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UAS Safety in Non-segregated Airspace

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1. Introduction

Unmanned Aerial Systems (UAS) are set to become part of everyday air traffic operations perhaps within the next few years; however there are significant challenges that need to be addressed in order to seamlessly introduce UAS into non segregated airspace. This chapter discusses some of the identified safety challenges in achieving this objective in the context of the current regulatory framework. It also takes a look at how one might rigorously argue the safety of UAS operations in non-segregated airspace from an Air Traffic Management (ATM) perspective. The chapter draws upon the experience of the authors' in the UAS domain, more specifically the lessons learnt from a number of safety assessments for flying UAS as Operational or General Air Traffic (OAT or GAT) inside and outside segregated airspace.

Most UAS operations are currently constrained to designated danger areas or within temporary restricted areas of airspace, commonly known as segregated airspace, or are flown under special arrangements over the sea. On some occasions, UAS operations are permitted in an extremely limited environment outside segregated airspace. To exploit fully the unique operational capabilities of current and future UAS and thus realise the potential commercial benefits of UAS, there is a desire to be able to access all classes of airspace and operate across national borders and airspace boundaries. Such operations must be acceptably safe but regulation should not become so inflexible or burdensome that the commercial benefits are lost.

The viability of the commercial market for UAS especially in the civil market is heavily dependent on unfettered access to the same airspace as manned civilian operations. Whilst it is essential that UAS demonstrate an equivalent level of safety compared to manned operations the current regulatory framework has evolved around the concept of the pilot-in-the-cockpit. There is a need to develop UAS solutions that assure an equivalent level of safety for UAS operations, which in turn will require adaptation of the current regulatory framework to allow for the concept of the pilot-not-in-the-cockpit without compromising the safety of other airspace users.

One of the major issues facing UAS operations is the demonstration of equivalence (in particular for See and Avoid) in the context of an evolving ATM environment. It is very important to understand that the current ATM environment is not static. Achieving equivalence with manned operations is not a fixed target as there are many significant changes proposed that aim to improve operational efficiency and performance or enhance safety. On the whole proposed changes to the ATM environment could be seen as

advantageous to UAS operations as more and more functions within the environment are automated thus there is a significant opportunity for the UAS industry to influence the shape of the future ATM environment to support wider UAS operations.

Assuring the safety of UAS operations in non-segregated airspace will therefore require a significant update to key elements of extant regulations and standards. UAS have yet to establish a good safety record¹ and there are many challenges both regulatory and technological to be resolved before such operations can become common place. Without a coherent regulatory framework (i.e. regulations, standards, etc.) for certifying UAS such systems must be argued as acceptably safe within the context of the whole operational Air Traffic environment². However, regulators are taking steps towards providing this infrastructure. Wider and more detailed regulations and standards will likely form around the technologies that become available to resolve the operational and safety issues that UAS operations must address.

2. Current Regulatory Framework

2.1 Overview

The regulatory context for UAS operations in non-segregated airspace can be split into three main considerations; certification of air vehicle airworthiness, safe provision of air traffic services and licensing of operators, pilots, etc. Most of the regulatory work carried out to date has focussed on airworthiness certification as well as the licensing of UAS Pilots. There is also a need for regulation to include the Air Traffic Management environment and for the co-ordination of all regulatory activities, a point noted by EASA in a recent regulatory consultation paper (EASA A-NPA, 2005) to ensure the safety of air travel as a whole.

However, the regulatory framework is changing rapidly especially with respect to integration of UAS into the air traffic management environment, (Degamo, 2004) suggests that whilst the United States leads in UAS technology developments, they apparently lag behind the UK and Europe in legislative activities relating to Unmanned Aerial Vehicles (UAVs), more specifically they currently have no regulation or guidance for UAS operations; (Degamo, 2004) also provides a good background on UAS issues in general.

2.2 UK Regulations

(CAP722, 2008) provides guidance for UAS operations in UK airspace and has been compiled by the Civil Aviation Authority (CAA) Directorate of Airspace Policy (DAP) to cater for the growing capabilities and anticipated increase of pilotless aerial vehicles. (CAP722, 2008) details the overarching military and civil regulations applicable to UK UAS operation.

In addition, civil certification aspects of UAS are the responsibility of the Design and Production Standards Division of the CAA Safety Regulation Group (SRG). Their position set out within (Hatton & Whittaker, 2002) is that UAS should be granted permission to fly

¹ The current UAV accident rate is 100 times that of manned aircraft. According to US Air Force studies (Degammo, 2004) the accident rate is 50 times greater than for F-16, US commercial aircraft accident rate is 0.06 per million flight hours compared to Global Hawk at 1,600 per million flight hours; very few of these accidents resulted in third party losses.

² When a UAS Sense and Avoid specification is defined within the regulatory framework then it would be sufficient to certify such systems against this specification.

by qualifying for Certificates of Airworthiness by demonstrating compliance with defined airworthiness standards comparable to, and derived from, those applied to manned aircraft.

The principles of the UK Policy for UAS are as follows:

- To operate within existing arrangements and regulations for air traffic
- No automatic right of airspace use
- An equivalent level of certification compliance
- No increased risk to existing users
- Operations must be “transparent”³ to the controller
- Currently flights outside Danger Areas will be in temporary segregated airspace

In addition to the later point rules apply for operations in non-segregated airspace, including carriage of mandated equipment as per manned aircraft and provision of an acceptable sense and avoid system. Other important considerations include UAS control link reliability and security.

2.3 European Regulations

Several European agencies are engaged in activities aimed at the development of rules that can accommodate the Joint Aviation Requirements (JARs) and satisfy member nations’ concerns over UAS safety and usage.

Prior to the formation of the European Aviation Safety Agency (EASA), the Joint Aviation Authorities (JAA) was an associated body of the European Civil Aviation Conference (ECAC) representing the civil aviation regulatory authorities of a number of European States who agreed to co-operate in developing and implementing common safety regulatory standards and procedures. One of the JAAs key functions was to develop and adopt Joint Aviation Requirements (JARs) in the fields of aircraft design and manufacture, aircraft operations and maintenance, and the licensing of aviation personnel. JARs applicable to UAS operations include (JAR 23, 1994 et al).

A Joint JAA/EUROCONTROL initiative on UAS (known as the UAV Task-Force) was established in September 2002 on the basis of a joint decision of the JAA and EUROCONTROL governing bodies. This decision was taken in reaction to the growing European UAS Industry and the recognised need for the authorities to commence work leading to European regulations for civil UAS. The non-existence of such regulations was seen as a major obstacle for further development of European UAS applications. The findings of the Final Report of the UAV-Task Force are documented in (JAA/EUROCONTROL, 2004).

Due to the significant interest in UAS operations shown by EASA, EUROCONTROL, the European Union and other National Organisations, the European Organisation for Civil Aviation Equipment (EUROCAE) set up a Working Group (WG-73 Unmanned Aerial Vehicles) to establish required recommendations and technical standards for UAS. The main objective of WG-73, as set out in (EUROCAE, 2006), is to ensure that UAS can operate safely within the airspace and are compatible with existing infrastructure and related systems and equipments.

³ As defined by (CAP722, 2008) “A controller must not be expected to do anything different using Radio Telephony or landlines than he would for other aircraft under his control. Nor should he have to apply different rules or work to different criteria. UAS must be able to comply with instructions and with equipment requirements applicable to the class of airspace within which they intend to operate.”

2.4 Future Air Traffic Management Environment

It is very important to understand that the air traffic regulatory framework is not static and achieving equivalence with manned operations is not a fixed target. The air traffic environment is constantly subject to changes that aim to improve operational efficiency, interoperability, performance, functionality or enhance safety. The technical changes proposed on the whole could be seen as advantageous to UAS operations as more and more functions within the environment are automated. There is a significant opportunity for the UAS industry to influence the shape of the future air traffic environment to support wider UAS operations. There is also clear evidence that UAS operations are being considered within the scope of some of these changes.

The most comprehensive package of changes proposed over the next 12 years or so is captured by the Single European Sky ATM Research or SESAR programme. The conceptual changes proposed by SESAR for the ATM environment are summarised in the ATM Target Concept (SESAR D3, 2007). There are many proposed changes, too many to describe here, but some may even affect the fundamental concepts in air traffic service provision. The most significant of these are:

- Simplification of the classification of airspace into managed and unmanaged, although managed airspace will also include high-density areas (e.g. around airports), dynamic and variable airspace reservations (known as “Moving ARES”) and delegated separation provision arrangements.
- Introduction of co-operative separation provision and self separation provision modes in controlled airspace based on Airborne Separation Assistance Systems (ASAS) applications.
- Greater deconfliction capabilities, with less reliance on Controllers, allowing the use of Precision Trajectory Clearances, combined with automated trajectory control by speed adjustment.
- Development of Collision Avoidance systems to take into account the changes to separation provision modes highlighted above. Enhancements to Airborne Collision Avoidance System (ACAS) and Short Term Conflict Alert (STCA) are expected to take advantage of the availability of more detailed aircraft information and the sharing of information between ground and airborne surveillance systems.

The deployment timeline for the SESAR changes is documented in the ATM Deployment Sequence (SESAR D4, 2008). It should be noted that all of these ideas are still in research and the case for safety has yet to be made.

3. Operations in Non-Segregated Airspace

UAS operations need to be acceptably safe irrespective of the type of airspace where unmanned air vehicles are flown. UAS operations in designated areas of airspace, from which other air users are excluded, however, can significantly simplify⁴ the problem of justifying that an acceptable level of safety is achieved. The justification becomes more complex when the air vehicle ventures into airspace shared with others, known as non-segregated airspace. The fundamental difference is that in segregated airspace the “system” in which the UAS operates can be bounded, controlled and is often unique to the UAS. In

⁴ Notwithstanding that levels of airworthiness and pilot competence still need to be assured for the UAS, i.e. the air vehicle, its control system and its pilot in command.

non-segregated airspace the UAS must integrate with an air traffic environment developed over decades to support manned aircraft.

To add to the complexity, non-segregated airspace is further classified into seven types; from Class A to Class G, as currently defined by (ICAO Annex 2, 1990) although this may change in the future as part of the Single European Sky initiative. This means that in addition to baseline airworthiness certification, UAS must demonstrate that they:

- Will not undermine the safety of the provision of those services to the UAS or other air users.
- Meet the rules of the air applicable to the meteorological conditions and class of airspace.

Specifically this would include for example:

- Meeting the mandatory equipment requirements for the class of airspace to be flown in (known as Minimum Aviation Specification Performance)⁵
- Interfacing with the existing air traffic services provided in that airspace (eg full air traffic control, flight information service, radar advisory service, etc.)

(ICAO ATM Operational Concept Document, 2003) identifies three main components of Air Traffic Management; Strategic Conflict Management, Separation Provision and Collision Avoidance. Strategic Conflict Management encapsulates all pre-flight planning activities that take place to ensure demand, capacity and conflicts are managed prior to the real time situation. The Strategic Conflict Management component includes pre-flight processes such as airspace / procedure design and flight plan management. It is anticipated that this component will be implemented the same for manned and unmanned operations. A functional representation of the 3 components is shown in fig 1 below. The concept of See and Avoid covers both separation provision and collision avoidance and is discussed below as it represents one of the most challenging aspects of UAS operations.

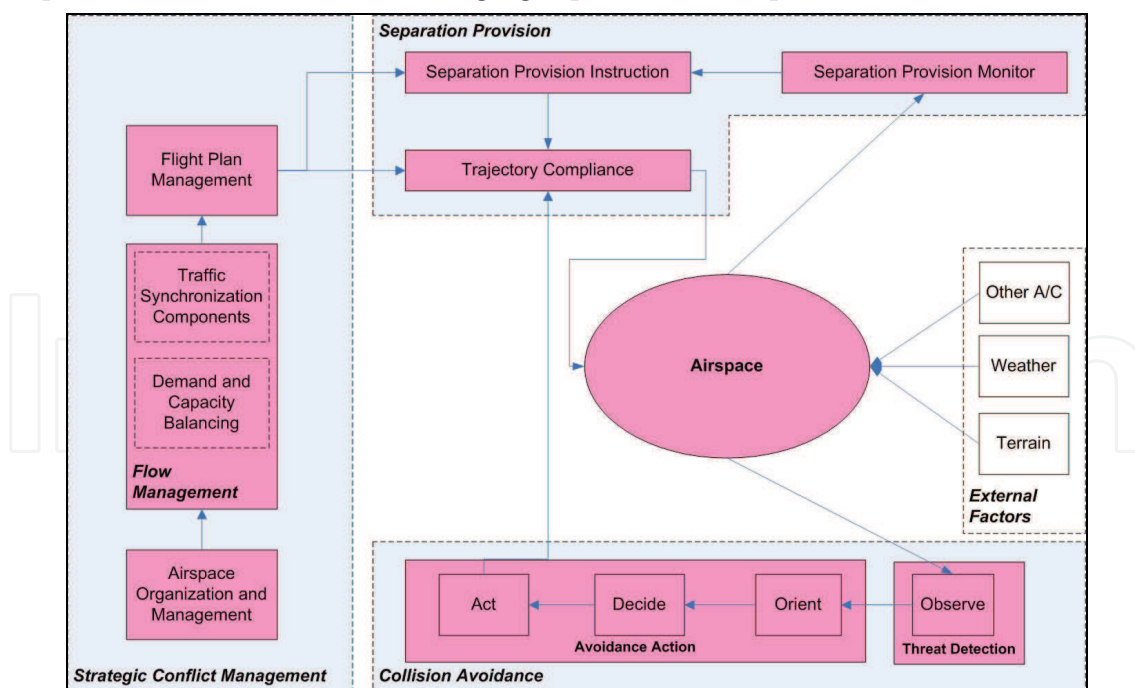


Figure 1. High-level Air Traffic Service Functional Model

⁵ The amount of equipment implied could be well in excess of the weight limits for the air vehicle and this may be one of the major limitations on the type of air vehicle than can use non-segregated airspace.

3.1 Separation Provision

Separation provision is the tactical process of keeping aircraft away from other airspace users and obstacles by at least the appropriate separation minimum. Depending upon the type of airspace and, where applicable, the air traffic service being provided, separation provision can be performed by air traffic controllers or by the pilot-in-command. Where a controller is responsible for providing separation provision, the Separation Provision Monitoring and Demand for an aircraft are provided by the controller and the pilot is responsible for Trajectory Compliance. Where the pilot is responsible for Separation Provision, all these functions are performed by the pilot in accordance with the Rules of the Air.

Under Visual Flight Rules (VFR) in certain types of airspace, there is currently no specified minimum separation distance and the pilot of, for example, a manned aircraft arranges his trajectory using airborne radar and/or visual means to separate his flight path from other air users. In these scenarios for UAS operations (EUROCONTROL UAV-TF, 2007) defines a minimum separation distance of 0.5nm horizontally and 500ft vertically. The term Separation Provision should therefore be taken to include the actions necessary to provide physical separation between a UAS air vehicle and other air users of at least 0.5nm or 500ft, even though no separation minima is currently defined for manned operations.

3.2 Collision Avoidance

The Collision Avoidance component can be separated into pilot and collision avoidance system functions. Manned aircraft may be fitted with collision avoidance systems such as Traffic Alert and Collision Avoidance System (TCAS) II or elements thereof such as Secondary Surveillance Radar (SSR) Transponders⁶. Collision avoidance systems are designed to activate when separation provision has been compromised; although air traffic controllers can instigate collision avoidance action from a pilot, this mechanism would not be available to an autonomous UAS.

(SRC Policy Document 2, 2003) states that collision avoidance systems (referred to as Safety Nets) are not part of separation provision so must not be included in determining the acceptable level of safety required for separation provision. However, the collision avoidance performed by a pilot of a manned aircraft must be performed to an equivalent level of safety by the UAS whether piloted or autonomous.

The Safety Regulation Commission (SRC) Policy statement implies that UAS must provide an equivalent level of interaction with the Separation Provision component as provided by pilots. Furthermore the UAS separation provision system must maintain the level of safety (with respect to the scope of (ESARR 4, 2001)) without the need for a Safety Net. This implies that UAS need to provide independence between separation provision and collision avoidance systems.

3.3 See and Avoid

Current manned operations include provisions for pilot "See and Avoid" to implement (or augment depending on the class of airspace) the separation provision and collision avoidance functions. UAS operations need to provide an equivalent level of safety with a

⁶ Mode A/C and S Transponders can be used by other aircraft fitted with TCAS.

“Sense and Avoid” capability to overcome the loss of manned “See and Avoid” capability⁷. However, it is important that separation provision and collision avoidance are addressed independently.

Firstly, if the Separation Provision component is working normally then the Collision Avoidance component is not under demand. Therefore in this environment the Collision Avoidance component should only provide situational awareness information⁸. Secondly, if Separation Provision fails in some way then the normal operation for the Collision Avoidance component is to act to avoid any imminent potential collisions. For this to work successfully a number of conditions must be satisfied; as a minimum the components should do as shown in Table 1.

Function	Collision Avoidance	Separation Provision
Be aware of all traffic in the vicinity	✓	✓
Implement and maintain appropriate separation minima with all other traffic		✓
Have criteria for when to implement traffic warnings (separation provision is potentially about to fail) and resolution warnings (separation has failed and immediate collision avoidance action is required)	✓	
Be able to identify traffic that is a collision (or near miss) threat, establish an appropriate avoidance response, taking into account other potential targets, and implement the response if the UAS pilot is unable to do so in time	✓	

Table 1. Sense and Avoid conditions

In addition since the UAS must integrate with the existing manned aircraft environment it must operate with extant co-operative and non-co-operative systems for surveillance and collision avoidance, *inter alia*:

- Other traffic must be able to ‘see’ the UAS air vehicle under all the conditions that other manned aircraft would be detected by another manned aircraft.
- Non-co-operative surveillance systems (e.g. Primary Surveillance Radar) must be able to ‘see’ the air vehicle.
- To cater for all potential air traffic scenarios a UAS Sense and Avoid system must be able to detect co-operative traffic (aircraft fitted with data link devices, e.g. Mode S transponders) and non-co-operative traffic (unfitted).

3.4 UAS Characteristics

The UAS encapsulates not only the air vehicle itself, but the entirety of equipment, people and procedures involved in the launch, control and recovery of the air vehicles. To establish

⁷ Sense and Avoid capability should address many of the issues associated with pilot-not-in-the-cockpit, however, consideration also needs to be given to *inter alia*, emergency responses and off-tether operations, etc.

⁸ This should not be taken to imply that the Collision Avoidance component must not be active, only that whilst the Separation Provision component is working correctly then the Collision Avoidance component should not interfere.

the potential differences in manned and unmanned operations, it is important to understand the specific characteristics of UAS that are potentially applicable to UAS operations.

A principle characteristic is physical separation of control of the air vehicle from the air vehicle itself. The UAS pilot will be remote from the UAV either on the ground or in another aircraft. The UAS pilot maintains control of the air vehicle through a UAS Control System via a UAS Control Link. The operation of the control link cannot be guaranteed under all conditions so the UAS must be able to work safely with or without the control link; this is referred to as flying on or off-tether.

The key characteristics that can affect UAS operations are as follows:

- **Conspicuity** - the visibility of the air vehicle to other airspace users is an important component in the Collision Avoidance component as well as when Separation Provision is the responsibility of the UAS pilot. This could be an issue for air vehicles that are smaller than manned aircraft, or those that present a poor signature for Primary Surveillance Radar.
- **Autonomous Operations** - One of the key characteristics of UAS's is the ability to operate under various conditions without human interaction. The necessity for human interaction, along with other factors such as safety, mission complexity and environmental difficulty determine the level of autonomy that the UAS can achieve. There are various taxonomies for classifying UAS autonomy for example Autonomy Levels For Unmanned Systems (Hui-Min Huang, et al, 2005). However, it is not possible to define UAS operation in non-segregated airspace under any one classification as UAS may be expected to operate with varying degrees of autonomy depending on the circumstances.
- **Airworthiness** - UAS air vehicles (and as applicable control stations) must be fitted with certified equipment equivalent to that required for manned operation in the intended airspace; this may pose problems for smaller or lighter air vehicles due to space or weight constraints.
- **Flight Performance** - the manoeuvrability of a UAS air vehicle is important to understand. Currently, Air Traffic Controllers are required to understand flight performance characteristics of the types of aircraft that come under their control and provide separation provision instructions based on this understanding. This requirement for understanding will also need to apply to unmanned operations to ensure ATC instructions can be implemented.

4. A Definition of Acceptably Safe

(JAA/EUROCONTROL, 2004) defines acceptably safe in terms of achieving an equivalent level of risk with that for manned aircraft.

- *UAV Operations shall not increase the risk to other airspace users or third parties*

This definition rightly focuses on the equivalence in risk and not safety levels, regulation or certification⁹ and cuts across the current debate on the certification versus safety target approach to assuring UAS safety, as discussed in (Haddon & Whittaker, 2002) and (EASA A-NPA, 2005).

⁹ Achieving equivalence with manned aircraft through regulation/certification alone may be inadequate or overly prescriptive unless the impact on the risk is fully assessed.

However, it does rely on a fundamental assumption that current manned operations are acceptably safe and does lack the level of detail required to appreciate some of the issues facing UAS operations in non-segregated airspace, which include:

- a. The level of acceptable risk for manned aircraft operations varies depending on the operational context.
- b. The public perception of the UAS risk may demand a harsher consideration of risk than for manned operations.
- c. In accordance with European ATM legislation (ESARR 3, 2000), the risk should also be reduced as far as reasonably practicable (AFARP).

In addition, levels of air traffic are predicted and expected to increase over the next few decades, which will also require an increasing level of safety. There is a significant demand¹⁰ to make improvements to the existing Air Traffic environment to achieve this, and the opportunity that UAS technology¹¹ may provide to support this should not be ignored or overlooked.

4.1 Public Perception of UAV Risk

One of the key influences that will determine the direction and strength of the UAS market is acceptance by the general public. It is well understood that any public trust and support for UAS operations that exists today will evaporate as soon as a UAS air vehicle is involved in an accident, regardless of fault.

A public opinion survey undertaken in the United States in 2003, the findings of which are documented in (MacSween-George & Lynn, 2003), found that up to 68% of the public support cargo and commercial UAS applications and most were not concerned by UAS flying overhead. However, the survey also found that the majority of respondents would not support the use of UAS to fly passengers.

The CAA Directorate of Airspace Policy recently invited members of the UK aviation industry to attend a one day workshop (CAA, 2005) to discuss UAS matters and the effect that emerging systems may have on existing and future manned aviation activity. One of the syndicate sessions at this workshop was tasked with discussing public and aviation industry perceptions, the following issues were identified:

- Potential negative public perception due to lack of knowledge or concerns over UAS historical safety records.
- Perception from the current manned community in terms of lack of trust in shared airspace.
- Public concern on the safety and security implications of UAS.
- Lack of trust in the regulation of industry.

It is vitally important therefore to secure public acceptance via positive promotion of the capabilities, limitations and safety of UAS by active communication with all affected stakeholders.

¹⁰ Under European Airspace Regulation, ANSPs are required to reduce risk As Far As Reasonably Practicable (ESARR 3, 2000).

¹¹ Or combining UAS and next generation manned technology.

4.2 A Practical Safety Criteria

From a safety perspective it is clear that the aim of the UAS industry, regulators and operators must be to ensure that the safety risk from UAS operations in non-segregated airspace shall be:

- No greater than for manned operations in the same operational context¹²
- Further reduced As Far As Reasonably Practicable

This supports the view proposed by Air Commodore Taylor as documented in (Taylor, 2005) but also takes into account the counter view expressed by (DeGarmo, 2004) and alluded to within (CAP72, 2008) by encouraging rather than mandating enhanced safety over and above manned operations. This is the basis on which (EUROCONTROL UAV-TF, 2007) was assessed in order to determine the safety requirements for such operations.

5. Safety Argument for UAS Operation in Non-segregated Airspace

The purpose of the safety argument presented below is to outline how the overall objective of “equivalent risk” can be broken down in relation to UAS operations in non-segregated airspace to a level where regulations can be defined that ensure that the resultant risk is acceptable in principle. In describing the safety argument some of the key issues and challenges facing the domain are described. Note that the safety argument is not specific to a type or class of air vehicle but rather to the concept of UAS operations in non-segregated airspace. This approach facilitates identification of specifications that are rigorous but avoid being implementation specific.

5.1 Top-level Safety Argument (Claim 0)

The overall objective for assuring that UAS operations will be safe is to show that they are and will continue to be acceptably safe (as defined in the previous section) within a clearly defined context. The context must include:

- Justification for the intended operational use.
- A definition of the operational scenarios (both mission and air traffic service related) that a UAS may face.
- Necessary assumptions (e.g. that current equivalent manned operations are acceptably safe).

Of necessity the argument must also consider all potential operational phases. An example scenario model for the latter phase of flight is shown in the Fig 3 below.

¹² This is a relative approach to assess risk. Within the air traffic management domain absolute safety targets are set for Air Traffic Service Providers in (ESARR 4, 2001) but the relative approach is still applied to manned operations although this will likely change over time. At some point in the future (sooner for some applications such as Area Navigation) UAS operations will also need to be compliant.

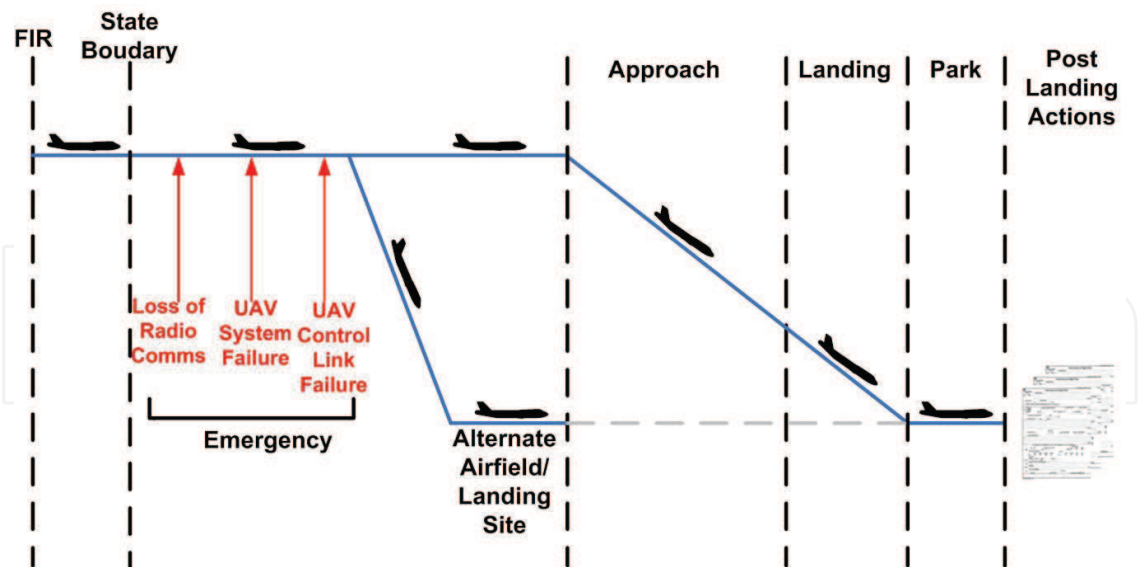


Figure 3. Example Scenario Model (1)

This top level goal can be shown to be met by demonstrating four principle safety goals:

1. Safety requirements are specified such that the safety criteria as discussed in section 4.2 is satisfied in principle.
2. Safety requirements are fully addressed in the relevant regulations and standards.
3. Safety requirements are developed at a level commensurate with the level of detail in regulations or standards.
4. UAS operations in non-segregated airspace fully satisfy the safety requirements within the regulations and standards in practice.
5. UAS operations in non-segregated airspace are monitored to ensure that the safety criteria continue to be satisfied in operation.

These principle goals are discussed in the following sections.

5.2 Safety Requirements for UAS Operations (Claim 1)

Safety requirements can be developed at almost any level of abstraction. For the purpose of setting regulation or standard specifications safety requirements need to reflect the level of detail determined by the scope and purpose of the regulation or standard. In turn the safety requirements need to be:

- Developed at a high-level but form a necessarily and sufficiently complete set to show the safety criteria are met.
- Based on validated models of UAS operation.
- Derived using an appropriate safety assessment methodology to include functional safety properties as well as integrity requirements.
- Realisable in implementation, although consideration as to whether the requirements are capable of implementation should not be limited by the capabilities of current UAS technology.

The safety requirements derived for (EUROCONTROL UAV-TF, 2007) were based on slightly more detailed models of UAS operations than those described in section 2. The principle conclusions of this work were:

- Despite the variety of airspace classifications, available ATM services, the multitude of possible scenarios and the different phases of flight etc. only three modes of operation needed to be considered, as follows:
 - Where ATC is responsible for separation provision.
 - Where the pilot in command is responsible for separation provision.
 - Where the air vehicle is not in contact with the pilot in command and so provides separation provision for itself.
- At the air traffic management functional safety level no distinction was drawn between manned and UAS operations, i.e. UAS operations do not introduce new hazards to the domain.
- Given the need for further research it was considered necessary to mandate that UAS pilots in command will require equivalent piloting skills to those of manned aircraft when flying in non-segregated airspace. However, this would be inadequate where pilots in command are responsible for more than one UAS at a time.
- Issues with requirements achievability were identified and are discussed further within section 5.4 below.

(SRC Policy Document 1, 2001) specifies a Target Level of Safety (TLS) for civil aircraft which is further apportioned within European ATM Regulation (ESARR 4, 2001) to ATM specific risks. These safety targets should be further apportioned by airspace users, Air Navigation Service Providers, etc. in order to set targets for specific operations. As this is often seen as too complex a task, many safety cases for European air traffic management concepts and systems rely on a relative argument, although not all, e.g. (EUROCONTROL RNAV, 2004), etc. In these cases UAS operations should demonstrate compliance with the specific defined absolute targets and safety requirements.

5.3 UAV Regulations and Standards (Claim 2)

Whilst there is a need for specific UAS regulations and standards for particular UAS technologies much of the regulations and specifications for non-segregated airspace operations already exist within the manned aircraft and air traffic regulations as outlined in section 2.2.

These provide a vital basis as advocated by (Haddon & Whittaker, 2002) for the creation of UAS specific regulations and standards. But regulations and standards need to be developed in accordance with derived safety requirements and not just based on the concept of “equivalence”. The safety assessment work carried out for (EUROCONTROL UAV-TF, 2006) can be seen as a model for the development of other UAS regulations and standards to ensure that the overall objective of “equivalent risk” is achieved.

There is a need for regulations and standards to be developed in the context of commonly agreed safety requirements based on a whole “system of systems” model of UAS operations to ensure that each perspective is fully considered including pilots, industry, Air Traffic Controllers, Operators, Maintainers and regulators. It is of particular concern that at the moment UAS security is not clearly covered by any regulatory authority, yet ensuring and maintaining the security of control centres, data links, etc. is fundamental to the substantiation that operations are acceptably safety.

5.4 UAS Safety Requirements Implementation (Claim 3)

The principle conclusions with regards the implementation of safety requirements for UAS operations in non-segregated airspace are as follows:

- There needs to be independence between the implementation of the separation provision (strategic) and the implementation of collision avoidance (tactical separation provision).
- This is easier to achieve when an air traffic controller is responsible for separation provision and the pilot in command can control the air vehicle and is aware of other air users (see next bullet), since the air vehicle can be fitted with a collision avoidance system similar to TCAS II. However, there are unresolved concerns regarding the efficacy of TCAS II logic and UAS operations¹³ and the level of risk reduction achieved by TCAS II, approximately 30% (EUROCONTROL ACAS, 2005) may be insufficient to achieve an equivalent level of risk.
- There are still some uncertainties with implementation of automated strategic and tactical separation provision systems to replace that currently performed by the pilot¹⁴, i.e. the “Sense and Avoid” issue.
- The safety assessment conducted on the (EUROCONTROL UAV-TF, 2007) concluded that UAS sense and avoid technology offers the potential to improve threat detection and avoidance capability, especially given concerns with the effectiveness of human see and avoid capabilities. Achieving equivalence or even equivalent risk seems inadequate in this case. A comprehensive discussion of the issues is provided in (DeGarmo, 2004).
- UAV and Data Link reliability are key to minimising the workload impact on air traffic controllers arising from excessive instigation of emergency or contingency procedures.
- UAS operations must consider the scenario when the communication between the pilot in command and the air vehicle is unavailable. In this scenario the air vehicle must conform to a predefined flight plan so that UAS behaviour remains as deterministic as possible¹⁵.
- Emergency Procedures may necessarily be different for UAS operations and as such UAS will need to be able to, for example, indicate when UAS are operating in isolation from the pilot in command (e.g. a unique transponder code), when to be provided increased separation provision, etc.
- For most of the risks identified no additional risk mitigation was identified within the air traffic domain that could further reduce the risk over and above manned operation. This leaves the challenge of achieving the AFARP safety criteria to the standards bodies and UAS implementers.
- There are other challenges that will arise during the implementation of the safety requirements, inter alia:

¹³ Due for example to the significant reliance on the timeliness of pilot response to Resolution Advisories (RA), but such concerns need to be resolved in order to ensure that TCAS II is still working as effectively in single and multiple manned vs. UAS air vehicle encounters.

¹⁴ JAR 91.113 Rights of Way Rules state that “regardless of whether an operation is conducted under instrumented flight rules (IFR) or visual flight rules (VFR), vigilance shall be maintained by each person operating an aircraft so as to see and avoid other aircraft”.

¹⁵ ATCO’s consulted during the safety assessment suggested that errant UAS behaviour is probably no worse than manned military errant behaviour.

- The inadequacy of the current integrity of aeronautical data for terrain maps, obstacle heights GPS based navigation systems, etc. although this is being addressed through the European Commission Interoperability Mandates.
- Operating characteristics of current and future UAS air vehicles that may undermine principle safety assumptions in current safety cases for air traffic operations or concepts, e.g. the timeliness of pilot/UAS implementation of controller instructions.

5.5 Monitoring UAS Operations (Claim 4)

A programme of safety monitoring and improvement will need to be implemented by state regulators and other international bodies to ensure that UAS operations in non-segregated airspace remain acceptably safe. The safety assessment for (EUROCONTROL UAV-TF, 2007) did not identify any monitoring requirements in addition to those already recommended for manned OAT operations.

6. Conclusions

There is clearly a desire in industry to produce commercially viable UAS and concern that UAS regulations do not become over burdensome or inflexible. Whilst there is a wealth of existing regulation and standards for manned operations, there is still a need to ensure that the transition to UAS operations in non-segregated airspace does not jeopardise the safety of other airspace users, and perhaps even contributes to an improved level of safety in aviation, directly addressing issues with the public perception of the risk from UAS.

The work for EUROCONTROL DG/MIL has shown that the development and specification of regulations and standards can be subject to safety assessment, which can assure the completeness and correctness of the specifications whilst providing the rigorous evidence that the regulations and standards capture the safety requirements relevant to the their scope and purpose.

By applying this process at all levels of UAS regulation and standard setting it would be possible to ensure not only a cohesive approach to UAS regulation but also that UAS operations will not increase the risk to other airspace users and third parties. There is an accepted and recognised need for regulatory bodies to work together to ensure that all aspects of UAS regulation including Air Traffic Management, Vehicle Certification, Operation, Maintenance and Licensing, etc. interface correctly, taking into account the impact of issues within, and assumptions made by, each of the aspects as well as the practicalities and commercial viability of the final UAS solutions.

Notwithstanding that regulations and standards can be developed or updated to incorporate UAS operations such that they are acceptably safe, there remain many issues with the practical implementation of technology to achieve the essential safety requirements. The most relevant of these is the development of Sense and Avoid specifications that address the overarching safety requirements **and** can still be achieved in practice.

Consideration should also be given to pursuing the regulatory aspects of Sense and Avoid systems and ensuring the UAS operations are considered in all current and future ATM research, particularly SESAR, which may alter the concepts or technologies deployed. However, regulators and industry (e.g. through Work Group 73 of EUROCAE) steps

towards providing the necessary UAS regulatory and standards infrastructure and specifications such as (EUROCONTROL UAV-TF, 2007) provide an important foundation. Wider and more detailed regulations and standards will likely form around the technologies that become available to resolve the operational and safety issues that UAS operations must address. There is still much scope for further research in the area of UAS regulation and implementation and programmes such as the UK DTI funded ASTRAEA project will help significantly to move the process forward.

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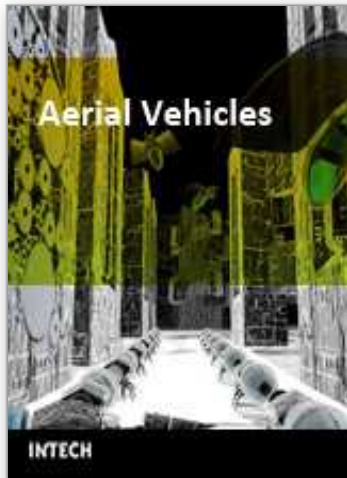
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This book contains 35 chapters written by experts in developing techniques for making aerial vehicles more intelligent, more reliable, more flexible in use, and safer in operation. It will also serve as an inspiration for further improvement of the design and application of aerial vehicles. The advanced techniques and research described here may also be applicable to other high-tech areas such as robotics, avionics, vetronics, and space.

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