and 24% to poor situational awareness (13% where both pilots had poor situational awareness). Conspicuity occurred in 20% of occasions when both pilots had an ineffective scan (usually just one aircraft as opposed to both) and 19% had a restricted field of view.

It is clear that issues with see and avoid are not limited to effective scanning technique and that there are many factors which can make visually acquiring other aircraft more challenging. As long as one pilot is able to visually acquire the other in enough time to react then it is effective, however it is clear that there are instances where this barrier fails for both pilots. Therefore it may be worth considering whether, in certain situations, it is advisable to have at least one other barrier present.

5.2.9 Mitigating risk Availability of the barriers

When considering how to manage risk in Class G airspace more effectively, it is useful to utilise the barrier model (Annex B). Due to the nature of the barriers and the spectrum of variables associated with operating in Class G airspace, none of the barriers in isolation are 100% effective at preventing a MAC. Indeed, human factor issues alone would prevent any of the barriers being completely successful.

There are up to 4 main barriers that prevent a hazard of two aircraft operating in the same area from developing into a conflict. Should these barriers fail, there are up to 3 recovery barriers that prevent a conflict developing into a MAC. Although one impenetrable barrier is far more effective than multiple leaky barriers, this analysis has shown that all the identified barriers are subject to failure and so having more barriers present in addition to strengthening them would likely reduce the chance of having a MAC.

Aircraft equipped with ACAS[7] and in receipt of a DS have 7 barriers that help prevent the occurrence of a MAC (Figure 12). Importantly the ACAS

[6] The operator of a model aircraft may be the other 'pilot'.

[7] Assumes the threat aircraft is fitted with a serviceable transponder and that it is switched on.

and DS both have the potential to aid a pilot's situational awareness and therefore make the pilot tactical control barrier more effective.

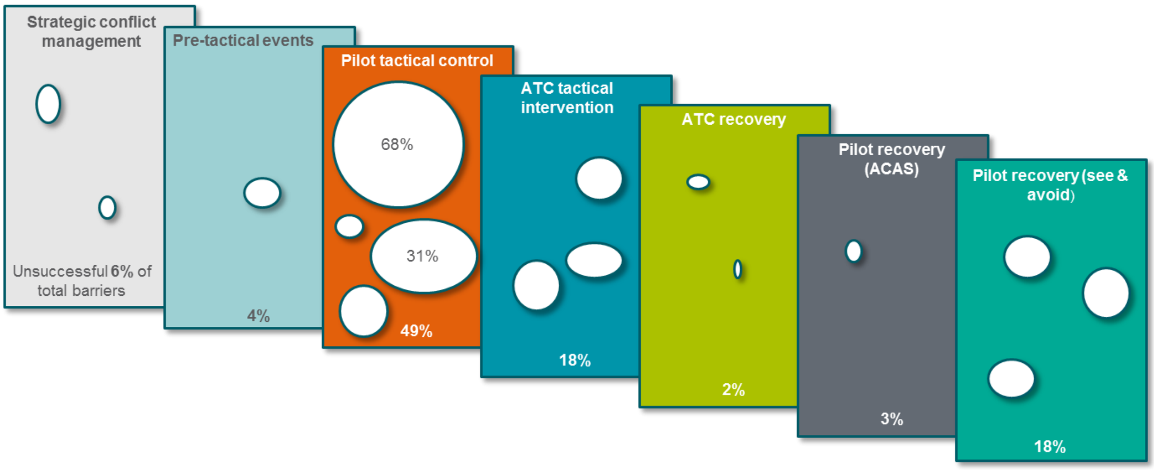


Figure 12: All available barriers preventing a MAC

As 77% of aircraft in the database (60% as at 2013) were not equipped with ACAS, this frequently reduced the number of barriers available to 6 (Figure 13). Furthermore the lack of an ACAS display and traffic alerts had the potential to reduce pilot situational awareness and therefore there could be a corresponding reduction in the effectiveness of the pilot tactical control barrier.

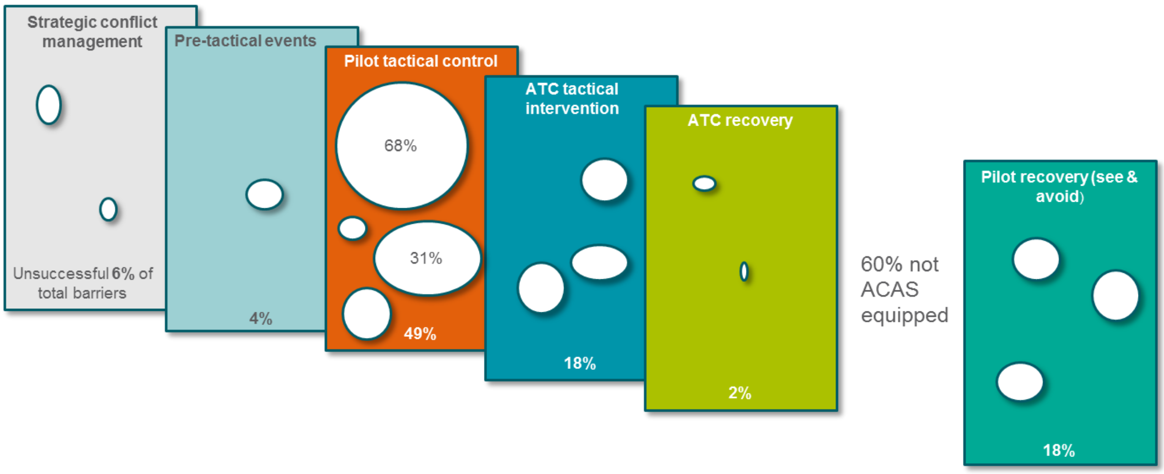


Figure 13: Barriers present when ACAS is not available or threat aircraft is not transponder equipped

The ATS selected by the pilot impacts the level of mitigation within the ATC tactical intervention barrier. This is also true for the ATC recovery barrier where those under a TS or BS will not be provided with avoiding action instructions once a conflict has developed. This reduces the number of recovery barriers to one (Figure 14).

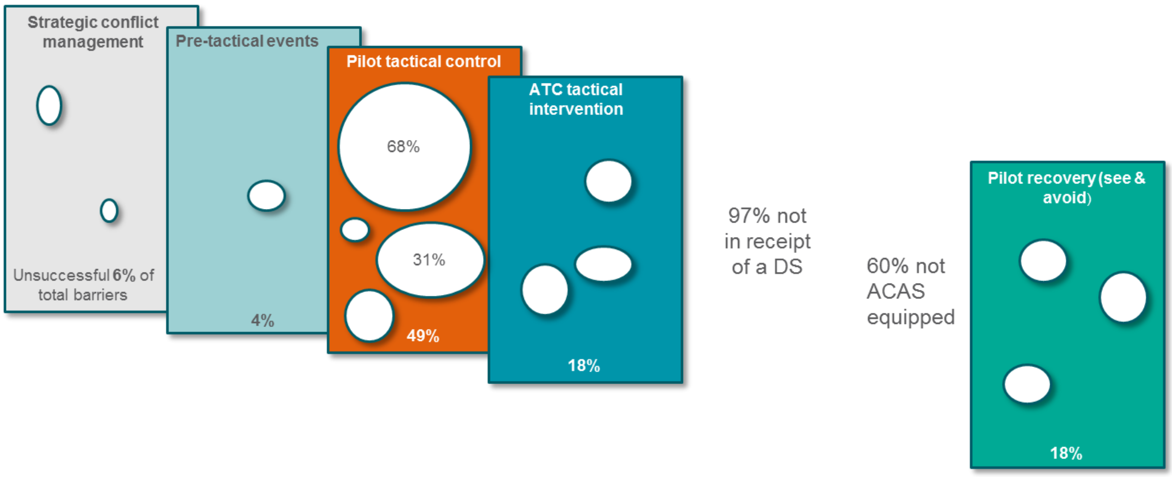


Figure 14: Barriers available without ACAS or a Deconfliction Service

Another influence on the effectiveness of the ATC barriers was the availability of ATM equipment, particularly surveillance information, which significantly enhances the situational awareness of the controller. The loss of primary surveillance radar reduced the effectiveness of the ATC barriers in areas where aircraft were operating without transponders.

For those aircraft not equipped with any form of ACAS or in receipt of UK FIS (approximately one third of all airprox), there were only 4 barriers aiding the prevention of a MAC (Figure 15).

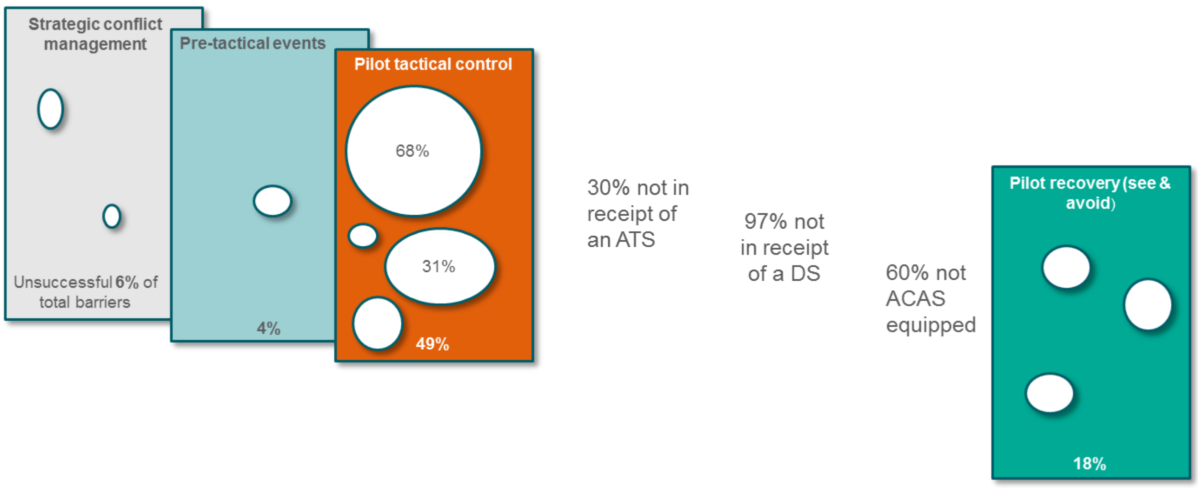


Figure 15: Barriers available without ACAS or ATS

Once in the air, pilot tactical control and pilot recovery are the remaining barriers. However, there are several variables that make effective see and avoid more challenging. Also of note was the absence of other barriers which can enhance a pilot's situational awareness and ability to see and avoid, meaning that the remaining barriers may not be as effective as when this information is available. Therefore not only has the number of barriers reduced, but the effectiveness of some of those remaining is also reduced.

Cat A reports accounted for 13% of the airprox and this provides an indication of the frequency of when all barriers were unsuccessful. However, utilising the findings from the barrier model analysis, the pilot did not see the conflicting aircraft in sufficient time to take effective avoiding action in 19% of the airprox. In 2% of the airprox ACAS was successful in preventing a MAC but neither pilot was visual with the other aircraft. This means that *all barriers were unsuccessful in 17% of the airprox*. The discrepancy between the UKAB Cat A figure and the barrier model analysis is explained in Annex G.

Given the importance of see and avoid as the primary mitigation against MAC in Class G airspace and the limitations highlighted in this paper, it is worth questioning if this barrier is sufficiently robust when no other tactical or recovery barriers are available, and if in certain situations it is advisable to have at least one other barrier present. When operating with minimal barriers, it is useful to consider what factors may degrade their effectiveness and, where available, opt to increase the number of barriers where possible.

5.3 Using the analysis

The primary scope of this study was to analyse the airprox reports and determine the specific contributory risk factors that increase the likelihood of a MAC within Class G airspace. It was not within the scope of the study to determine any specific courses of action but some recommendations on the management of incident data are made in Annex G.

From the analysis it can be determined that human performance plays a crucial role in why things go wrong with human factors accounting for 69% of contributory factors. The most significant human factor in this study was pilot scan and the stage (if at all) that the pilot was able to visually acquire the other aircraft had an important bearing on the severity of the outcome.

Under existing regulations [5, 6] an aircraft does not have to be equipped with a radio, transponder, or ACAS to operate in Class G airspace. Therefore see and avoid remains the prime means of collision avoidance and the findings from this study will naturally lead to increased focus on pilot scan. However, *it is not sufficient to tackle pilot scan in isolation* as there is a complex interaction between other contributory factors that influence a pilot’s ability to see other aircraft. Figure 16 provides an overview of some of the key interactions that may impact a pilot’s ability to visually acquire other aircraft.

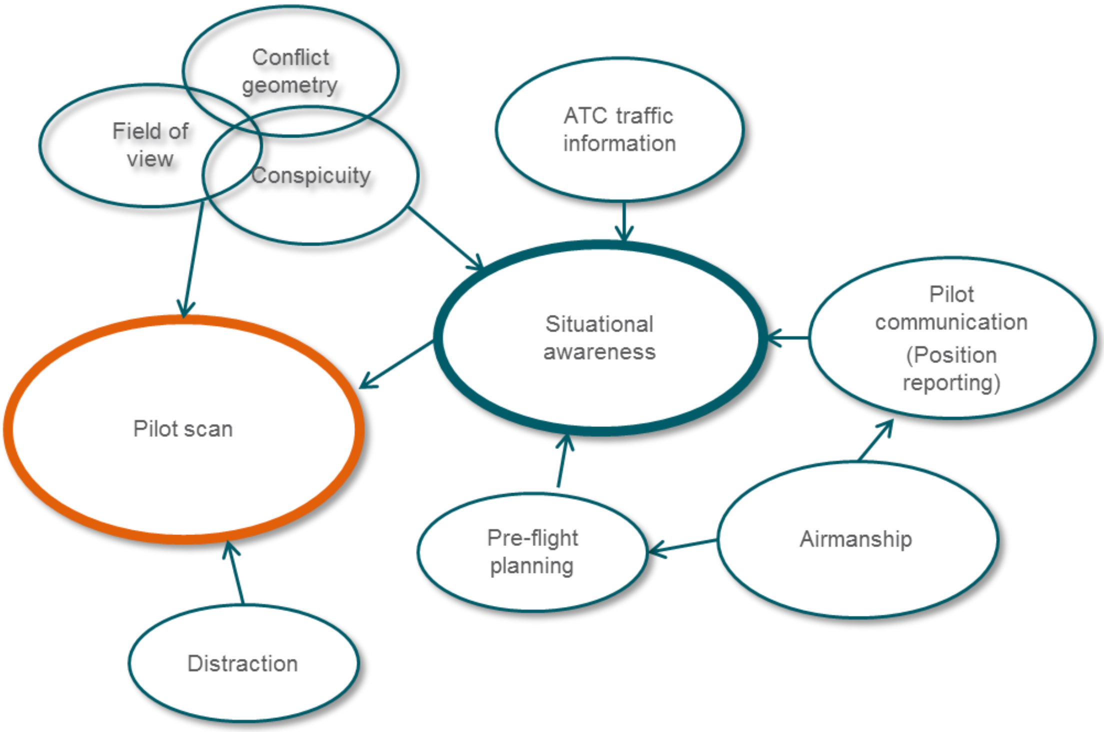


Figure 16: Interactions between key contributory factors that impact pilot scan

A pilot may have excellent scanning techniques but a combination of conflict geometry, field of view, and conspicuity may make it incredibly difficult to visually acquire another aircraft. Furthermore, it is clear that a pilot's situational awareness of the proximity of aircraft around them significantly enhances the likelihood that the pilot will consciously scan and acquire them.

The barrier model is useful to illustrate the components and their relative strengths and availability but it has its limitations in that it depicts a linear combination of failures. However, the events did not develop in any pre-defined sequence such as those used in event and fault trees. *Instead the airprox occurred due to unexpected combinations of factors that occurred in a non-linear sequence.*

A more systemic view of the interaction between the contributory factors is required as it is the combination of factors occurring together that leads to an incident. A greater appreciation for both pilots and controllers of the system as a whole will have more of an impact than focusing on a specific contributory factor. A greater understanding of how their actions influence the number and strength of the barriers is likely to prove more beneficial than targeting education in a few selected areas. Some thought on how this can be achieved are contained in Section 6 on leading indicators.

6 Leading Indicators

Before identifying leading indicators, the validity of the approach and metrics must be ascertained. The first part of this section therefore discusses the argument for leading indicators, and why multiple indicators (with links to contributory factors) should be used.

The second part discusses possible indicators within the context of the airprox report analysis. The framework could be used for other risk-indicator relationships.

6.1 Assessing safety

The current ICAO definition describes safety [7] as:

"The state in which the possibility of harm to persons or of property damage is reduced to, and maintained at or below, an acceptable level through a continuing process of hazard identification and safety risk management"

The method of determining the "possibility of harm" has traditionally focused on extrapolating trends for metrics of harm being caused or nearly caused – i.e. accidents or serious incidents. In other words, a focus on the number of occasions things have gone wrong. As with this study, it is useful to identify the contributory factors to the incident in order to gain an understanding of the risks and reduce their impact in the future by improving the barriers. On the other side, this data also shows us where barriers were successful in preventing the incident becoming any more serious, thus reducing the possibility of harm.

A focus on major accident and incidents over a long period of time certainly provides a useful amount of data on successful and failing elements of the wider system, which could in theory be extrapolated forwards to give an indication of likely future levels of risk (all other things remaining equal).

However, the recorded occurrences, even including minor incidents, only account for a small proportion of the overall number of flights. What is less well understood is what has gone well or successfully in the majority of circumstances. It is very difficult to

a) Collect the data at such a detailed level, and

b) Understand the exact factors contributing to things going well.

The relatively small amount of airprox reports makes it difficult to assess, with any statistical significance, the impact of any safety initiatives whilst relying on this data alone. This makes it more challenging to allocate resources to where they can have the greatest effect. Another issue in determining which safety initiatives are best to implement is that it is rare (1.7% of airprox) for a single factor to lead to an incident. In this study there was an average of 5 contributory factors for each incident. The analysis in Section 5 demonstrated that these factors are interrelated and often combine to impact more than one barrier at a time. Dealing with contributory factors one by one may not necessarily be the optimum way of improving safety.

Components within the barriers work together as part of an overall system. People interact with each other and with the equipment and their behaviours are underpinned by robust procedures and appropriate training. It is difficult to define the boundaries of such a system as some parts like the organisations and economic or operational pressures are less visible.

A focus on individual barrier components therefore becomes less effective with increasing system complexity. When considering changes to a specific component it is necessary to take into account the wider impact on the system as whole. Hollnagel's functional resonance model [8] develops this theory more for a variety of systems. Whilst not providing a quantitative link, the model allows an understanding of the inter-relationships in a complex interactive system.

6.2 Concept of operation versus operational reality

A concept of operation explicitly describes the 'system' and how it is expected to perform given the technology, people and procedures in place. The airborne and ground technology is getting increasingly more complex, interrelated and interdependent, including interactions with humans. Due to this complexity it is becoming progressively more challenging to describe a specific concept of operation that, when operating as envisaged, ensures safety is maintained.

It is hypothesised that it is not possible to specify procedures and provide training that will account for every scenario that may be faced by pilots and controllers. The human must be flexible enough to adapt to a range of equipment modes and variations in the operating environment. Therefore, the operational reality (work-as-done) is rarely completely in line with the concept of operation (work-as-imagined).

Considering the distribution of contributory factors in the airprox reports, 69% are attributed to individual/human factors. It would therefore be easy to view the human element in the system as a liability. However, it is these same humans who are able to adapt their behaviour to ensure the work-as-done is performed reliably in the majority of occasions. Focusing on human error within incidents is not sufficient on its own as it does not explain why human performance usually goes right. A greater understanding of the operational reality, what is actually happening in the aircraft and on the ground, and why things usually go right will help ensure that these behaviours are repeated in the future. As systems become more complex, human adaptability will become ever more important for successful performance.

6.3 Human performance

When assessing the effectiveness of the barriers for each airprox report, there was usually a mix of barrier components that were successful and unsuccessful. In terms of human performance their contribution to an unsuccessful barrier can be viewed as being part of their everyday variation in performance levels rather than being a unique, individual occurrence. Unlike certain hardware components which may either be working or fail completely (binary performance), human performance is variable along a continuum over time. In Figure 17 the blue bars represent human performance the majority of the time, where although not 100% perfect, it is sufficient to ensure safety. However, occasionally human performance may drop below the level required due to workload pressure, inadequate training, or experience-related factors. This may be a contributory factor in an incident or, potentially, have no impact on safety at all due to other contextual elements (e.g. no traffic nearby).

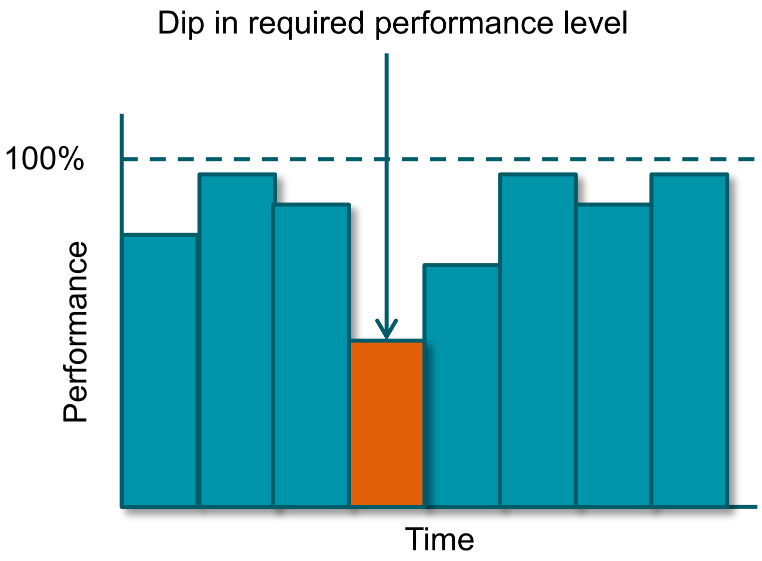


Figure 17: Variability in everyday human performance

Rather than focusing on a specific occurrence where a barrier was unsuccessful, the emphasis here is to ensure key indicators reach a certain level more of the time and that as a result, there are fewer dips in performance levels. It is consistency (or reduced variability) to a certain level which is key, rather than 100% performance.

6.4 Common activities

Safety activities need to be proactive to ensure common activities are performed as expected more of the time and interventions are made before an incident occurs. At present, a system is deemed to be unsafe if adverse outcomes occur yet it is equally important to understand *how* it is safe when things go right. Safety in this instance is defined by what happens when it is present, rather than by what happens when it is absent, and is thus directly related to the high frequency, acceptable outcomes (routine day-to-day performance) illustrated in Figure 18.

According to this theory, the greater the number of successful barrier components there are, the higher the level of safety is and vice versa. These barrier components must be shown to be linked to the end outcome; this can be done by analysing contributory factors to the end outcome (both positive outcomes and negative outcomes), and understanding what mitigates poor performance.

It is not thought necessary at present to understand the detailed relationship in terms of how the performance of each barrier component leads to the end outcome. It is enough to know the barrier components and the fact they may 'resonate' with each other to create the end outcome; in other words, poor performance in one component can easily lead to other components showing poor performance where a link can be made.

In time however, it should be possible to identify the priority barrier components; which ones have the most impact on the end outcome. This can be be done through data analysis and extrapolation of contributory factors to successful and unsuccessful outcomes (e.g. airprox, incidents etc.). This helps target measures to improve the performance of certain elements, leading to more cost effective interventions to improve safety.

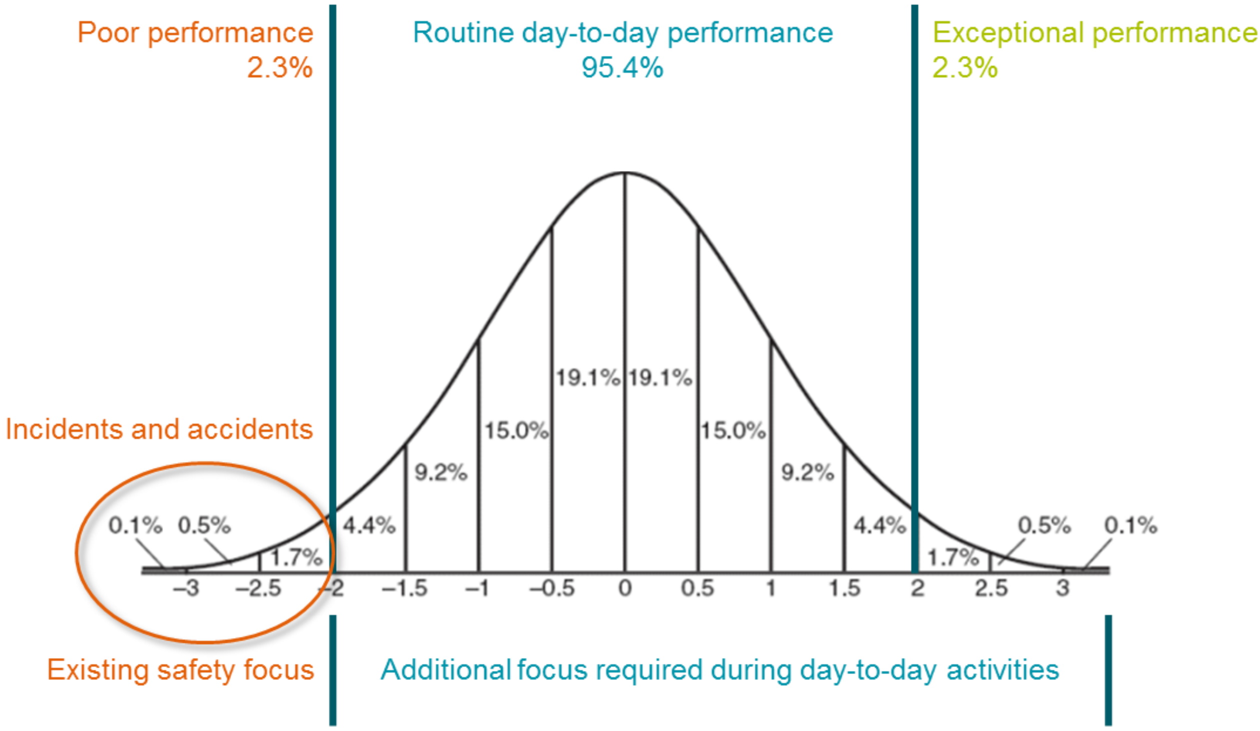


Figure 18: Areas of safety focus

In Figure 18 above, a Gaussian curve is used. In practice, the exact shape may change dependent on what is being assessed. The aim is to move the mean of the data expressed by the curve further to the right, and ideally to reduce variability (standard deviation) such that the tails become longer to the left.

This can be done by changing the activity itself, or by influencing the performance of that activity through training, currency, awareness, and so on. The link between the activity and its influencers may be determined through expert opinion rather than data analysis.

6.5 Role of a regulator

Traditionally, the monitoring of day to day performance of various activities is carried out by the operator; either the human undertaking the tasks, or the manager or organisation overseeing (e.g. aircraft operator or service provider of airport or ANS). For example, if a contributory factor identified was appropriate visual scanning technique, monitoring the day to day performance of that could really only be done by the pilot or ATCO, or those managing them.

Where a regulator could assist is in understanding the elements which typically lead to better performance (moving the curve as described above), and monitoring these. Whilst some of this is already done through training, certification and checks, it is not targeting the barrier component performance specifically.

Figure 19 below outlines the argument being made here:

The measurements that could be made by a regulator do not solely lie at the outcome level. The contributory factors and influencers to those could also be measured at some level. There are of course pros and cons with these measures:

- Outcomes are easier to measure, generally being tangible. However, they are measured after the risk impact has occurred, which is not ideal. We want to try to prevent the outcome in the first place.

- Contributory factors are useful given enough data to show a statistical link to the outcome. As discussed earlier, the model in aviation is not a single causal chain, but rather a group of factors which may react together to reduce performance and cause the eventual risk outcome. By assessing the performance of some key contributory factors, a better understanding may be gained of where to focus efforts or add mitigations in the system. However, detailed factors are difficult to measure if you are not the operator. They tend to need to be collected in real-time. For example, ANSPs and the military may be more able to put in place collection mechanisms; innovation may be needed to understand how to accomplish the same for private pilots.

- The influencers to the contributory factors are more subjective, and thus less easily able to determine whether a change in the influencer leads directly to a change in the risk outcome rate (for example, it will be difficult to judge whether a change in % pilots trained in a certain risk directly leads to a reduction in that risk outcome). However, for a regulator they can be easier to measure than contributory factors. Assessment of training in its various forms can be carried out, including using Analytics techniques available online.

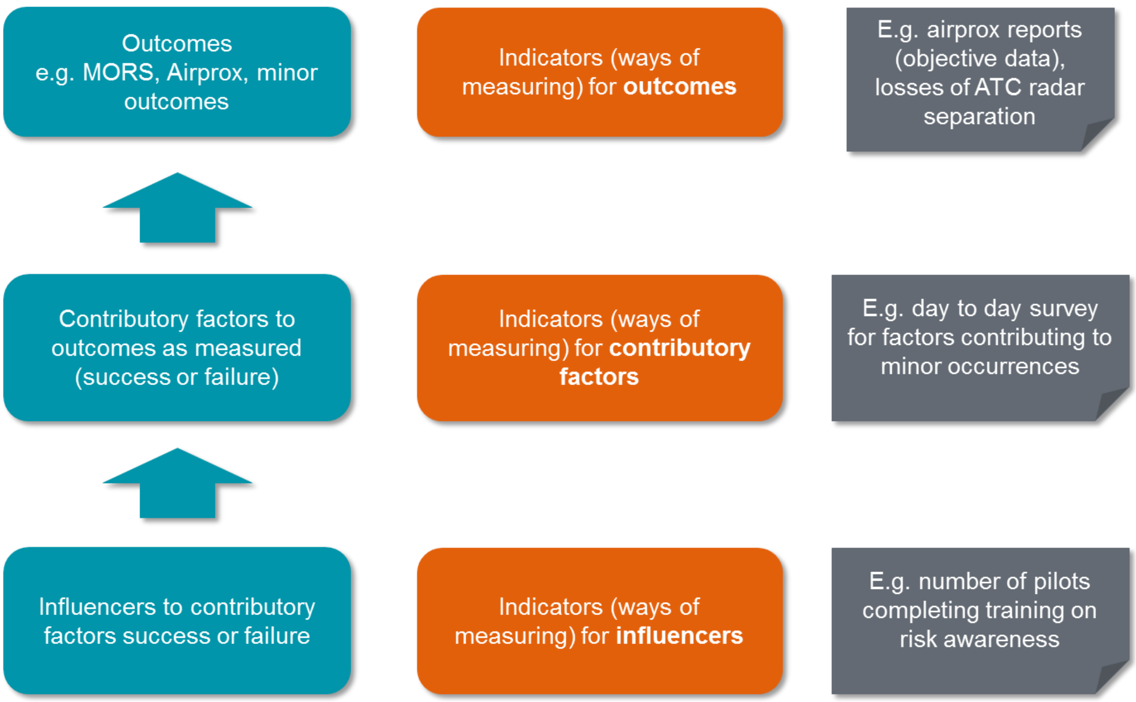


Figure 19: Link between influencers and outcomes

In Section 5 we developed a greater understanding of how the availability and strength of barriers impact the level of risk. Strategic and pre-tactical barriers aside, the unsuccessful components within barriers frequently occurred coincidentally as opposed to sequentially. The initiating event, such as a misheard transmission, would usually be fairly minor, but the level of risk could escalate quickly as multiple contributory factors occurred together. By developing and using leading indicators targeting a range of contributory factors, regulators are able to have a better oversight of work-as-done that will aid the identification of variable performance within each barrier.

It is important to remember that the environment, technology and human reactions to this in the UK airspace are continually evolving, and what works well today may be less successful in the future. Monitoring the actual performance of barrier components will aid the detection of issues as they emerge as opposed to waiting for sufficient incident data to indicate a specific trend. Even though this is usually the operator's remit, it may be useful to understand the impact of certain initiatives on the actual performance (work-as-done).

There are several sources of information that further our understanding of work-as-done. Currency and standards checks provide excellent information on work-as-done and the monitoring and sharing of lessons identified is a powerful tool. The use of safety surveys that consider a specific area of operations is also of benefit to increasing our understanding of why routine activities go well. However, a safety survey that looks at extant procedures must look at *how they are actually being applied* in addition to assessing how robust the actual procedures are.

6.6 Lagging vs Leading indicators

Leading and lagging indicators are two different methods for identifying safety concerns. A leading indicator gives a signal before an event or trend has occurred whereas a lagging indicator gives a signal after the event or trend is seen. The role of leading indicators in safety is to "*improve future performance by promoting action to correct potential weaknesses without waiting for demonstrated failures*".[8] It is an indicator which changes prior to the outcome indicator already being monitored (i.e. the lagging indicator). For example airprox occurrence and risk is being monitored, but what are the indicators which change prior to the occurrence rate/risks changing? These leading indicators could include human factors, as well as organisational, technological and environmental factors.

Accident occurrences are an example of lagging indicators. These are easy to gather data on, can indicate performance trends up to the present, and are an established method with a long history of use. However, with thankfully low occurrence rates it can be difficult to establish trends. They are also prone to bias and are reactive, meaning safety improvements tend not to be made until after serious events.

For leading indicators to play an effective role in performance assessment, there must be a reasonable association between the inputs being measured and the lagging outputs, and confidence that measures to improve the

[8] http://stepchangeinsafety.net/stepchange/News/StreamContentPart.aspx?ID=1517

leading performance indicators will result in improvements to the lagging output indicators.

In economic terms, leading indicators are chronological in nature in the system. For example, if employment level increases in year 1, economists may expect GDP to increase in years 2 and 3 (all other things remaining equal). If the relationship can be verified through data analysis, the use of employment level as a leading indicator can be powerful in decision making.

This economics view of chronology may be more helpful in determining which leading indicators to target – the question becomes *"Which contributory factor performance, if improved, should lead to improved safety levels in the years to come?"*

6.7 Practical application

One reference source [9] described the application of this as follows: "*The purpose of a Leading Indicators Programme is to identify which safety metrics are most strongly associated with safety performance in a particular area. This information can be used to guide actions to improve future safety performance*."

Leading indicators can be particularly useful when assessing the potential for human error or organisational failures. This is because the techniques used for controlling technical failures (e.g. quality assurance, redundancy) are not as relevant in the human performance field. In this study, 78% of contributory factors were attributed to human or organisational domains and so the use of leading indicators is particularly relevant.

Leading indicators can be objective or subjective measures and consider positive or negative actions. The advantage of objective leading indicators is that they utilise metrics that have been collected by the organisation and the analysis is relatively straight forward. The disadvantage is that it does not identify new metrics for collection and may not be suitable to capture the quality of the system in place.

Subjective leading indicator analysis utilises the responses from a safety culture assessment (a survey of the attitude and opinions of those involved). The advantage of this is that it may give rise to new metrics that were not previously collected and can be used even if no metrics have been collected. The disadvantage of this is that it requires a safety culture assessment and the responses require conversion into suitable metrics which even then are still subjective, making them difficult to quantify.

6.8 Identifying leading indicators

There is a large amount of information in the current safety literature across safety critical industries about the theory and value of leading indicators but very little about their practical application, particularly within aviation. As the interaction between people, equipment, and environment is complex it is difficult to determine a clearly defined process as to how leading indicators should be identified.

For the purposes of this study we have followed the following stages in order to develop a series of leading indicators:

- Identify the barriers that prevent a MAC (Task 1);
- Identify the key elements (people, procedures, equipment) required for the barriers to be available and successful (Task 1 validated during Task 2);
- Determine metrics that will monitor the availability and/or functionality of those key elements (Task 3 – this chapter).

6.9 Determining the metrics

In order for the metric to be of value there must be a direct traceable link between the leading indicator and the function it is monitoring. The value of a leading indicator is how close it relates to the barrier that it is monitoring.

The leading indicator must be measurable even if for some metrics it may be more appropriate for aircraft operators and service providers to collect the data. The metrics employed should be reviewed and changed as necessary to cater for changes to people, procedures, environment, and hazards.

A small set of meaningful leading indicators that have a direct relationship to the work-as-done is more useful than a multitude of metrics without clear focus.

6.10 Proposed leading indicators

In order to focus the formulation of an initial set of leading indicators, it is useful to consider which key factors have the greatest impact on the availability and strength of the barriers. As a starting point we will consider the equipment, human, and procedures that influenced the most prevalent contributory factors.

<u>Equipment</u>

Aside from a system to provide aeronautical information such as NOTAMs to airspace users no other CNS-ATM equipment needs to be in place[9] for a flight to take place. It is not generally mandatory for an aircraft to be equipped with a radio, transponder or any form of collision avoidance system when flying in Class G airspace in the UK. However, the availability and use of equipment has a direct impact on the number of barriers that are present and their overall effectiveness. In Figure 20 below the availability of radio equipment is required for ATC tactical intervention and ATC recovery barriers to be present. A radio in the aircraft also strengthens the pilot tactical control barrier by aiding such things as airmanship, awareness, and enabling the use of an ATS.

[9] Regulations may state otherwise in specific circumstances or areas.

Barrier	Equipment			
Strategic conflict management				
Pre-tactical events	Effective briefing system			
Pilot tactical control	Radio	ACAS/TAS/FLARM	Transponder	Internal surveillance
ATC tactical intervention	Radio	Surveillance information	Transponder	
ATC recovery	Radio	Surveillance information	Transponder	STCA
Pilot recovery (ACAS)	ACAS	Transponder		
Pilot recovery (Visual warning)				

Required for barrier to be present
Strengthens the barrier

Figure 20: Impact of equipment on barrier availability and effectiveness

There is therefore a case for considering the inclusion of leading indicators which address the rate of equipage for various CNS airborne technologies, where the availability of individual technologies appears to impact the overall risk levels from the data.

The availability of transponders is only essential for the pilot recovery (ACAS) barrier to be present. However, the presence of transponders has the potential to strengthen three other barriers. For pilot tactical control, a transponder is required for some forms of collision avoidance systems in order for them to provide an initial warning of traffic. Depending on the use of appropriate surveillance display equipment in the aircraft (e.g. graphical display or aural warning of surrounding aircraft) a transponder may also aid situational awareness via this equipment. For ATC tactical intervention and ATC recovery barriers, transponders significantly enhance a controller's situational awareness and ability to provide a more effective service to the individual aircraft.

Ground based surveillance information is not required for all barriers to be present at some level. However, it is essential for certain ATS to be available and its presence significantly enhances a controller's situational awareness and this in turn benefits pilot tactical control through situational awareness for the prevention of airproxes. The availability and coverage of different types of surveillance information, such as PSR, SSR, and multilateration, will also impact the strength of the barrier.

Traffic avoidance systems aid situational awareness in the Pilot tactical control barrier and ACAS is essential for the Pilot recovery (ACAS) barrier to be available.

It is for regulators to decide if or how they may wish to influence equipage rates via incentives or policy. Any intervention could be targeted where uptake rates are low or in specific geographical areas to mitigate increased risk.

6.11 Human factors

Whilst the adoption of technology has the potential to bring tangible benefits to the overall safety of the system, it is the people themselves who make the system more resilient. The more people involved in Class G operations understand the whole system and the means by which risks are mitigated (or safety levels enhanced), the greater their ability to adapt performance beneficially in a variety of situations.

This leads to a very general leading indicator which is 'awareness of factors impacting risk levels in Class G'. An increase in awareness should, by common sense, lead to an increase in safety levels.

One method of facilitating that knowledge is to use relevant occurrence reports which can be targeted at specific user groups. This already happens within the CAA and through specific user groups (e.g. BGA, BHPA), and should be reinforced dependent on the trends of safety data arising. Learning material could accompany the report detailing how equipment, people, and procedures combined within the system. Furthermore, the learning material could articulate how specific actions impacted the system (impact within and across the barriers) as a whole.

A separate step will be to assess how best to pass that knowledge on. Should it be e-learning (computer based training), or is it better done through face-to-face workshops or train-the-trainer type activities through instructors or refresher training? With modern technology, there is also the potential to track the percentage of users taking up the new material (e.g. online via analytics). All leading indicators seeking to build knowledge or awareness will benefit from this type of assessment, which should be done coherently across the group of indicators. The key human factor elements that contributed to the airproxes are summarised in Table 7 along with the factors, behaviours, and actions associated with each particular element. These provide a useful framework with which to identify specific areas that can be monitored through the use of leading indicators.

Barrier	Human Factors				
	Element	Key factors, behaviours, and actions			
Strategic conflict management					
Pre-tactical events	Pilot planning	Route selection	Assessment and understanding of NOTAMS	Knowledge of procedures	
Pilot tactical control	Scan	Conflict geometry	Conspicuity	Field of view	Distraction
	Situational awareness	Use of radio	Selection of ATS	Position reporting	
	Airmanship	Navigation	Due regard		

Barrier	Human Factors				
	Element	Key factors, behaviours, and actions			
		(selection of area/route)	for other airspace users		
	Pilot inaction (general)	Rules of the air (applying correct joining procedures in the visual circuit)			
ATC tactical intervention	Traffic information (ATC-pilot)	Timely, accurate, full picture	Information passed to pilot in receipt of a Basic Service		
	ATCO inaction (general)	Coordination	Scan	Conflict assessment	
	Traffic information (ATC-ATC)	Update to aid the situational awareness of others			
ATC recovery	ATCO inaction (general)	Late/ineffective avoiding action			
Pilot recovery (ACAS)	Operation of transponder	Selection of Mode C when available			
Pilot recovery (visual warning)	Scan	Conflict geometry	Conspicuity	Field of view	Distraction

Table 7: Key human factor elements that contributed to airprox incidents

As discussed in Section 6.7, leading indicators can be derived from monitoring behaviours (work as done) from a human factors perspective.

Subjective monitoring typically entails the use of safety surveys which aim to build a greater understanding of specific areas of behaviour such as the practical implementation of ATS or rules of the air. The attitudes and opinions of pilots and ATCOs are captured and then subjectively converted into metrics.

The objective monitoring of day-to-day activities can be undertaken during training, examination, currency, and standards checks as well as during any additional monitoring. It is more difficult to monitor certain pilot activities in the air, particularly in single seat aircraft.

These objective leading indicators can include measures that people's knowledge, skills, attitude or performance levels are changing through various forms of training.

Some indicators that could be monitored by *subjective* safety surveys include:

Barrier	Focus area
Strategic conflict management	
Pre-tactical events	Identification and understanding of relevant NOTAMS *How easy is it to access the information?* *How easy is it to identify the relevant NOTAMs?* *How easy is it to interpret the information?*
Pilot tactical control	Level of distractions impacting effective scan *What actions do pilots take when things like workload distract from maintaining an effective scan?*
ATC tactical intervention	Actions and duty of care when providing a Basic Service *What information is being passed and when?* *What impact does the duty of care have on service provision?* Practical application of ATSOCAS *How practical are the current procedures to implement?*
ATC recovery	
Pilot recovery (ACAS)	
Pilot recovery (visual warning)	

Table 8: Subjective monitoring of key human factor behaviours

The leading indicators for the table are also subjective, and therefore difficult to justify in terms of responsive policy or actions.

The most basic leading indicator is to measure the percentage change in responses to the survey, assuming a controlled survey population of respondents. As there is an improvement in the positive behaviours expressed in the survey responses, it may be inferred that this reflects real life. Care must be taken with this measure, as individual perceptions and attitudes will influence the responses given over time.

Key areas that lend themselves to *objective* monitoring and resultant leading indicators include:

Barrier	Focus area	Potential leading indicator
Strategic conflict management		
Pre-tactical events	Pilot planning	
	How effective was the route planning in terms of minimising exposure to risk? (could be objective for certain user groups e.g. Military)	% of flights where independent assessment was that route planned minimised exposure to undue risk of MAC
	How well did the pilot identify the relevant NOTAMs applicable for the selected route?	% of relevant NOTAMs identified
	How successful was the pilot in maintaining an effective scan?	% of pilots maintaining effective visual scan during refresher training (instructor-assessed)
	How well was the pilot able to minimise issues limiting the field of view?	% of pilots implementing a consistent strategy to overcome limitations in their field of view
	How well did the pilot maximise their conspicuity (electronic/visual)?	% uptake of devices (overall) to aid electronic conspicuity
	How comprehensive, timely and accurate was their position reporting?	Performance score on position reporting – particularly where it aided the situational awareness of others (instructor-assessed)

Barrier	Focus area	Potential leading indicator
	How appropriate was the level of ATS that was requested?	Performance score based on a range of factors such as workload (distraction), traffic conditions (and types), traffic density, weather etc.
	How aware was the pilot of the impact of their activities on other airspace users?	Performance score.
	Did the pilot comply with local and national procedures when joining the visual circuit?	% compliance with procedures (where aerodrome is monitored, or where surveillance is widely used to track)
	How successfully did the pilot integrate into the visual circuit?	Performance score (taking into account communication, position reporting, scan, awareness of other airspace users, rules of the air etc.)
ATC tactical intervention	How timely and effective was the controller's traffic information to the pilot?	Performance score (taking into account compliance with policy and ability to provide good situational awareness) (measured during routine observations, standards/currency checks, other informal / formal checks)
	How effective was the controller in assisting the pilot to build their situational awareness?	Performance score Could also be measured by short post-flight questionnaire of pilots via e.g. a phone app?[10]
	How effective was any coordination?	Performance score
	How effective was the controller in	Performance score

[10] Care will need to be taken with pilot measures of controller performance, since the pilot may not have the full picture. This could result in more positive (where the pilot did not ever know about the conflicting traffic, so couldn't judge the lack of controller information) and negative (where the pilot was not aware of the bigger picture, and overestimated the risk) consequences in the metric.

Barrier	Focus area	Potential leading indicator
	identifying potential conflicts at an early stage? How effective was the controller in assisting the situational awareness of other controllers (internal and external) through the passing of timely and accurate traffic information?	Performance score
ATC recovery	How timely and effective was the controller's avoiding action?	Performance score
Pilot recovery (ACAS)		
Pilot recovery (visual warning)		

Table 9: Objective monitoring of key human factor behaviours

Each of the objective measures could be improved through direct training provision, giving rise to leading indicators measuring the uptake of the training in the table above. Examples of these include:

- % of pilots undertaking annual online training (CBT) on maintaining effective visual scans (broken down per user group);
- % of pilots reading flight planning (including NOTAM) refresher training

To make it useful, whenever training is provided, a short set of data could be collected to indicate user group (as per the airprox taxonomy) etc.

By taking each of the learning objectives relating to reducing risk levels of MAC, the stakeholders could work this into a Training Needs Analysis alongside existing training objectives, understanding the best way to pass the information and measure take-up. The delivery of the training could be via classroom training, synthetic training, online training (including CBT with interactive testing), coaching, mentoring, action learning (similar to refresher training), etc.

6.12 Conclusions

Leading indicators target the changes in performance levels of certain measures prior to the end outcome levels changing e.g. safety risk levels.

Individual leading indicators can be identified by looking at the combinations of contributory factors both causing and successfully preventing an incident. These contributory factors are built into a model earlier in this study, and it is the performance (or effectiveness) of this model which can then be assessed by leading indicators.

The other factor introduced in this section is the system-based thinking where:

- Safety risk is not a series of individualistic cause-effect chains, but a complex inter-related system where one factor impacts others, and

- Many factors operate on a performance continuum rather than merely being a success or failure, in particular human performance;

- Procedures are not always followed, but the flexibility of human performance can be the mitigating element preventing a more serious incident, meaning we are particularly interested in a greater understanding of operational reality as opposed to procedure design.

This leads to the paradigm where a set of leading indicators can be derived, representing best known factors influencing the effectiveness of the barrier model and performance of individual elements, where an improvement across all of them is likely to lead to an improvement in the end safety risk level.

The effective measurement of leading indicators is complicated in the Class G environment by the fragmented user base. In the field of human performance, it necessarily leads to self-assessment, which is inherently subjective. However, interventions can be defined to ensure a more objective assessment, either through training provision or online testing.

Whilst targeted intervention in human behaviour through training and on-going education can have significant benefits in improving performance, they can only influence the strength of the barriers if the barriers themselves are present. For some of the barriers, this starts with the availability of equipment, and the measurement of uptake over time.

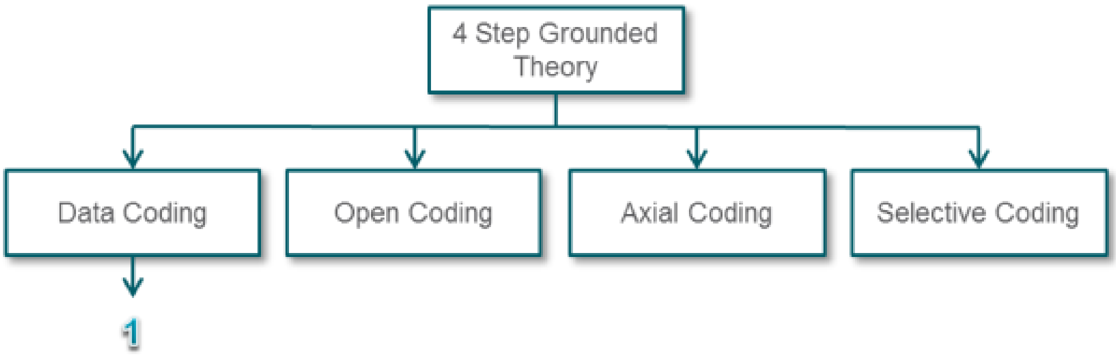
Leading indicators have been suggested above taking account of these points. Several next steps are recommended:

- Expert assessment of priority areas for improvement (in terms of effectiveness of barrier components);
- Translation into equipment, procedure or human performance outcomes. If the latter, it is recommended to phrase as 'learning outcomes' in the same way as a Training Needs Analysis. The aim here is to ensure coherency with other objectives of training, so the knowledge, awareness and applied practice on reducing risk levels in Class G is strategically designed to fit into the wider training picture (e.g. initial examinations, refresher training, online training etc.).
- Assessment of the cost of measurement. For some leading indicators, some design is necessary to be able to capture the metrics (e.g. online surveys etc.). If the benefit is not likely to be high, the value of capturing the metric in the first place must be assessed.
- Think innovatively. In overcoming the inherent context of operations in Class G airspace, namely a diverse user base with many individual operators, new techniques may be necessary to capture the data. Whilst in large organisations, over-the-shoulder surveys such as day-to-day surveys are used; for individual operations, self-assessment is likely to be the answer for wide data collection. This could be achieved by e.g. mobile phone applications being used to collect data at the end of each flight.

A Grounded Theory Approach

The 4 step Grounded Theory

Having developed a taxonomy with which to code the reports, a 4 step Grounded Theory approach was followed in order to apply the taxonomy consistently in categorising the reports:



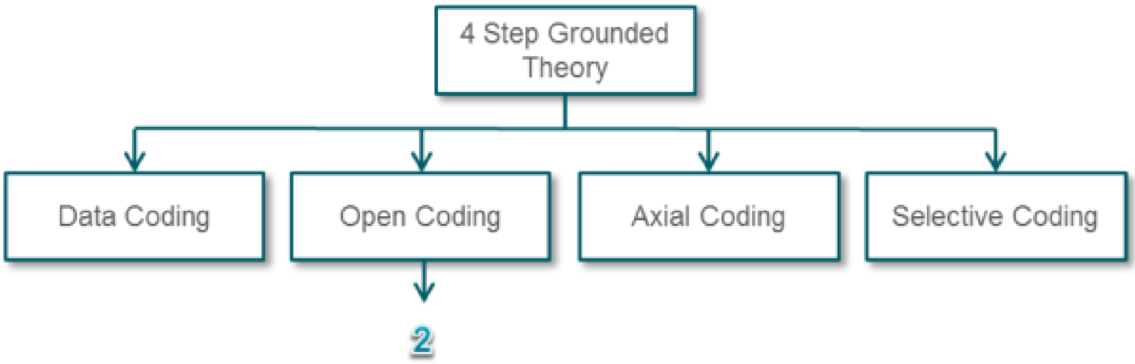
Step 1: Data Coding

This was a detailed line by line analysis of 1813 Airprox reports. Elements in the taxonomy were assigned to each report (coding) based on the information available. Some statements enabled more than one category to be applied, whilst some simple ‘sighting reports’ contained no causal factors as they were in effect a non-event.

We developed an excel spread sheet that reflects the taxonomy and allowed each individual report to be coded for which contributory factors from the taxonomy contributed to the Airprox. The contributory factors were assigned to the specific aircraft involved and distinguished between the pilots and ATCOs.

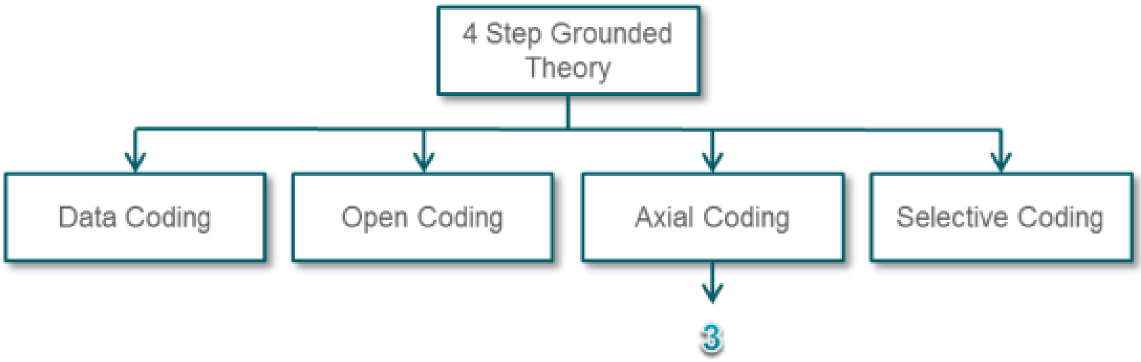
Unqualified statements made by those reporting were not captured, unless they were either contained in an additional ‘factual’ element of the report or referenced by the UKAB as having an influence/impact on the event. For example, in the pilot’s opinion the incident would not have occurred if the other aircraft had been fitted with a radio. If this was later qualified by the UKAB as relevant, then it would be captured in the database.

In many cases the UKAB were not unanimous in what may or may not have contributed to the outcome of an incident, so some professional judgement was required as to what was captured.



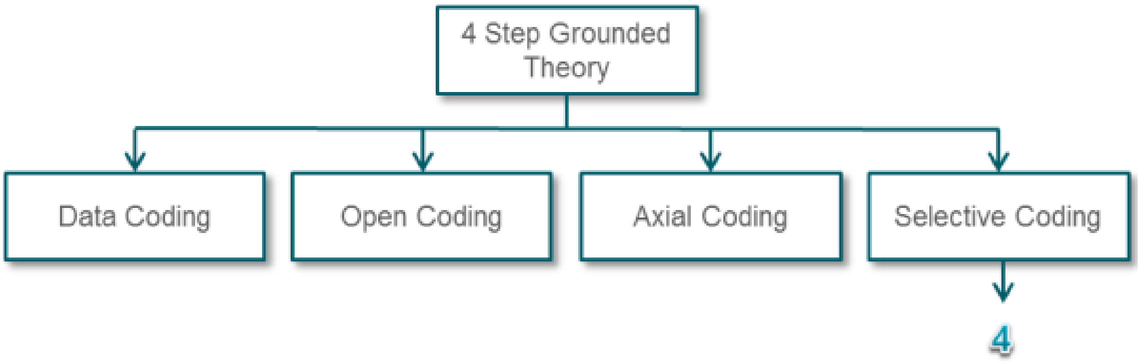
Step 2: Open Coding

This step was aimed at checking the reliability of the coding by each specialist to ensure the cross-section of experts was consistent in their application of the taxonomy. A specific sample of reports targeting recurrent elements was cross checked to see if they were consistent with the scenarios in the data. This was done at various points during step 1 to maximise consistent application throughout the process.



Step 3: Axial Coding

This was an additional reliability check and was a process of relating disciplines to their sub-elements. An independent person took a random cross-section of reports and looked at the content to ensure the elements were consistent. Even with steps 2 and 3 it was inevitable that individual specialists drew out slightly different issues in the reports but this approach was designed to keep any variations in individual interpretation to a minimum.



Step 4: Selective Coding

Once the data-set was complete, it was possible to identify the key causal factors involved. Step 4 was then a process of integrating and refining the theory through a descriptive story of what the coding has produced. This was completed based on the elements and disciplines in the taxonomy, along with existing fields in the Airprox database.

Through analysis of the data, it was possible to identify relationships between the factors and enable a series of statements to be made.

B Barrier Model

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.

Figure 21 illustrates the 7 key barriers that mitigate the risks that lead to a MAC.

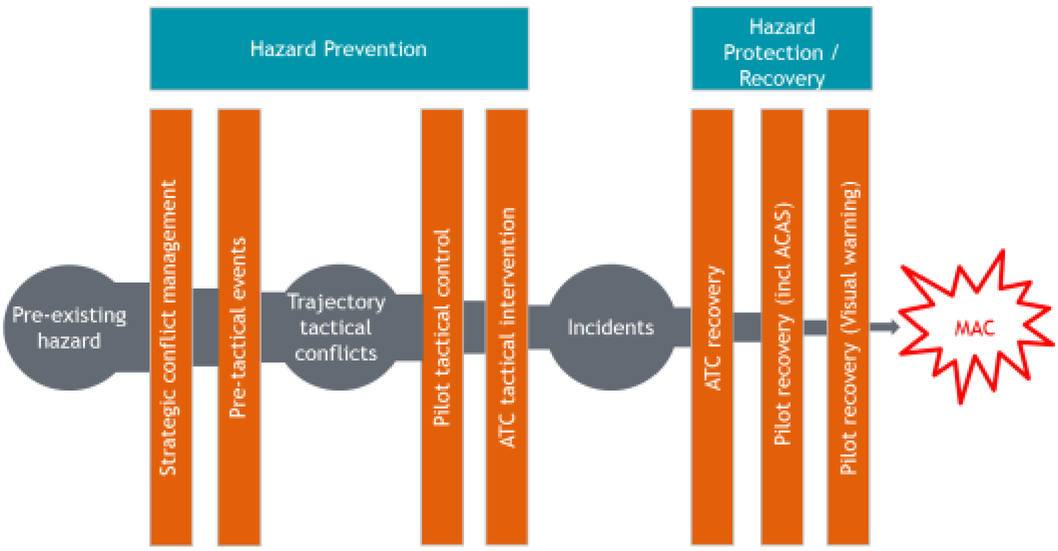


Figure 21: Key barriers mitigating risk in Class G Airspace

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.

B.1 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 UK FIS 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.

B.2 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 **Error! Reference source not found.** shows that if pilots have an increased awareness of where a hazard may present itself, they are more likely to 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 that equipment is checked such as navigation devices having up-to-date maps. The pilot should also be sufficiently familiar with 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.

B.3 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, 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 that any applied 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 BS or no ATC service. For example, at an airfield where only a BS 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. Furthermore, ATC surveillance equipment may not detect 100% of all targets due to coverage limitations 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.

B.4 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 UK FIS, 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.

B.5 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 an avoiding action (subject to the ATC service being provided).

The parameters for the activation of STCA are usually set at a sufficient distance that an ACAS RA is unlikely to have occurred at the point of activation. However, if the alert goes unnoticed, then an ACAS 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 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 having 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.

B.6 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.

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 Resolution Advisory (RA). Reaction by the pilot is also a vital part of this barrier in that they must react to the 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 decides to ignore the RA. There is also the potential for a 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 ACAS 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.

B.7 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 that 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.

B.8 Key considerations

It is clear that the dynamic nature of Class G airspace has an impact 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 make 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.

B.8.1 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 one. 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 it is an environment which, by its very nature, tends to have aircraft in a more concentrated area and require to use 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.

B.8.2 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.

B.9 Barrier components

Each barrier was subdivided into a second layer of components as depicted in Table 10 below.

Strategic Conflict Management			
Safe Airspace Design	Procedures to reduce risk	Segregation to protect airspace users	Effective management

Pre-tactical Events		
Pilot briefing	Pilot equipment	ATCO briefing

Pilot Tactical Control						
Effective navigation	Effective situational awareness and/or see and avoid	Effective airmanship skills	Effective reaction to instructions	Effective application of procedures	Correct readback of instructions	Cued awareness enables visual acquisition

ATC Tactical Intervention						
Adequate surveillance picture	Adequate communication	UK FIS are available	ATCO provides effective service	ATCO detects potential pilot or controller induced conflict	ATCO implements effective resolution	Avoidance not invalidated by other aircraft

ATC Recovery					
Short-term conflict alert (STCA) forms part of the ATM system and is available	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

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

Pilot Recovery (See and 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

Table 10: Barrier Components

C Safety Functional Map

For each barrier to be effective, certain components need to be present and correct actions taken. This can be summarised by usage of the functional map shown below in Table 11.

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			
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		

SAFETY FUNCTIONAL MAP - MID AIR COLLISION - CLASS G AIRSPACE								
BARRIER	**COMPONENTS**							
		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			

SAFETY FUNCTIONAL MAP - MID AIR COLLISION - CLASS G AIRSPACE							
BARRIER	**COMPONENTS**						
	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		
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

SAFETY FUNCTIONAL MAP - MID AIR COLLISION - CLASS G AIRSPACE							
BARRIER	**COMPONENTS**						
	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
ATC Tactical Intervention	Adequate surveillance picture	Adequate communication	UK FIS are available	ATCO provides effective service	ATCO detects potential pilot or controller induced conflict	ATCO implements effective resolution	Avoidance not invalidated by other aircraft

SAFETY FUNCTIONAL MAP - MID AIR COLLISION - CLASS G AIRSPACE							
BARRIER	**COMPONENTS**						
	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 UK FIS are available (e.g. LARS)	Required ATM equipment is available			Change in aircraft trajectories

SAFETY FUNCTIONAL MAP - MID AIR COLLISION - CLASS G AIRSPACE							
BARRIER	**COMPONENTS**						
	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					

SAFETY FUNCTIONAL MAP - MID AIR COLLISION - CLASS G AIRSPACE							
BARRIER	**COMPONENTS**						
	Pilot navigates effectively and does not infringe any other airspace Pilot requests ATC assistance if required (e.g. 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 (e.g. 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				

SAFETY FUNCTIONAL MAP - MID AIR COLLISION - CLASS G AIRSPACE							
BARRIER	**COMPONENTS**						
	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			

Table 11: Safety Functional Map – MAC in Class G Airspace

Table 12 below provides a breakdown of each tier and lists the individual elements. A full description of each element can be found below.

CONTRIBUTORY FACTOR TAXONOMY	
DOMAIN Individual Human Factors	
Experience Level / Knowledge	Currency (Pilot) Currency (ATC) Qualification (Pilot) Qualification (ATC) Understanding of procedures (Pilot) Understanding of procedures (ATC)
Perceptual	Situational awareness (ATC) Situational awareness (Pilot) Perception bias (ATC) Perception bias (Pilot) Conflict assessment (ATC) Conflict assessment (Pilot)
Physical / Sensory	Sensory (ATC) Sensory (Pilot) Health / Fitness (ATC) Health / Fitness (Pilot)
Procedural / task performance	Planning (pre-tactical) Equipment utilisation (general) Equipment utilisation (altimeter) Equipment utilisation (transponder) Equipment utilisation (Navigation/GPS) Equipment utilisation (Radio) Scan (Environment) Scan (ATC equipment) Scan (Aircraft equipment) Workload (Pilot) Workload (ATC) Priorities (ATC) Priorities (Pilot) Coordination (ATC) Traffic Information (ATC-ATC) Traffic Information (ATC-Pilot) Pilot ATS Selection Confusion with level of service provided Teamwork (CRM) Violation (General) Violation (ACAS) Action / inaction (non-intentional) (General) Action / inaction (non-intentional) (ACAS) Action / inaction (non-intentional) (Altitude) Action / inaction (non-intentional) (Navigation)

CONTRIBUTORY FACTOR TAXONOMY	
	Action / inaction (non-intentional) (Airmanship) Action / inaction (non-intentional) (Readback) (ATC) Action / inaction (non-intentional) (Readback) (Pilot) Action / inaction (non-intentional) (Communication) (ATC) Action / inaction (non-intentional) (Communication) (Pilot) Action / inaction (non-intentional) (Phraseology) (ATC) Action / inaction (non-intentional) (Phraseology) (Pilot)
Psychological	Distraction (ATC) Distraction (ATC Handover) Distraction (Pilot) Cognitive limitation (Pilot) Cognitive limitation (ATC) Information Processing Assessment of risk (Pilot) Assessment of risk (ATC) Emotional state (ATC) Emotional state (Pilot) Personality / attitude (Pilot) Personality / altitude (ATC)
Fatigue	Fatigue (ATC) Fatigue (Pilot)
DOMAIN Organisational Factors	
Oversight	Supervision (ATC) Supervision (CRM) Staff allocation
Ops Planning	Route Planning Deconfliction of activity with other groups Resources
Policy Procedures	UK FIS ACAS Quadrantal / semi-circular Procedures Rules of the air Updates / Communication
Culture (safety)	Culture (working practices)
Training	Training (ATC) Training (Pilot)
Record Keeping	Document accuracy
Enforcement	Assurance
Safety Programme	Safety Programme
DOMAIN Equipment Factors	

CONTRIBUTORY FACTOR TAXONOMY	
Aircraft Systems	Communication (availability) Communication (serviceability) Transponder (availability) Transponder (serviceability) ACAS (availability) ACAS (serviceability) Collision Warning System – TAS (availability) CWS – TAS (serviceability) Conspicuity Internal radar (availability) Internal radar (serviceability) GPS
ANSP Systems	Communication (availability) Communication (serviceability) PSR (availability) PSR (serviceability) SSR (availability) SSR (serviceability) STCA (availability) STCA (serviceability) Maintenance Visual display
DOMAIN Operating Environment	
Infrastructure	Airspace design Airspace complexity Airspace availability Traffic Density Aircraft speed ATC service availability (General) ATC service availability (LARS) Field of view Conflict Geometry Terrain
Weather	Light conditions Visibility Precipitation Wind Temperature VMC IMC
Special Events	Military exercise Flight check Emergency services Air policing

CONTRIBUTORY FACTOR TAXONOMY	
	Parachute Balloon Low flying Pipeline inspection Civil event Model Flying Air show
Emergencies	Emergencies

Table 12: Contributory Factor Taxonomy

C.1 Individual/Human Factors

In line with the CICTT AT taxonomy, this domain is defined as a set of disciplines and elements that describe an individual's performance in relation to their environment. The disciplines include Experience/Knowledge, Perceptual, Physical/Sensory, Procedural/Task Performance, Psychological, and Fatigue, all of which include characteristics that may influence how an individual performs in their working environment.

C.1.1 Experience level/knowledge

C.1.1.1 Currency (Pilot)

This includes how recent an individual's experience is and the amount of time spent performing one's task. There are set guidelines for professional aircrew regarding currency.

C.1.1.2 Currency (ATC)

As above, specifically related to controllers such as their level of experience in a particular rating.

C.1.1.3 Qualification (Pilot)

This includes total and recent instruction received, recurrent instruction, type of instruction, or lack of. Also included are the document status, ratings, and current certifications of an individual.

C.1.1.4 Qualification (ATC)

As above, specifically related to ATC.

This includes situations where controllers are still under training and this impacted the event.

C.1.1.5 Understanding of procedures (Pilot)

This relates to an individual's understanding of procedures. For example, familiarity with local or national directives, aircraft operating handbooks, regulatory requirements, airspace classifications, ATS provision, and rules of the air.

Example: Pilot is unaware of the requirement to inform the controller before changing level under a TS.

C.1.1.6 Understanding of procedures (ATC)

As above, but specifically related to ATC.

C.1.2 Perceptual

C.1.2.1 Situational awareness (ATC)

Example: For the ATCO, an aerodrome controller needs to keep track of the aircraft in the circuit, but as the circuit gets busier he/she can lose situational awareness. Situational awareness can be lost even when using a surveillance screen.

Importantly, a lack of situational awareness does not necessarily infer that the individual has done something wrong. A lack of situational awareness may be as a result of the primary radar not being available or a lack of pilot communication when providing a PS.

C.1.2.2 Situational awareness (Pilot)

This is the perception of environmental elements with respect to time and/or space, the comprehension of their meaning and the projection of the status after some variable has changed, such as time. Behaviours related to situational awareness include an individual's perception of the conditions or changes in their operational environment and they are often described in relation to decision making or actions. Situational awareness includes the loss or incomplete perception of or changes to elements present in an individual's operational environment and includes an individual's ability to maintain a high level of vigilance.

Example: For a pilot, this would involve situational awareness of where other aircraft are around them. If they are purely relying on radio, they should be able to build a picture in their head of the traffic around them. When turning/climbing/descending, it is possible to lose situational awareness.

As with controllers above, a lack of situational awareness does not necessarily infer that the pilot has made an error. For example, the lack of an RT call in the visual circuit could reduce the situational awareness of others.

C.1.2.3 Perception Bias (Pilot)

This refers to habitual behaviours, where a decision is made based on past experience.

Example: The pilot used the wrong approach procedure, as this is the procedure he usually performs or he did not report on frequency because it is usually busy.

C.1.2.4 Perception Bias (ATC)

This refers to habitual behaviours, where a decision is made based on past experience.

Example: The ATCO gave clearance for the flight to land on RW24 as he had been working on that runway all day, despite the runway having recently changed.

C.1.2.5 Conflict assessment (Pilot)

For a pilot, this is an individual's assessment of the conflict geometry/speed.

Example: Glider pilot orbiting saw potential conflict a good distance away but did not consider it a threat until the next orbit, when avoiding action had to be taken later than ideal.

C.1.2.6 Conflict assessment (ATC)

For a controller, it is an individual's assessment of the surveillance/procedural information available or what can be deduced visually.

C.1.3 Physical limitations/sensory

C.1.3.1 Sensory (Pilot)

Factors related to a person's sensory abilities, characteristics, limitations or behaviours, not including psychological or visual/vestibular illusions. Sensory ability/limitation pertains to visual function, the use of corrective lenses, colour vision, hearing ability, vestibular function, and tactile function.

For example: The use of NVGs reducing ability to discern ranges and to look closely at well-lit CAT.

C.1.3.2 Sensory (ATC)

Factors related to a person's sensory abilities, characteristics, limitations or behaviours, not including psychological or visual/vestibular illusions. Sensory ability/limitation pertains to visual function, the use of corrective lenses, colour vision, hearing ability, vestibular function, and tactile function.

Example: The controller misread the reporting aircraft's altitude on the surveillance display because of not wearing his corrective lenses (glasses) and mistakenly assigned another aircraft the incorrect altitude.

C.1.3.3 Health/Fitness (Pilot)

Factors related to a person's general health, fitness, and lifestyle including chronic physical issues including fitness; diet such as poor nutrition, fasting, etc.; extended use of medication/drugs; alcohol; smoking; or a predisposing condition.

C.1.3.4 Health/Fitness (ATC)

Factors related to a person's general health, fitness, and lifestyle including chronic physical issues including fitness; diet such as poor nutrition, fasting, etc.; extended use of medication/drugs; alcohol; smoking; or a predisposing condition.

C.1.4 Procedural/task performance

C.1.4.1 Planning (pre-tactical) (Pilot)

Factors related to the planning or preparation of operational tasks. This refers to tasks such as performance calculations, weight and balance calculations, weather planning, flight planning, navigational planning, traffic management planning, arrival and departure sequencing, and fuel planning.

Example: poor route selection, or not briefing correctly / not checking all the NOTAMs (e.g. of glider activity).

C.1.4.2 Briefing (pre-tactical) (ATC)

Factors related to briefing prior to commencing a shift.

Example: The ATCO did not read relevant NOTAMS and briefing material prior to commencing the shift.

C.1.4.3 Equipment utilisation (general) (Pilot)

Factors related to the utilisation, configuration, or interaction with a system. This category specifically refers to general equipment usage, such as use of automation, use of manuals, checklists, overlays, visual aids and charts, and use of available resources.

C.1.4.4 Equipment utilisation (general) (ATC)

Factors related to the utilisation, configuration, or interaction with a system. This category specifically refers to general equipment usage, such as use of automation, use of manuals, checklists, overlays, visual aids and charts, and use of available resources.

C.1.4.5 Equipment utilisation (altimeter) (Pilot)

Factors related to the utilisation, configuration, or interaction with a system. Specifically this category includes equipment utilisation specifically related to altimeter usage.

Example: The pilot entered the wrong pressure setting, so was at an incorrect altitude.

C.1.4.6 Equipment utilisation (transponder) (Pilot)

Factors related to the utilisation, configuration, or interaction with a system. Specifically this category refers to usage of transponder.

Example: Aircraft was equipped with a transponder, but it was not turned on or the incorrect squawk had been entered.

C.1.4.7 Equipment utilisation (Navigation/GPS) (Pilot)

Factors related to the utilisation, configuration, or interaction with a system. Specifically this includes the use of navigation devices or maps.

C.1.4.8 Equipment utilisation (Radio) (Pilot)

Factors related to the human utilisation of the radio.

Example: This includes the selection and monitoring (e.g. volume setting) of the correct frequency.

Example: Pilot was unable to operate the radio to obtain a channel requiring three decimal places.

C.1.4.9 Scan (Environment) (Pilot)

Factors related to the systematic observation/monitoring of the operational environment by pilot. Specifically related to see and avoid, monitoring other aircraft and the environment.

For example: Pilot failed to move his head in order to scan effectively.

The application of this category does not necessarily infer that the pilot's scan technique was at fault. The ability to scan effectively may have been reduced due to such things as poor visibility or terrain but nevertheless, a late sighting was a factor in the incident.

C.1.4.10 Scan (ATC)

Factors related to the systematic observation of the operational environment by an ATCO or Flight Information Service Officer (FISO) - includes task monitoring, monitoring aeronautical information, surveillance displays and aircraft in the visual circuit.

C.1.4.11 Scan (Aircraft equipment)

Factors related to the systematic observation of the operational environment. This includes task monitoring, monitoring equipment/instruments, specifically aircraft equipment.

Examples: It includes failure to monitor automation, displays, or instruments. This element is distinct from miss-see and miss-hear.

C.1.4.12 Workload (Pilot)

Factors related to the amount of workload or more specifically the number of tasks someone is exposed to. Those with a high workload may struggle to manage and they underperform and those with a very low workload may be bored and this can cause a loss of attention and again underperformance. This includes task load shedding and task overload. This is specifically related to pilot.

C.1.4.13 Workload (ATC)

Example: Multiple aircraft reporting in-flight emergencies at the same time overwhelmed the controller.

Example: ATCO was operating in a ‘bandboxed’ configuration and handling multiple UHF and VHF frequencies became too challenging.

C.1.4.14 Priorities (Pilot)

Example: The pilot receives an ACAS RA and instead of acting on the instruction, asks the controller to confirm before manoeuvring.

C.1.4.15 Priorities (ATC)

Factors related to the organisation and prioritisation of work tasks, including task scheduling and task allocation.

Example: Controller continues to coordinate with another controller and does not provide deconfliction advice (avoiding action) in good time.

C.1.4.16 Coordination (ATC)

Factors related to the transfer of information among air traffic controllers and related to the movement of aircraft or the use of airspace. Includes tasks such as handovers, position relief briefings, point-outs, information exchange, coordination between ground and local controllers or two ATSUs, and sector/team coordination.

Example: Controller may enter a coordination agreement when there is insufficient time to implement the coordination or when not in a position to ensure coordination can be implemented.

Example: Controllers do not coordinate their respective aircraft in order to deconflict flight profiles which then resulted in an airprox.

C.1.4.17 Traffic Information (ATC-ATC)

Internal controller-to-controller traffic information to aid in building up their situational awareness and to determine if coordination is required. Once that information is passed, it becomes dead information and if something changes at one end, that controller has no obligation to update the other controller. Good controlling skills may dictate the passing of traffic information to improve the situational awareness of other controllers.

C.1.4.18 Traffic Information (ATC-Pilot)

Traffic information passed to the pilot. However, it is the responsibility of the pilot to request which kind of air traffic service they want and the pilot is ultimately responsible for separation in Class G airspace.

Example: Poor/incorrect/late traffic information passed to the pilot contributes to the loss of separation.

Example: Instances where traffic information did not provide a full picture of the situation thus reducing the situational awareness of the pilot.

C.1.4.19 Pilot ATS Selection

The pilot has chosen the wrong Service type or not opted for a service at all when operating in IMC. Also if the pilot is wrongly in communication with Radar instead of tower, or vice versa.

Example: A pilot has selected a BS or TS, but due to poor weather a DS may have been more appropriate.

Example: A pilot is flying CAT in IMC under a BS.

C.1.4.20 Confusion with service provided (Pilot)

Example: There is confusion about what service the pilot is actually on or what the service actually provides.

Example: Pilot thought that when he was under BS with a non-radar unit other agencies and other aircraft would remain clear of him.

Example: Assumption that pilot would be separated from all traffic as opposed to all known traffic.

C.1.4.21 Teamwork (CRM) (Pilot)

Crew Resource Management - this refers to on-board crew management. This includes the effective interaction between instructor and student.

Example: Poor CRM led to both pilots being ‘heads in’ at the same time.

Example: Student assumed the instructor had seen the other aircraft and therefore did not mention it.

C.1.4.22 Violation (General) (Pilot)

Factors related to intentional behaviour contrary to applicable regulations and/or policies related to completion of required procedures or tasks. This includes intentional acts related to completion of required tasks, workarounds, aviation regulation violations, and other wilful disregard for rules or regulations.

Example: Pilot deliberately ignores the regulations and transits through the ATZ of an active aerodrome without contacting ATC.

C.1.4.23 Violation (General) (ATC)

Factors related to intentional behaviour contrary to applicable regulations and/or policies related to completion of required procedures or tasks. This includes intentional acts related to completion of required tasks, workarounds, aviation regulation violations, and other wilful disregard for rules or regulations.

Example: ATCO deliberately ignore a unit temporary order because they didn’t agree with it.

C.1.4.24 Violation (ACAS)

Factors related to intentional behaviour contrary to applicable regulations and/or policies related to completion of required procedures or tasks. This category specifically relates to the violation of ACAS warning, choosing to ignore or not acting upon instructions.

Example: A pilot deliberately ignored a ACAS RA due to the number of recent RAs experienced in busy airspace.

C.1.4.25 Action/inaction (non-intentional) (General) (Pilot)

Factors related to a non-intentional behaviour contrary to applicable regulations and/or policies related to action, series of actions, or the lack of action. This includes non-intentional behaviours such as incorrect action selection, incorrect or inadequate action performance, incorrect action sequence, delayed action, lack of action, forgotten action/omission, incomplete action, or unnecessary action. This category should be used if a behaviour is not specifically referenced in the other procedural factors.

This category was applied frequently where pilots did not implement the rules of the air correctly.

C.1.4.26 Action/inaction (non-intentional) (General) (ATC)

Factors related to a non-intentional behaviour contrary to applicable regulations and/or policies related to action, series of actions, or the lack of action. It includes non-intentional behaviours such as incorrect action selection, incorrect or inadequate action performance, incorrect action sequence, delayed action, lack of action, forgotten action/omission, incomplete action, or unnecessary action. This category should be used if a behaviour is not specifically referenced in the other procedural factors.

Example: Controller did not pass information on activity of restricted airspace as required in Local Orders.

This category was applied frequently where controllers did not apply UK FIS in accordance with CAP 774. Another common usage was when the controller did not plan effectively.

C.1.4.27 Action/inaction (non-intentional) (ACAS) (Pilot)

Factors related to a non-intentional behaviour contrary to applicable regulations and/or policies related to action, series of actions, or the lack of action. Specifically related to ACAS.

Example: Pilot did not react to the ACAS RA as he was distracted by ATC providing avoiding action instructions on a busy frequency.

C.1.4.28 Action/inaction (non-intentional) (Altitude) (Pilot)

Factors related to a non-intentional behaviour contrary to applicable regulations and/or policies related to action, series of actions, or the lack of action. Specifically related to altitude.

Example: Pilot readbacks the instruction correctly but then does not ascend/descend to the right altitude.

C.1.4.29 Action/inaction (non-intentional) (Navigation) (Pilot)

Factors related to a non-intentional behaviour contrary to applicable regulations and/or policies related to action, series of actions, or the lack of action. Specifically related to Navigation.

Example: Pilot fails to provide sufficient attention to navigating effectively and inadvertently flies through an approach path or glider site.

C.1.4.30 Action/inaction (non-intentional) (Airmanship) (Pilot)

Factors related to a non-intentional behaviour contrary to applicable regulations and/or policies related to action, series of actions, or the lack of action. Poor airmanship is related to an individual’s assessment of risk and appreciation of how your own behaviour impacts on others.

Example: Pilot transits through a busy IFR approach area without contacting the controlling authority.

This category was applied frequently when a pilot flew in close proximity to another aircraft such that it caused alarm to the other pilot.

C.1.4.31 Action/inaction (non-intentional) (Readback) (Pilot)

Factors related to a non-intentional behaviour contrary to applicable regulations and/or policies related to action, series of actions, or the lack of action.

Example: Pilot makes an incorrect readback and thus performs the wrong action.

C.1.4.32 Action/inaction (non-intentional) (Readback) (ATC)

Factors related to a non-intentional behaviour contrary to applicable regulations and/or policies related to action, series of actions, or the lack of action. Readback is where the pilot is required to read back the verbal instruction of the ATCO verbatim.

Example: There is an incorrect readback from the pilot and controller does not spot the incorrect readback.

C.1.4.33 Action/inaction (non-intentional) (Communication) (Pilot)

Factors related to a non-intentional behaviour contrary to applicable regulations and/or policies related to action, series of actions, or the lack of action. Note this factor can relate to a range of behaviours such as misspeaking, mishearing, misunderstanding, or inaccurate information.

Example: Language difficulties caused a communication breakdown.

Example: Pilot does not provide position information required for others to maintain situational awareness.

C.1.4.34 Action/inaction (non-intentional) (Communication) (ATC)

Factors related to a non-intentional behaviour contrary to applicable regulations and/or policies related to action, series of actions, or the lack of action. Note that this factor can relate to a range of behaviours such as misspeaking, vague/ambiguous instructions, and mishearing.

Example: Air traffic controller used the wrong callsign causing confusion.

C.1.4.35 Action/inaction (non-intentional) (Phraseology) (Pilot)

Factors related to a non-intentional behaviour.

Example: Poor phraseology led to a misunderstanding of intentions in the visual circuit.

C.1.4.36 Action/inaction (non-intentional) (Phraseology) (ATC)

Factors related to a non-intentional behaviour. Controllers have to use given phrases and words to ensure an agreement is binding or instructions are clear and unambiguous.

Example: Coordination between ATCOs was unsuccessful as non-standard phraseology led to a misunderstanding.

C.1.5 Psychological

C.1.5.1 Distraction (ATC)

Factors related to a person’s management of concentration, focus, and understanding of a situation under their direction and control. Includes task fixation and diversion of focus, specifically related to ATC. Examples include failure to pay attention, lack of focus on tasks, individual ability to remain on task and likelihood to become distracted.

Example: ATCO lost situational awareness when he focused on a particular aircraft’s emergency, thereby not recognizing a potential traffic conflict with other aircraft under his control, thus allowing two aircraft to lose required separation.

Example: Controller was distracted by the ATC assistant and therefore spotted the developing confliction late.

C.1.5.2 Distraction (ATC Handover)

A sub-set of distraction, specifically where the ATCO is distracted by the handover process.

C.1.5.3 Distraction (Pilot)

Factors related to a person’s management of concentration, focus, and understanding of a situation under their direction and control.

Example: Pilot was distracted by passengers on a recreational flight and did not see another aircraft approaching.

Example: Pilot focuses on another aircraft at the expense of maintaining a full scan.

A common application of this category was where an instructor was focused on making a teaching point to a student at the expense of maintaining a good look out.

C.1.5.4 Cognitive limitation (Pilot)

A factor related to a person’s mental or cognitive limitations, e.g. the operational demand exceeds the mental capabilities of the operator. This includes cognitive overload and memory limit.

C.1.5.5 Cognitive limitation (ATC)

As above, but specifically related to ATC.

C.1.5.6 Information processing (Pilot)

Factors related to the ability to process available information in the decision-making process. It includes but is not limited to identification, interpretation, and prioritization of visual or auditory data; understanding and comprehension of information; and judgment, expectation, assumption, and assessment of operational risks.

Example: Student pilot was unable to follow ATC advice as multiple inputs were passed during a busy phase of flying.

Example: Pilot was passed TI on 3 tracks but only assimilated the information on the first 2.

C.1.5.7 Information processing (ATC)

As above, but for controllers.

C.1.5.8 Assessment of risk (Pilot)

An individual's assessment of risk, related to decision making.

Example: How close a military aircraft passes to a light aircraft or CAT. Two pilots may assess the conflict (perceptual) the same but only one takes action because his assessment of the risk is different. This is often tied to airmanship where a military aircraft gets too close to CAT such that it causes them alarm. The military pilot does not consider there to be any risk but their proximity may cause alarm (sometimes literally with ACAS) and cause the other to take evasive action.

C.1.5.9 Assessment of risk (ATC)

As above, but for ATC.

C.1.5.10 Emotional state (Pilot)

Factors related to an individual's mental or emotional state of well-being. This includes but is not limited to personal stress, anxiety, boredom, apprehension, and denial.

C.1.5.11 Emotional state (ATC)

As above, but specifically related to ATC.

C.1.5.12 Personality/attitude (Pilot)

Factors related to an individual's traits, temperament, habits, or inclination. Includes issues of self-confidence, confidence, or reliance on equipment; complacency, motivation, or response to pressures; and personality issues such as aggressive, assertive, or lack of assertiveness.

Example: Pilot was low on fuel and did not wish to be turned off track and therefore requested a level of ATS that was not appropriate to the prevailing met conditions.

C.1.5.13 Personality/attitude (ATC)

Example: Controller was overconfident in his/her ability and accepted too many aircraft on frequency. This led to high workload issues and a loss of separation occurred.

Example: Controller felt too junior to question senior controller's decision.

C.1.6 Fatigue

C.1.6.1 Fatigue (Pilot)

Fatigue can be commonly expressed as “too tired to perform or function properly.”

Example: Pilot had been flying in good VMC during a long transit without incident in low density airspace. Effective scan levels reduced due to fatigue and resulted in a non-sighting of another aircraft.

C.1.6.2 Fatigue (ATC)

Factors referring to a physiological state of reduced mental or physical performance capability resulting from sleep loss or extended wakefulness, that can impair an individual’s alertness and ability to safely operate an aircraft, control air traffic, or perform safety-related duties. Fatigue is a complex state that includes a lack of alertness and a reduced capacity for mental and physical performance.

Example: Controller was coming to the end of a night shift and found it difficult to raise his/her work-rate when required.

C.2 Organisational Factors

In line with the CICTT AT taxonomy this domain refers to factors related to organisational oversight, support, and monitoring of organisation programs, policies, and personnel.

C.2.1 Oversight

C.2.1.1 Supervision (ATC)

Factors related to the oversight, support, and monitoring of personnel, and organisation policies, specifically related to ATC supervision.

Example: Supervisor allowed two control positions to be bandboxed when traffic levels were too high. This resulted in a controller becoming overloaded.

Example: Supervisor placed an inexperienced controller in a difficult position by placing him/her in a complex and busy control position that was beyond his/her level of ability.

This category was often applied where a screen controller/instructor failed to monitor the person under training effectively, particularly stepping in at an appropriate time.

C.2.1.2 Supervision (Aircrew)

Crew Resource Management. Factors related to the oversight, support, and monitoring of personnel, specifically related to on-board pilot crew resource management.

Example: Poor organisation of crew resources.

C.2.1.3 Staff allocation (ATC)

Factors related to the oversight, support, and monitoring of personnel, and organisation policies, specifically related to the allocation of staff. This is usually liked with supervision element.

Example: The supervisor did not allocate staff effectively to meet anticipated demand.

C.2.2 Ops Planning

C.2.2.1 Route Planning (Pilot)

This includes effective planning to minimise an exposure to risk by avoiding a NOTAM gliding competition or not conducting aerobatics in a busy approach lane.

C.2.2.2 Deconfliction of activity from other user groups (Aircrew)

Factor related to pre-flight operational planning.

Example: Two military aircraft operating in the same area. Though both aircraft are operating in class G, it might have reduced risk if they had deconflicted their operations and coordinated with each other before hand.

Example: Aircrew did not adequately deconflict activities in the low flying areas.

This category was applied frequently where military and gliding activities were not being deconflicted as effectively as they could have been.

C.2.2.3 Resources (ATC)

The availability of equipment and facilities, documents of information (navigational warnings, NOTAMs, MET, latest procedures), equipment scheduling, maintenance scheduling.

Example: Taking the primary radar off for maintenance in the middle of the day rather than the evening thus reducing the situational awareness of controlling staff.

C.2.3 Policy Procedures

C.2.3.1 UK FIS Policy

Factors related to guidance and instructions (e.g. manuals) set forth by the organisation; policies or procedures that are out-of-date, not widely disseminated, unclear, or inadequate.

C.2.3.2 ACAS Policy

Factors related to guidance and instructions (e.g. manuals) set forth by the organisation.

C.2.3.3 Quadrantal/semi-circular policy

Factors related to guidance and instructions (e.g. manuals) set forth by the organisation. Policies or procedures that are out-of-date, not widely disseminated, unclear, or inadequate.

Example: Policy is unclear or at odds with other policy and procedures

C.2.3.4 Procedures

Factors relating to the procedures of the organisation, typically local procedures.

Example: Following the incident the procedures at RAF Lossiemouth were updated to mandate deconfliction of traffic recovering from the west with Inverness.

C.2.3.5 Rules of the air

The rules of the air are a set of principles to prevent collisions.

C.2.3.6 Updates/Communication

Examples include policies or procedures that are out-of-date, not widely disseminated, unclear, or inadequate.

C.2.4 Culture (safety)

C.2.4.1 Culture (working practices)

Culture includes organisational or team-wide operating practices, pressures, and demands or expectations from the organisation to perform or meet operational goals and timelines.

Example: Despite the procedures stating that after a runway change the runway to be used should be circled in the heading and level box, the ATCO's were uncertain as to whether this procedure was regularly followed.

C.2.5 Training

C.2.5.1 Training (Pilot)

Factors related to the adequacy, effectiveness, completeness, and management of the organisation's training and examination program.

Training Program refers to the organisation's training program, including overall program management, course curriculums, instruction, instructors, course evaluations, adequate recurrent training program, adequate remedial training program, and examinations.

C.2.5.2 Training (ATC)

Factors related to the adequacy, effectiveness, completeness, and management of the organisation's training and examination program.

Training Program refers to the organisation's training program, including overall program management, course curriculums, instruction, instructors, course evaluations, adequate recurrent training program, adequate remedial training program, and examinations.

Example: Every control position was occupied by a trainee, significantly reducing ATS quality.

Also used when having a trainee in position has had an impact on the incident or when the OJTI has responded poorly.

C.2.6 Record Keeping

C.2.6.1 Document accuracy

Factors related to the creation, storage, and retrieval of organisational records. Includes organisational records and documentation such as operation records, personnel records, testing records, and maintenance records.

Example: Clarity of symbols on maps or incorrect information in the AIP entry.

C.2.7 Enforcement

C.2.7.1 Assurance

Factors related to the enforcement actions of the organisation and its adherence to organisation enforcement policies regarding personnel performance, operational procedures, regulatory requirements, equipment requirements, and company/organisational policies.

C.2.8 Safety Programme

C.2.8.1 Safety Programme

Factors related to the availability, adequacy, and adherence to an organisation safety program. This considers the availability, adequacy, and adherence to the organisation's safety program.

C.3 Equipment Factors

Causal and contributory factors include cases where such equipment is not functioning as designed (i.e. malfunction), not functioning as intended (i.e. design flaw), or inoperative (i.e. either as a result of a planned outage or unplanned failure). Causal and contributory factors specifically addressing the human-machine interface are classified under "Human/Individual Factors."

C.3.1 Aircraft Systems

C.3.1.1 Communication (availability)

Communication factors that affect aircraft in such a way as to cause, or contribute to, a loss of separation with another aircraft, an unintended loss of separation with terrain or obstacles, or other air traffic anomaly.

Example: Aircraft is not fitted with a radio so the pilot is unable to communicate.

C.3.1.2 Communication (serviceability)

Communication factors that affect aircraft in such a way as to cause, or contribute to, a loss of separation with another aircraft, an unintended loss of separation with terrain or obstacles, or other air traffic anomaly.

Example: Aircraft is fitted with a radio but it is not switched on or is unserviceable.

C.3.1.3 Transponder (availability)

Transponder factors that affect aircraft in such a way as to cause, or contribute to, a loss of separation with another aircraft, an unintended loss of separation with terrain or obstacles, or other air traffic anomaly.

Example: Aircraft is not fitted with a transponder and had it been so the incident may not have occurred (in the opinion of the airprox board).

Example: Aircraft is fitted with a transponder (Modes A and C) but the pilot does not select mode C to be on.

C.3.1.4 Transponder (serviceability)

Transponder factors that affect aircraft in such a way as to cause, or contribute to, a loss of separation with another aircraft, an unintended loss of separation with terrain or obstacles, or other air traffic anomaly.

Example: Aircraft is fitted with a transponder but it is unserviceable or providing inaccurate information.

C.3.1.5 ACAS (availability)

ACAS factors that affect aircraft in such a way as to cause, or contribute to, a loss of separation with another aircraft, an unintended loss of separation with terrain or obstacles, or other air traffic anomaly. Only used when it is stated by the board.

Example: Aircraft is not fitted with ACAS and had it been, the accident may not have happened.

C.3.1.6 ACAS (serviceability)

ACAS factors that affect aircraft in such a way as to cause, or contribute to, a loss of separation with another aircraft, an unintended loss of separation with terrain or obstacles, or other air traffic anomaly. Only used where the opinion is of the board.

Example: Aircraft is fitted with ACAS but it is unserviceable.

C.3.1.7 Traffic Alerting System (TAS) (availability)

TAS such as FLARM/PowerFLARM that cause, or contribute to, a loss of separation with another aircraft. Only used where it is the opinion of the board.

Example: Had the other aircraft been fitted with TAS, then the aircraft would have spotted each other and the incident may have been avoided.

C.3.1.8 Traffic Alerting System (TAS) (serviceability)

Only used where it is the opinion of the board, here relating to the serviceability of TAS.

C.3.1.9 Conspicuity

Specifically related to the visual conspicuity of the aircraft or the ability of surveillance systems to detect and display the aircraft.

Example: Colour of the aircraft blended into the background making it hard to see.

C.3.1.10 Internal radar (availability)

Internal radar factors that affect aircraft in such a way as to cause, or contribute to, a loss of separation with another aircraft, an unintended loss of separation with terrain or obstacles, or other air traffic anomaly.

Example: Aircraft is not fitted with an internal radar and had it been so the accident might not have happened.

C.3.1.11 Internal radar (serviceability)

Internal radar factors that affect aircraft in such a way as to cause, or contribute to, a loss of separation with another aircraft, an unintended loss of separation with terrain or obstacles, or other air traffic anomaly.

Example: Aircraft is fitted with an internal radar but it is unserviceable.

C.3.1.12 Stand-alone GPS devices

This includes the impact of stand-alone GPS devices including smart phones and tablets with aeronautical and navigation applications.

Example: Outdated navigation information may result in unintended flight over glider site.

C.3.2 ANSP Systems

C.3.2.1 Communication (availability)

This element refers to ATC equipment required to exchange information among various agents in the air space system.

Example: Frequency was too congested to make timely information calls.

C.3.2.2 Communication (serviceability)

This element refers to ATC equipment required to exchange information among various agents in the air space system.

Example: The air traffic controller's landline system failed, preventing coordination of traffic with adjacent sector.

C.3.2.3 PSR (availability)

Primary Surveillance Radar.

Example: There is no primary radar available.

C.3.2.4 PSR (serviceability)

Primary Surveillance Radar.

Example: The primary radar is unserviceable or under maintenance.

C.3.2.5 SSR (availability)

Secondary Surveillance Radar.

Example: There is no secondary radar available.

C.3.2.6 SSR (serviceability)

Secondary Surveillance Radar.

Example: SSR is unserviceable or under maintenance.

C.3.2.7 STCA (availability)

Short term conflict alert, if aircraft get too close together it flashes. Has to be carefully set up in class G.

Example: It is not set up correctly or not available.

C.3.2.8 STCA (serviceability)

Example: STCA is unserviceable.

C.3.2.9 Maintenance (General)

This element refers to systems related to the maintenance of air navigation service provider equipment and facilities.

C.3.2.10 Visual Displays

Factors referring to the nature of the visual display.

Example: The display contained a significant amount of clutter making it difficult to detect primary only contacts such as gliders.

Example: Traffic density led to significant overlap of track data blocks on the surveillance display.

C.4 Operating Environment

In line with CICTT AT taxonomy this domain includes system states and circumstances that influence flight operations and air traffic management.

C.4.1 Infrastructure

C.4.1.1 Airspace design

Factors pertaining to the specific dimensions and/or boundaries of the airspace through which aircraft traverse. It includes how airspace is constructed around an airfield. For example, whether there is a glider site in the way or whether aircraft are funnelled into a particular area.

Example: The proximity of adjacent airfields and controlled airspace funnelled different user groups into the same airspace.

C.4.1.2 Airspace complexity

Factors relating to the complexity of airspace.

Example: The airspace has numerous base levels making it difficult for infrequent flyers to navigate successfully.

C.4.1.3 Airspace availability

Factors relating to the availability of airspace.

C.4.1.4 Traffic Density

Factors relating to traffic density in the sky. This includes too many aircraft in the visual circuit for pilots to integrate themselves safely.

C.4.1.5 Aircraft speed

Factors related to aircraft speed such as difficulty maintaining adequate spacing in the visual circuit due to differing aircraft speeds.

Example: Aircraft was flying at such a speed that there was no time to react.

Example: Aircraft was flying so slowly that it was hard to spot.

C.4.1.6 ATC service availability (General)

Factors relating to general ATC service availability.

Example: Only a PS was available to IFR traffic as it was outside the published hours of a surveillance service.

C.4.1.7 ATC service availability (LARS)

Factors relating to the availability of LARS service.

Example: LARS controller is too busy to provide a service to pilot, who then has an Airprox due to reduced situational awareness.

C.4.1.8 Field of view (Pilot)

Specifically for aircrew, if there are any cockpit/aircraft design limitations that restrict field of view to undermine see and avoid. This includes the use of instrument flying screens, night vision devices where they have impacted field of view, and the location of the pilot within the cockpit relative to the trajectory of the conflict.

Example: The aircraft configuration reduced visibility.

C.4.1.9 Conflict geometry

This includes aircraft approaching each other on reciprocal or constant bearings which can lead to aircraft appearing stationary and therefore more difficult to detect.

Example: Conflict geometry of the encounter made it difficult for the pilots to visually acquire each other.

C.4.1.10 Terrain

Factors relating to the terrain such as reduced time to visually acquire another aircraft as it is shielded by terrain.

Example: Snow covering the fields made seeing other aircraft more difficult.

C.4.2 Weather

C.4.2.1 Light conditions

Factors involving ambient brightness or darkness. This includes having vision obscured because of flying into the sun.

C.4.2.2 Visibility

Factors involving fog or other obscuration phenomena, including ceiling, reported visibility, runway visual range, and other factors relating to the greatest distance one can see and identify objects.

In the absence of a separate category for cloud, this was also included under visibility.

C.4.2.3 Precipitation

Factors involving rain, hail, snow, sleet, or similar phenomena. This includes rain, hail, snow, or sleet in the aircraft operating environment including airport and flight environment.

C.4.2.4 Wind

Factors involving the movement of air relative to the surface of the earth, include crosswinds, headwinds, tailwinds, gusts, wind shear, microbursts, clear air turbulence, and mountain waves.

C.4.2.5 Temperature

Factors involving heat or cold that affect systems or human performance.

C.4.3 Special Events

C.4.3.1 Military exercise

Factors relating to military exercises.

C.4.3.2 Flight check

Factors relating to the certificating authority's verification of navigation aids and facilities. This includes ILS calibrations or Area Navigation (RNAV) approach verifications.

C.4.3.3 Emergency services

Factors related to expedited handling of priority medical aircraft.

C.4.3.4 Air policing

This includes law enforcement activities as well as traditional air policing.

Example: Military planes flying at increased speed due to terrorist threat.

C.4.3.5 Parachute

Factors related to parachute jumps.

C.4.3.6 Balloon

Factors relating to lighter-than-air vehicles.

C.4.3.7 Low flying

Including low level photography missions and low flying military.

C.4.3.8 Pipeline inspection

Including pipeline and power line inspection.

C.4.3.9 Civil event

Factors related to special events not specifically pertaining to aviation, includes events such as coordinated flyovers at sporting events or flight restrictions imposed for security of large public events.

C.4.3.10 Model Flying

Factors related to the flying of model aircraft (remote controlled).

C.4.3.11 Air show

Factors related to large congregations of aircraft for the purpose of promoting aviation.

Also used for aircraft positioning for, and holding prior to, an air show or completing aerobatics.

C.4.4 Emergencies

C.4.4.1 Emergencies

Factors related to non-routine, unplanned occurrences involving some level of system degradation, equipment malfunction, operator incapacitation, or environmental circumstances, such that it requires immediate corrective action to restore safety of the flight or operation.

Emergencies include aircraft security events, controller declared emergency landings, expedited handling, operator- or pilot-declared emergencies, aircraft technical emergencies, and medical emergencies. There are also included under this discipline other circumstances requiring immediate or expedited corrective action, including items such as weather avoidance, traffic collision avoidance, and ground proximity warning. This would also include natural disaster assessment.

D Additional Taxonomy Categories

Having completed the analysis, it was felt that some new elements could be added to strengthen the taxonomy for use in the future. These were:

- Individual/HF; Procedural/task performance; Effective avoiding action (ATC)
- Individual/HF; Procedural/task performance; Application of rules of the air (Pilot)
- Individual/HF; Procedural/task performance; Effective integration into the visual circuit
- Individual/HF; Perceptual; Incorrect assumption (Pilot)
- Individual/HF; Perceptual; Incorrect assumption (ATC)
- Operating environment; Special events; Gliding
- Operating environment; Special events; Gliding (winching)
- Operating environment, Special events; Model aircraft
- Operating environment, Special events; UAS
- Operating environment; Weather; Cloud
- Equipment Factors; Aircraft systems; HMI
- Equipment Factors; ANSP systems; HMI

E Full Results

E.1 High-level Domains

As described in Section 2, the taxonomy contained four high-level domains. Figure 22 below depicts the split between Individual/Human Factors, Organisational Factors, Equipment Factors, and Operating Environmental Factors.

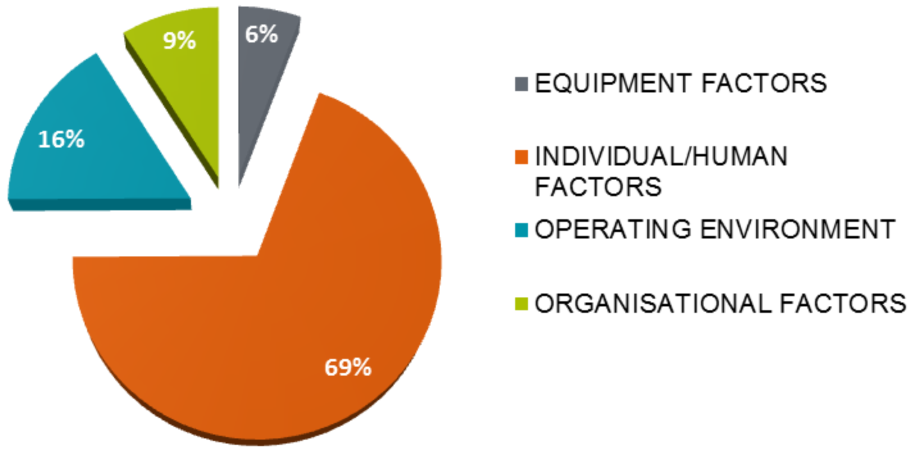


Figure 22: High-level Domains

E.2 Contributory Factors

A total of 137 different contributory factors were coded into the database. The top 20 most prevalent contributory factors are depicted in Figure 23 below:

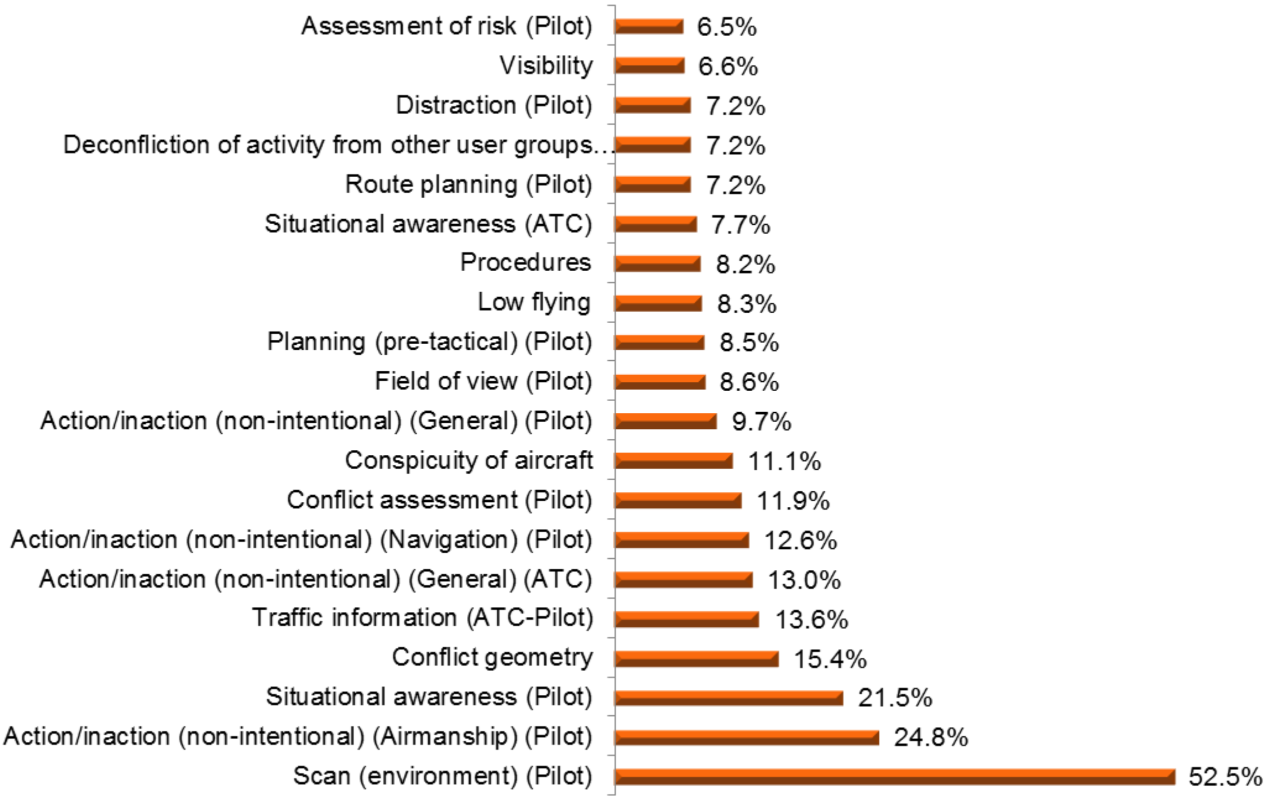


Figure 23: Top 20 Contributory Factors

E.3 Contributory Factors – Pilot

The top 10 contributory factors associated with pilots are depicted in Figure 24 below.

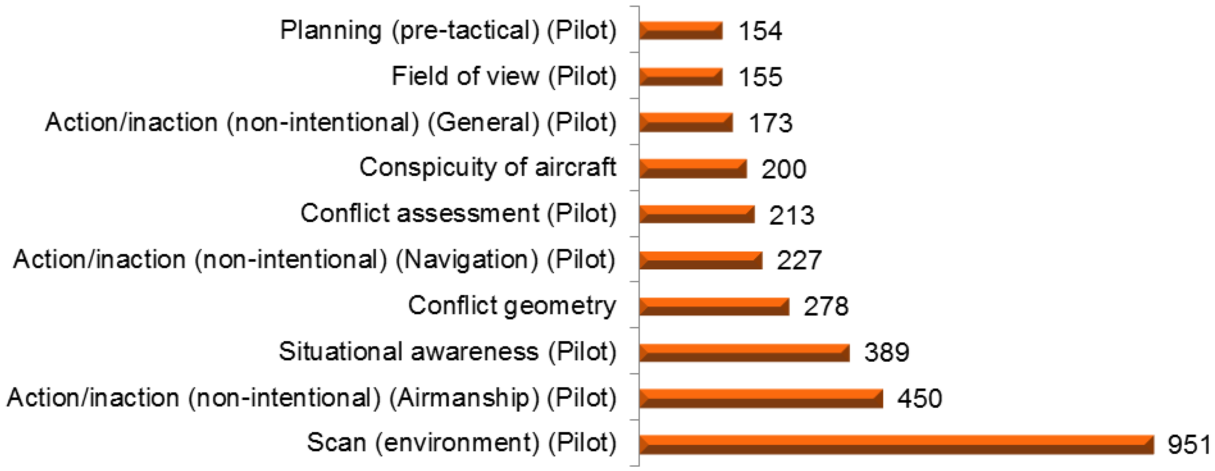


Figure 24: Top 10 Contributory Factors – Pilot

Scan (environment) (Pilot)

The most prevalent causal factors noted by the UKAB are 'did not see traffic' and 'late sighting of traffic'. As expected, this is consistent with the key contributory factor of 'Scan (environment) (Pilot)' which occurred in 52% of the reports. This category was not just applied where the pilot may not have had an effective scan technique but also where, due to other circumstances, their ability to scan effectively was compromised. For example, the ability to scan effectively was reduced due to high terrain in the vicinity which led to a late sighting of an aircraft on a conflicting trajectory.

Action/inaction (non-intentional) (Airmanship) (Pilot)

Action/inaction (non-intentional) (Airmanship) (Pilot) relates to a non-intentional behaviour which was contrary to applicable regulations and/or policies related to action, series of actions, or the lack of action. Poor airmanship is related to an individual's assessment of risk and appreciation of how pilot's own behaviour impacts on others. This occurred in 25% of reports and was applied frequently where a pilot flew in close proximity to another such that it caused alarm to the other pilot.

Situational Awareness (Pilot)

This is the perception of environmental elements with respect to time and/or space, the comprehension of their meaning and the projection of the status after some variable has changed, such as time. Behaviours related to situational awareness include an individual's perception of the conditions or changes in their operational environment and are often described in relation to decision making or actions. Situational awareness includes the loss or incomplete perception of or changes to elements present in an individual's operational environment and includes an individual's ability to maintain a high level of vigilance.

This element occurred in 21% of the airprox reports and was applied in situations such as late or no position reporting from other aircraft which resulted in a loss of situational awareness.

Conflict Geometry

Conflict geometry occurred in 15% of the airprox reports and includes such things as aircraft approaching each other on reciprocal or constant bearings which can lead to aircraft appearing stationary and therefore more difficult to detect.

Action/inaction (non-intentional) (navigation) (Pilot)

Action/inaction (non-intentional) (navigation) (Pilot) occurred in 12.5% of the reports and included an inability to navigate along a planned route and therefore flew in close proximity to an ATZ or glider site without realising.

Conflict assessment (Pilot)

Conflict assessment is an individual's assessment of the conflict geometry/speed and occurred in 12% of the airprox reports. This was typically applied where a pilot misjudged the conflict and therefore did not take action in sufficient time to avoid the airprox. Whilst this figure may appear to be relatively high, it must be viewed in the context that the airproxes themselves only account for a small number of the overall flights occurring in Class G airspace.

Conspicuity

Conspicuity is related to the visual conspicuity of the aircraft or the ability of surveillance systems to detect and display the aircraft and occurred in 11% of the airprox reports.

Action/inaction (non-intentional) (general) (Pilot)

Action/inaction (non-intentional) (general) (Pilot) relates to a non-intentional behaviour contrary to applicable regulations and/or policies. This element occurred in 9.5% of the airprox reports and was applied frequently where pilots did not implement the rules of the air correctly.

Field of view (Pilot)

Field of view (Pilot) occurred in 8.5% of the airprox reports and relates to any cockpit/aircraft design limitations that restrict field of view to undermine see and avoid. This includes the use of instrument flying screens, night vision devices when they impacted field of view, and the location of the pilot within the cockpit relative to the trajectory of the conflict.

Planning (pre-tactical) (Pilot)

Planning (pre-tactical) (Pilot) relates to the planning or preparation of operational tasks. This refers to tasks such as performance calculations, weight and balance calculations, weather planning, flight planning, navigational planning, traffic management planning, arrival and departure sequencing, and fuel planning. This element occurred in 8.5% of the airprox reports and was typically applied for poor route selection/planning and not checking current NOTAMs.

E.4 Contributory Factors – Pilot User Groups

In addition to reporting the overall contributory factors for pilots, it was useful to consider if there were any differences between the following user groups: General Aviation (GA), Military, and Commercial Air Transport (CAT). The total number of factors for each user group is as follows:

- GA 4089;
- Military 2755;
- CAT 230.

The top 5 contributory factors for each of the main user groups are depicted in Table 13 below. The percentages relate to the proportion of the individual user groups total contributory factors.

GA	Military	CAT
Scan 20.4%	Scan 20%	Scan 16.1%
Airmanship 7.7%	Low flying 7.4%	Situational Awareness (Pilot) 9.6%
Conflict Geometry 6.9%	Situational Awareness (Pilot) 6.4%	Conflict Assessment (Pilot) 9.1%

Situational Awareness (Pilot) 6.8%	Conflict Geometry 6.3%	Visibility 5.7%
Navigation 3%	Airmanship 4.6%	Conflict Geometry 5.2%

Table 13: Top 5 contributory factors - percentage of causal factors within the individual user group

It is difficult to make a direct comparison with CAT due to the small sample size but it is interesting to note that 9.1% of their factors relate to poor conflict assessment. One possible explanation for this is the difficulty in anticipating the evolution of a situation based solely on the ACAS traffic display.

The other noticeable variation in the table is the contribution of low flying (7.4%) in military incidents. This factor was attributed to an incident where the low flying activity itself placed the aircraft in conflict with another aircraft operating low level.

E.5 Contributory Factors – ATC

The top 10 contributory factors associated with ATC are depicted in Figure 25 below.

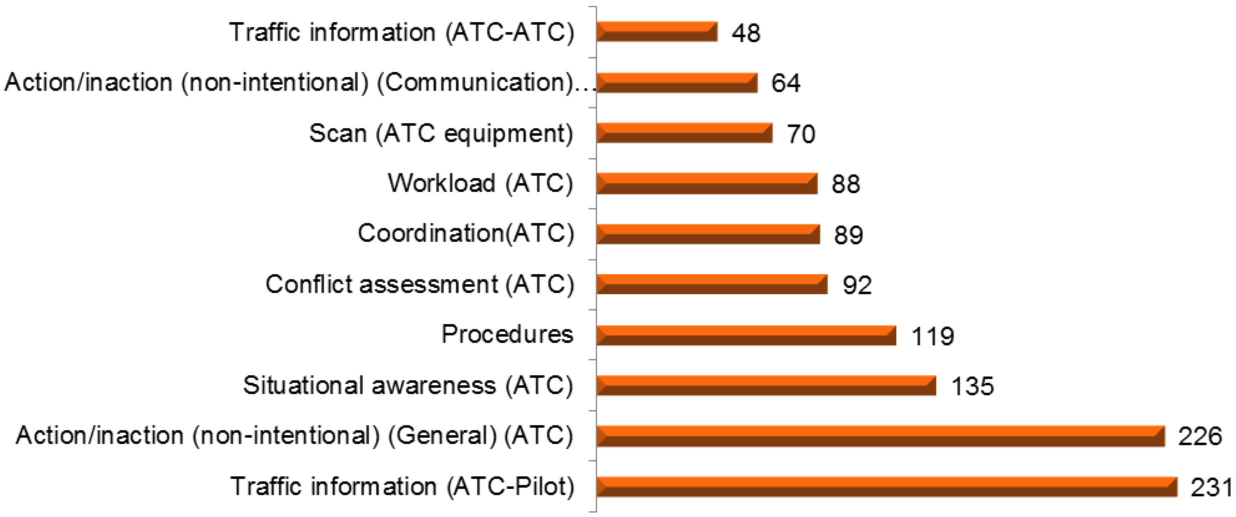


Figure 25: Top 10 Contributory Factors – Number of occurrences ATC

Traffic information (ATC-Pilot)

This was the most common ATC contributory factor (13% of the airprox reports) and relates to the timeliness and accuracy of traffic information passed between ATC and the pilot.

Action/inaction (non-intentional) (General) (ATC)

This category occurred in 12.5% of the airprox reports and relates to non-intentional behaviour contrary to applicable regulations and/or procedures. This category was applied where controllers did not apply air traffic services outside controlled airspace (UK FIS) in accordance with CAP 774 [4].

Another common usage was when the controller did not plan effectively and this contributed to the aircraft coming into close proximity with each other.

Situational awareness (ATC)

Situational awareness (ATC) occurred in 7.5% of the airprox reports and was included in both surveillance and aerodrome activities. A common application was a lack of situational awareness when providing a PS due to incorrect/inaccurate/late position reporting and also unknown aircraft in the vicinity.

Procedures

This element occurred in 6.5% of the airprox reports and relates to the procedures of the organisation. The ‘procedures’ element was typically applied where local procedures were not as robust as they could have been. In particular this was often a lack of effective deconfliction procedures between adjacent units or user groups.

Conflict assessment (ATC)

This relates to an individual’s assessment of the surveillance/procedural information available or what can be deduced visually. ATC conflict assessment occurred in 5% of the airprox reports and was typically applied where the controller did not identify the emerging conflict and therefore did not provide effective separation between aircraft.

Coordination (ATC)

Coordination occurred in 5% of the airprox reports and relates to the transfer of information among air traffic controllers related to the movement of aircraft or the use of airspace. Poor planning and misunderstandings were typical examples which led to ineffective coordination.

Workload (ATC)

Workload was a factor in 5% of the airprox reports and was a factor in both surveillance and aerodrome ratings. A common application of this element was where controllers were in a bandboxed configuration and the handling of multiple UHF and VHF frequencies became problematic.

Scan (ATC)

Scan relates to the systematic observation of the operational environment by an ATCO or Flight Information Service Officer (FISO) and includes task monitoring, monitoring aeronautical information, surveillance displays and aircraft in the visual circuit. Poor scan was a factor in 4% of the airprox reports and usually occurred in the surveillance rating.

Action/inaction (non-intentional) (Communication) (ATC)

This element relates to a range of behaviours such as misspeaking, vague/ambiguous instructions, and mishearing and was a factor in 3.5% of the airprox reports.

Traffic Information (ATC-ATC)

This relates to internal controller-to-controller traffic information to aid in building up their situational awareness and to determine if coordination is required. A typical example would be the lack of traffic information shared between adjacent units to the detriment of each other's situational awareness and therefore their ability to provide the highest levels of service. This contributory factor occurred in 2.6% of the airprox reports.

E.6 Key contributory factors over time

Due to the small sample size (110 to 162) of reports for each individual year, it is difficult to draw any meaningful conclusions from the data. The contributory factors are expressed as a percentage of the total number of airproxes for that particular year to remove the error caused by fluctuations in reporting rates. In Figure 26 below, Scan, Navigation, and Conspicuity elements have no discernible trends. The amount of factors attributed to pilot situational awareness appears to have increased since 2005. However, there is no discernible rationale to explain this as improvements in technology should have, at worst, maintained the status quo. Possible explanations may include a subtle change in the style and content of the reports themselves, which enabled more detailed coding to be made over the past 8 years or simply a result of the small sample size.

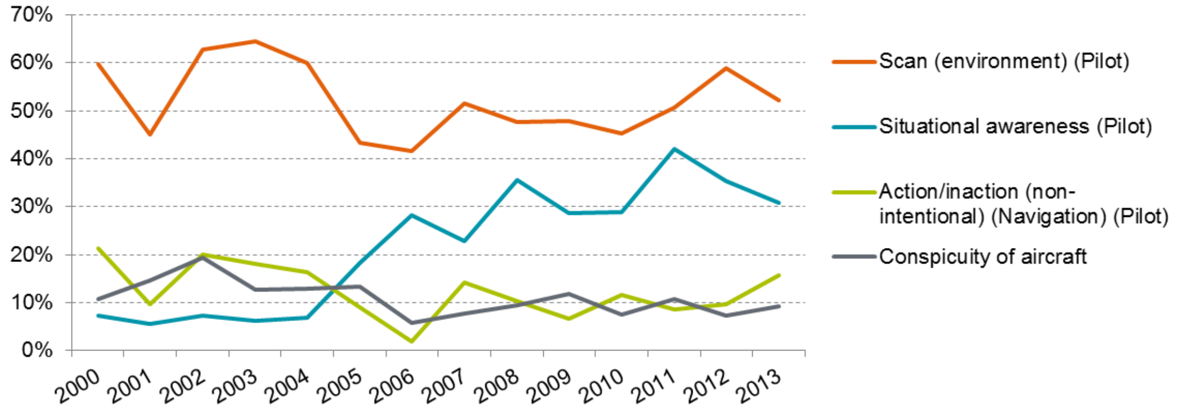


Figure 26: Changes over time I

Figure 27 below considers airmanship, conflict geometry, conflict assessment, and general inaction by the pilot. No trends are identifiable other than the rates remaining plus or minus 8% of the average.

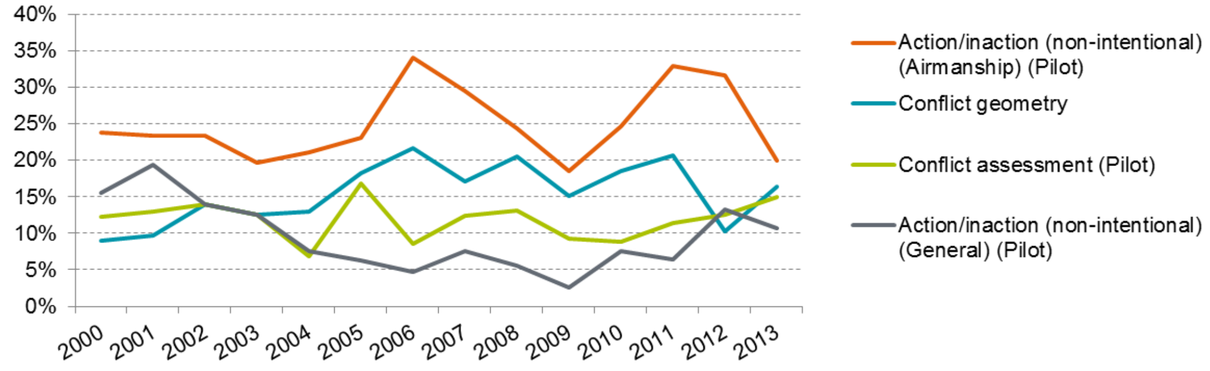


Figure 27: Changes over time II

Figure 28 below depicts the two key ATC contributory factors, traffic information and general inaction over time. These factors account for less than 20% of the reports which means the sample size is less than 40 reports each year. There are no discernible trends over time.

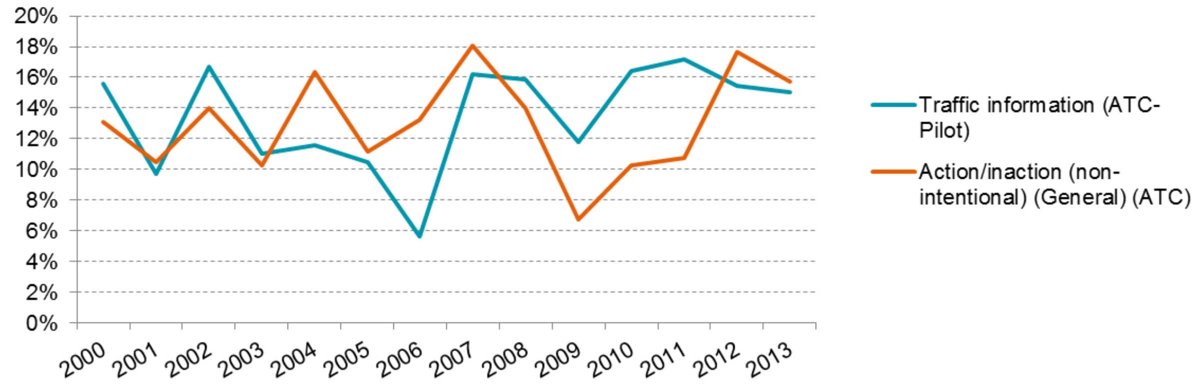


Figure 28: Changes over time ATC

E.7 Contributory Factors by Aircraft Category

The following UKAB aircraft categories are the 6 most significant in the airprox database in terms of number of reports:

- Piston powered <45ft (wingspan);
- Helicopter;
- Jet powered >90ft;
- Jet powered <45ft;
- Jet powered 45-90ft;
- Glider.

Table 14 below depicts the key contributory factors by aircraft category

Piston powered <45ft 2788 contributory factors	Helicopter 1455 contributory factors	Jet powered >90ft 112 contributory factors	Jet powered <45ft 488 contributory factors	Jet powered 45-90ft 1197 contributory factors	Glider 388 contributory factors
Scan Pilot	Scan Pilot	Scan Pilot	Scan Pilot	Scan Pilot	Scan Pilot
21.1%	18.0%	9.8%	21.9%	20.0%	22.9%
Airmanship	Conflict Geometry	Conflict assessment	Low flying	Low flying	Conspicuity
8.7%	7.1%	8.9%	9.4%	8.2%	20.6%
Situational awareness pilot	Airmanship	Navigation	Situational awareness pilot	Conflict geometry	Conflict geometry
8.1%	5.8%	6.3%	7.2%	5.5%	12.1%
Conflict geometry	Situational awareness pilot	Visibility	Conflict geometry	Situational awareness pilot	Situational awareness pilot
6.7%	5.8%	6.3%	6.6%	5.2%	4.1%
Navigation	Field of view	Perception bias pilot	Terrain	Airmanship	Transponder availability
3.9%	3.5%	5.4%	4.9%	4.7%	4.1%
Field of view	Visibility	Situational awareness	Airmanship	Conflict assessment pilot	Deconfliction of activity
3.0%	3.4%	4.5%	4.7%	3.3%	3.4%
General inaction pilot	Low flying	Pilot ATS selection	General inaction pilot	Aircraft speed	Conflict assessment pilot
2.7%	3.4%	3.1%	3.3%	3.1%	2.8%
Pre-tactical planning	Conflict assessment pilot	Confusion with service provided	ACAS availability	General inaction pilot	Airmanship
2.7%	2.9%	4.5%	2.5%	2.9%	2.8%
Conflict assessment pilot	Pre-tactical planning	Understanding of procedures pilot	Deconfliction of activity	Workload	Visibility
2.6%	2.9%	3.6%	2.5%	2.9%	2.6%
Visibility	Navigation	Route planning pilot	Navigation	Visibility	Traffic density
2.5%	2.7%	2.7%	2.3%	2.8%	2.1%

Table 14: Top 10 contributory factors - percentage of causal factors within the individual aircraft group

As expected the following key contributory factors identified in the top 20 (Section 4.2) are evident across the majority of aircraft groups:

- Scan (environment) (Pilot);
- Airmanship;
- Situational awareness;
- Conflict geometry.

However, poor airmanship is noticeably absent from Jet powered >90ft and relatively low for Gliders although this may be, in part, due to the small data sets for these two groups.

The significant difference across aircraft groups is conspicuity accounting for 20.6% of contributory factors in glider airprox.

E.8 Contributory Factors by Altitude

The following altitudes are the 4 most prevalent where airproxes are likely to occur:

- FIR-3000ft;
- ATZ;
- 3001ft-FL79;
- FL80 and above.

Table 15 below depicts the 5 key contributory factors by altitude.

FIR-3000ft 3419 contributory factors	**ATZ** 1043 contributory factors	**3001ft-FL79** 958 contributory factors	**FL80 and above** 412 contributory factors
Scan pilot	Scan pilot	Scan pilot	Scan pilot
22.1%	15.7%	21.4%	17.5%
Conflict geometry	Situational awareness	Situational awareness	Situational awareness
8.4%	11.6%	7.0%	6.8%
Airmanship	Airmanship	Conflict geometry	Conflict assessment pilot
6.5%	10.8%	6.3%	5.3%
Situational awareness	Inaction general pilot	Airmanship	Airmanship
5.9%	5.3%	5.3%	4.6%
Conspicuity	Navigation pilot	Conspicuity	Conflict geometry
3.7%	5.1%	5.2%	4.4%

Table 15: Top 5 contributory factors - percentage of causal factors within the height bands

E.9 Contributory Factors by Flight Phase

The following flight phases are the three most prevalent where airproxes are likely to occur:

- Level cruise;
- Circuit;
- En-route descent to 1500ft.

Table 16 below depicts the 5 key contributory factors by flight phase.

Level cruise 2319 contributory factors	**Circuit** 641 contributory factors	**En-route descent to 1500ft** 340 contributory factors
Scan pilot	Scan pilot	Scan pilot
21.3%	19.3%	22.9%
Conflict geometry	Situational awareness	Situational awareness
8.3%	12.8%	7.9%
Airmanship	Airmanship	Visibility
7.6%	10.9%	7.1%
Situational awareness	Inaction general pilot	Airmanship
5.9%	5.9%	5.9%
Navigation	Conflict geometry	Conflict geometry
4.4%	5.3%	5.6%

Table 16: Top 5 contributory factors - percentage of causal factors within the flight phase bands

The main difference across the three phases of flight is the impact of visibility (7.1% of causal factors) for aircraft descending to 1500ft. This was typically due to cloud impacting effective scan and conspicuity of other aircraft.

F Airprox Risk Factor analysis

Using the three main risk categories (A-C), it was possible to assess the relative impact of the top 15 contributory factors. The results are depicted in Table 17 below.

	Risk category		
Contributory factor	**A**	**B**	**C**
Scan (environment) (Pilot)	16%	16%	9%
Situational awareness (Pilot)	6%	5%	5%
Action/inaction (non-intentional) (Airmanship) (Pilot)	4%	5%	7%
Conflict geometry	6%	5%	2%
Conspicuity of aircraft	3%	4%	2%
Traffic information (ATC-Pilot)	3%	3%	3%
Action/inaction (non-intentional) (Navigation) (Pilot)	2%	3%	3%
Field of view (Pilot)	3%	3%	1%
Distraction (Pilot)	3%	2%	1%
Action/inaction (non-intentional) (General) (ATC)	2%	2%	4%
Low flying	3%	2%	2%
Action/inaction (non-intentional) (General) (Pilot)	2%	2%	2%
Planning (pre-tactical) (Pilot)	1%	2%	2%
Workload (Pilot)	2%	2%	1%
Route planning (Pilot)	1%	2%	2%

Table 17: Top 15 contributory factors by risk category A-C

F.1 Barrier components

Using the three main risk categories (A-C), it was possible to assess the relative impact of the top 15 unsuccessful barrier components. The results are depicted in Table 18 below.

	Risk category		
Unsuccessful barrier	**A**	**B**	**C**
Effective situational awareness and/or see & avoid	22%	28%	21%
Flight crew observes visible aircraft in time	14%	6%	4%
Flight crew initiates effective avoiding action	11%	6%	2%
Other aircraft is visible to the flight crew	9%	5%	5%
Effective airmanship skills	7%	10%	13%
ATCO provides effective service	4%	5%	8%

	Risk category		
Unsuccessful barrier	**A**	**B**	**C**
Effective navigation	4%	6%	7%
Effective application of procedures	4%	5%	5%
ATCO detects potential pilot or controller induced conflict	3%	4%	5%
ACAS is installed and functional	3%	2%	1%
ATCO implements effective resolution	3%	3%	5%
Procedures to reduce risk	2%	4%	4%
Pilot briefing	2%	3%	4%
Adequate surveillance picture	2%	1%	2%
Cued awareness enables visual acquisition	2%	2%	1%

Table 18: Top 15 unsuccessful barrier components by risk category A-C

G Airprox Reports – Suggested Recommendations

G.1 Observations of existing reporting mechanism

Critical to the success of this review was the quality of information contained in the airprox reports. It was evident that the content of the reports had evolved over the past 14 years as safety management systems had matured and there was increasing efforts to determine the contributory factors in addition to identifying a specific cause.

The airprox reports make an assessment of risk based on the specific event. This is useful in understanding the actual level of risk that a collision may have occurred. However, such an assessment does little to aid understanding of what barriers or controls were unsuccessful. For example, the aircraft may have been separated by 200ft vertically and a quarter of a mile laterally and therefore there was no actual risk of collision (Risk Cat C) but neither pilot was aware of the other until they had passed each other and therefore all barriers were unsuccessful in some way. It was only by chance that a MAC did not occur and this would not necessarily be reflected in the risk classification.

To further illustrate the point, a PA 30 transited through an active glider site below the cable winch height whilst a launch was already in progress. The PA 30 pilot was not aware of the winch but did see a glider above. By chance the PA 30 was laterally displaced from the winch cable and there was no risk of collision with the glider above. This event was recorded as ‘no risk of collision’ (Cat C) which was true but it does not aid a broader understanding of the situation in terms of the absence of any mitigation preventing a MAC other than providence.

Some of the causal factor descriptions also do little to promote a broader understanding of the event. For example:

- FIR conflict;
- Conflict in other type of airspace;
- Flew too close

Monitoring the trend in FIR conflicts will provide insufficient information on how to proactively manage the risk in the future. It also doesn’t aid our understanding of whether specific initiatives have been successful. A particular trend may go down but there is not necessarily a documented or identifiable link to the initiative itself.

Whilst the contributory factors are discussed in many of the reports they are not formally captured so that trends can be identified and monitored. Additionally, there is little reference to the successful events that mitigated risk and so our understanding of what is working effectively is less well understood.

Finally, whilst some recommendations are made within the reports to help prevent a reoccurrence there is no formal assessment within each report as to the repeatability of an event (likelihood of reoccurrence).

G.2 Recommendations

Contributory factors

Having developed a database containing the specific contributory factors for each airprox between 2000 and 2013 there is an opportunity to conduct further analysis in specific areas. The database contains all the information from the Joint Airprox Reporting System (JARS) and so cross comparison of the data can be completed. Whilst a large amount of analysis was completed in the production of this report there are many more ways in which the data can be used in the future. This could range from looking at specific geographical areas to individual user groups or aircraft types.

It is recommended that, following some adjustments to the taxonomy (see Annex D), it continues to be used to categorise and record contributory factors for all classifications of airspace. Experts on the UKAB already discuss and agree the contributory factors when each incident is reviewed and so this is an ideal time to formally record the outcome. The UKAB may decide to use a new database in the future in which case the data should still be of use as the terminology is consistent with that used by ICAO and EUROCONTROL.

Causal factors

The current list of causal factors assigned by the UKAB does not necessarily promote a broader understanding of the airprox itself or enable meaningful trend analysis. It is recommended that the list of causal factors is updated, in line with the terms used in a common taxonomy such as the one developed by EASA - European Co-ordination Centre for Aviation Incident Reporting System (ECCAIRS). Again this could be used going forward for use across all classifications of airspace. Adoption of a common taxonomy would have the added benefits of enhancing common data sharing and benchmarking.

Barrier model

Some consideration could be given to developing the barrier model further and linking occurrences to barriers in the future. This would provide an indication of the number of barriers available and which ones were unsuccessful or successful. This would promote a greater understanding of risk and could complement the existing risk classification scheme. It would also aid analysis of the effectiveness of safety initiatives.

The airprox reports were never designed to capture information on barriers or ‘controls’ in the past and so there are undoubtedly some significant gaps in the data, particularly in terms of successful barriers. Furthermore, there is little information about the effectiveness of the strategic factors that influence risk. These are important factors that underpin the safe operation of flight. A slight restructuring of the report forms would enable some of this information to be captured at source without making the reporting process too cumbersome.

It is recommended that the airprox reporting system endeavours to capture the barriers that are available along with which components were successful or unsuccessful.

Risk analysis

Consideration should be given to utilising additional methods to assess risk. Use of the Risk Analysis Tool (RAT) developed by EUROCONTROL would aid the assessment of severity and risk and improve on the current risk descriptions. It would also allow the analysis of a single event in order to understand the factors involved and then place the event in context with other events. The tool may not fully capture some of the nuances of Class G airspace as it is used in the UK but there are still some useful applications that aid the understanding of risk.

The RAT defines the severity of an incident as a combination of the objective safety margin lost (separation achieved and rate of closure) and the controllability of the occurrence. In general, the less controllable an occurrence is, the fewer barriers that may have been available and/or the more that were unsuccessful.

An example of the type of barriers assessed using the RAT is illustrated in Figure 29 below. The figure also aims to provide a graphical illustration of how some of the risk analysis activities are linked together. This includes the use of a common taxonomy to capture contributory factors whilst also capturing the effectiveness of the strategic factors that influence the barriers. The Barriers in this example are slightly different[11] from those in the model developed for this paper but the existence of strategic, tactical and recovery events are still evident.

[11] The barriers cover all classifications of airspace as opposed to Class G alone.

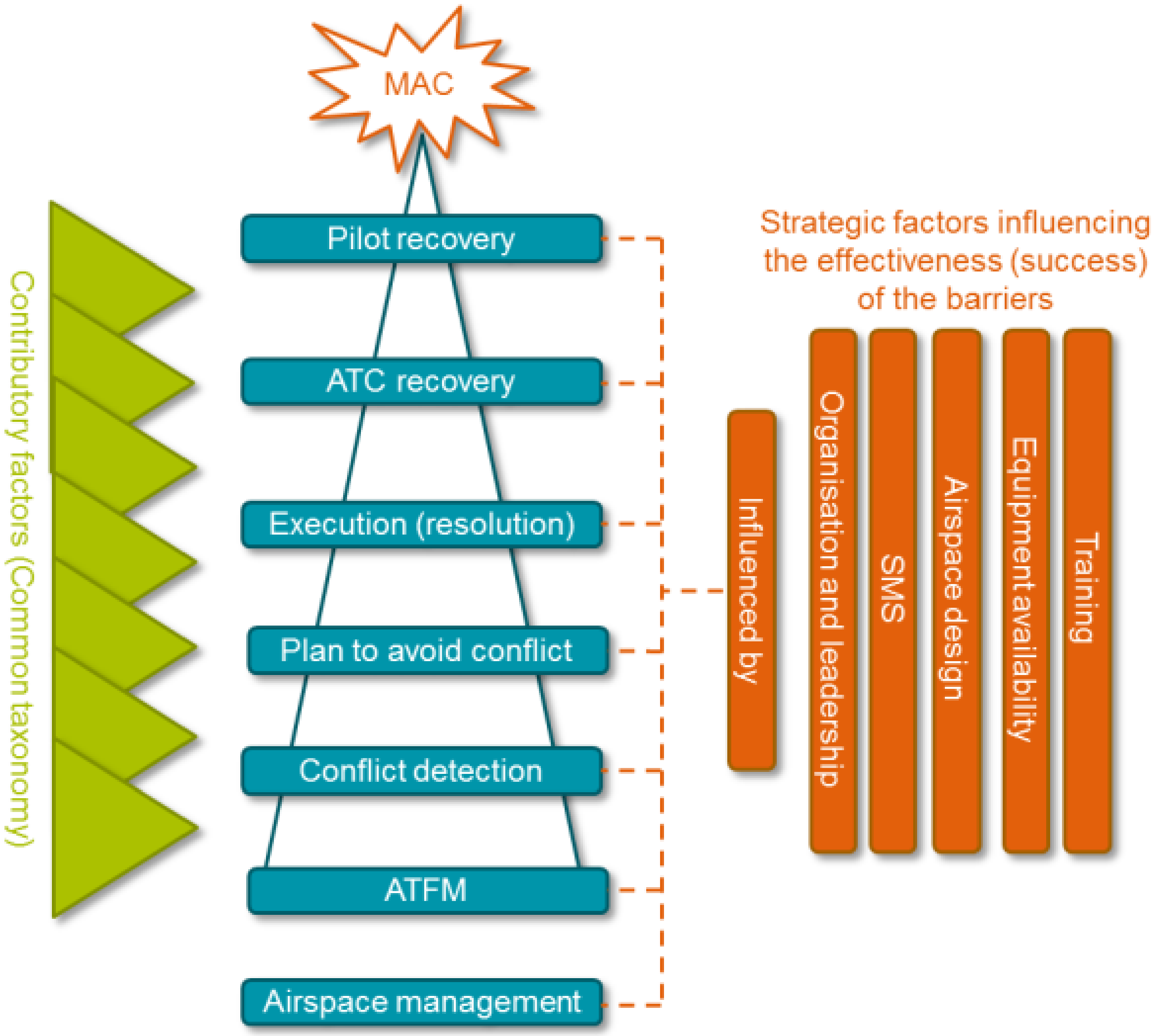


Figure 29: Assessment of contributory factors and monitoring of barriers using the Risk Analysis Tool

Repeatability

As part of the UKAB assessment process of each incident, it is recommended that they consider the probability that it could occur again. The RAT could assist with this analysis as it also looks at repeatability and then draws a relationship between the outcome of the analysis and the risk classification matrix.

The UKAB currently make recommendations aimed at preventing reoccurrence of some events but the likelihood of reoccurrence is not currently documented and monitored.

Complete risk picture

Figure 30 below indicates a typical iceberg relationship (Heinrich's Model) whereby there is a decreasing frequency of occurrence the higher up the pyramid we travel.

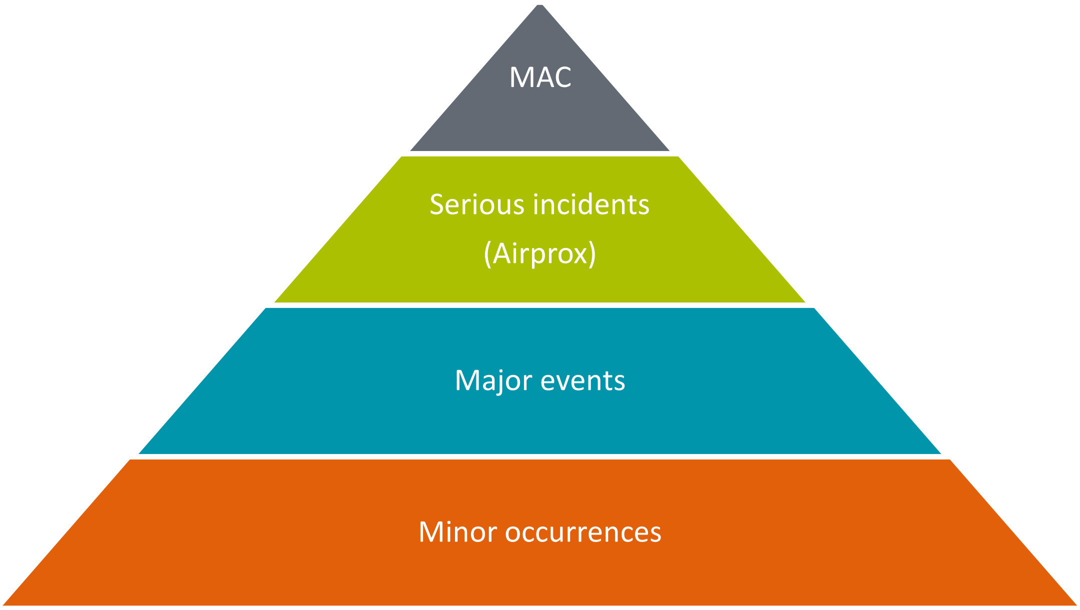


Figure 30: Example relationship of incident severity and occurrence rates

In addition to recording serious incidents there may be added value in recording more minor events in the same database, or at least within the same department, to enable trend analysis and risk management across a broader spectrum of events. Specific causal factors identified in airprox reports could be monitored at a lower level where the size of the data sample may be greater. Some of the most common errors will be at the minor occurrence level and the CAA has already established a robust reporting culture such as Mandatory Occurrence Reporting to aid the capture of data at this level. At present the UKAB has a very specific focus on one area of the pyramid but there may be value in broadening its role into something that provides a more comprehensive and integrated role in the management of safety.

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I Abbreviations

ACAS	Aircraft Collision Avoidance System
ASI	Airspace and Safety Initiative
ATC	Air Traffic Control
ATCO	Air Traffic Control Officer
BS	Basic Service
CAA	Civil Aviation Authority
CANP	Civil Aircraft Notification Procedures
CAT	Commercial Air Transport
CRM	Crew Resource Management
DS	Deconfliction Service
EASA	European Aviation Safety Agency
FAS	Future Airspace Strategy
FISO	Flight Information Services Officer
GA	General Aviation
IMC	Instrument Meteorological Conditions
JARS	Joint Airprox Reporting System
MAA	Military Aviation Authority
MAC	Mid Air Collision
MOD	Ministry of Defence
NOTAM	Notice to Airmen
PINS	Pipeline Inspection Notification System
PS	Procedural Service
PSR	Primary Surveillance Radar
STCA	Short Term Conflict Alert
TAS	Traffic Avoidance System
TCAS	Traffic Collision Avoidance System
TS	Traffic Service
UHF	Ultra High Frequency
UKAB	UK Airprox Board
UK FIS	UK Flight Information Service
VHF	Very High Frequency