EUROCONTROL

FAA/EUROCONTROL COOPERATIVE R&D

'Principles of Operations for the Use of ASAS'

This document was developed under the auspices of Action Plan 1 of the FAA/EUROCONTROL Co-operative Research and Development Committee. Its objective is to elaborate the 'Principles of Operation for the use of Airborne Separation Assurance Systems'. These principles are seen as essential to advance the research in this area in a co-operative manner, taking into account US and European perspectives for global applicability.

A small team of experts from different backgrounds was formed to write the document with members from USA (FAA, NASA/Ames, NASA/Langley and MITRE/CAASD) and from Europe (EUROCONTROL/HQ, EUROCONTROL/EEC, CENA and DERA). A draft version of the document was circulated for comments to a larger audience.

The main guiding principle is to explore the concept that Air Traffic Services can be enhanced through greater involvement of flight crews and aircraft systems in co-operation with controllers and the Air Traffic Management system. The concepts of 'airborne spacing' and 'airborne separation' are used to support this argument.

The document is seen as a foundation stone and a framework to provide further research progress in this area considering the global dimension. This document is not an FAA or EUROCONTROL approved policy for ASAS applications and does not address implementation.

Following its presentation and discussion during the FAA/EUROCONTROL R&D Committee meeting held in Paris on 14-15 June 2001 and with the above restriction, it has been agreed to disseminate the document outside the FAA/EUROCONTROL R&D Committee to solicit comments and to form a basis upon which further research can be conducted.

Paris, 15 June 2001,

The Co-chairs of the FAA-EUROCONTROL R&D Committee.

Dr. Herman Rediess	Mr. Guido Kerkhofs
Director, Aviation Research, AAR-1	Director DIS a.i.
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Your comments are very welcome and should be sent via the FAA/EUROCONTROL R&D Committee web site: www.eurocontrol.be/projects/eatmp/faa-euro .

ACTION PLAN 1

FAA/EUROCONTROL COOPERATIVE R&D

Principles of Operation for the Use of Airborne Separation Assurance Systems

Version: 7.1 **Date:** 19 June 2001

Executive summary

This work was conducted under the auspices of Action Plan 1 of the FAA/EUROCONTROL Co-operative Research and Development Committee. Its objective is to elaborate the 'Principles of Operation for the use of Airborne Separation Assurance Systems'. These principles are seen as essential to advance the research in this area in a co-operative manner, taking into account US and European perspectives for global applicability.

The main guiding principle is that Air Traffic Services (ATS) can be enhanced through greater involvement of flight crews and aircraft systems in co-operation with controllers and the Air Traffic Management (ATM) system. The concepts of 'airborne spacing' and 'airborne separation' are used to support this argument.

The document uses the following definitions:

- ✓ **Airborne Separation Assurance System (ASAS)**: An aircraft system that enables the flight crew to maintain separation of their aircraft from one or more aircraft, and provides flight information concerning surrounding traffic.

- ✓ **ASAS application**: A set of operational procedures for controllers and flight crews that makes use of the capabilities of Airborne Separation Assurance Systems to meet a clearly defined operational goal.

Taking into account various considerations (conceptual, operational procedures, human factors, aircraft systems, enabling technologies, users' perspectives and implementation), four ASAS application categories have been defined:

- ✓ **Airborne Traffic Situational Awareness applications**: These applications are aimed at enhancing the flight crews' knowledge of the surrounding traffic situation, both in the air and on the airport surface, and thus improving the flight crew's decision process for the safe and efficient management of their

flight. No changes in separation tasks or responsibility are required for these applications.

- ✓ **Airborne Spacing applications**: These applications require the flight crews to achieve and maintain a given spacing with designated aircraft, as specified in a new ATC instruction. Although the flight crews are given new tasks, separation provision is still the controller's responsibility and applicable separation minima are unchanged.

- ✓ **Airborne Separation applications**: In these applications, the controller delegates separation responsibility and transfers the corresponding separation tasks to the flight crew, who ensures that the applicable airborne separation minima are met. The separation responsibility delegated to the flight crew is limited to designated aircraft, specified by a new clearance, and is limited in time, space, and scope. Except in these specific circumstances, separation provision is still the controller's responsibility. Implementation of these applications will require the definition of airborne separation standards.

- ✓ **Airborne Self-separation applications**: These applications require flight crews to separate their flight from all surrounding traffic, in accordance with the applicable airborne separation standards and rules of flight.

For each ASAS application category, principles of operation have been further developed including the relationship to airborne collision avoidance. Where it was not possible to develop firm principles, specifically for the Airborne Self-separation applications, guidance based on current knowledge and research is given.

When defining an ASAS application, its category should be carefully selected because categories are associated with different principles. The wrong selection of the application category could lead to the misuse of that application and have major impact on the safety of flight.

ASAS applications involving major reliance on aircraft systems and changes to present responsibilities and procedures to ensure aircraft separation will require rigorous safety analysis and validation before implementation. This analysis will need to demonstrate conclusively that the ASAS application meets or exceeds the required Target Level of Safety, including consideration of equipment failure and human error. Methodologies and guidelines for these analyses will need to be agreed at the international level.

This document is not an approved policy for ASAS applications and does not provide an implementation road map. It was not its objective to develop operational and technical standards, and many identified issues need to be resolved.

Nevertheless, **it is hoped that this document will be used as guidelines by the research community, at the international level (ICAO Panels), at the national level (Airspace Authorities, ATS Providers and Certification Authorities), at the technical standardisation level (RTCA, EUROCAE). It seeks to focus the work necessary prior to the implementation of any ASAS application.**

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Acronyms

4-D	Four Dimension
ACAS	Airborne Collision Avoidance System
ADS	Automatic Dependent Surveillance
ADS-B	ADS - Broadcast
ADSP	Automatic Dependent Surveillance Panel (now OPLINKP)
AIRSAW	Airborne Situational Awareness
AP1	Action Plan 1
ASAS	Airborne Separation Assurance System
ATC	Air Traffic Control
ATM	Air Traffic Management
ATMCP	ATM Concept Panel
ATS	Air Traffic Services
CDTI	Cockpit Display of Traffic Information
CNS	Communication, Navigation and Surveillance
CONOPS	Concepts of Operations
E-TIBA	Enhanced - TIBA
EVA	Enhanced Visual Acquisition
FAA	Federal Aviation Administration
FMS	Flight Management System
GNSS	Global Navigation Satellite System
ICAO	International Civil Aviation Organisation
IFR	Instrument Flight Rules
IMC	Instrument Meteorological Conditions
MASPS	Minimum Aviation System Performance Standards
MHz	Mega Hertz
NM	Nautical Mile
OCD	Operational Concept Document
OPLINKP	Operational Data Link Panel (former ADSP)
R&D	Research and Development
RGCSP	Review of the General Concept of Separation Panel (now SASP)
RTCA	Radio Technical Commission for Aeronautics
SARPs	Standards and Recommended Practices
SASP	Separation and Airspace Safety Panel (former RGSCP)

SCRSP	Surveillance and Conflict Resolution System Panel (former SICASP)
SICASP	SSR Improvements and Collision Avoidance System Panel (now SCRSP)
SSR	Secondary Surveillance Radar
TIBA	Traffic Information Broadcast by Aircraft
TIS-B	Traffic Information Service - Broadcast
TLS	Target Level of Safety
US	United States of America
VFR	Visual Flight Rules
VHF	Very High Frequency
VMC	Visual Meteorological Conditions

1. Introduction

1.1. Objectives of the Document

Several innovative concepts have been elaborated involving the notion of airborne separation:

- ✓ The 'ASAS Concept' [3] & [7] by the ICAO SCRS Panel (former SICASP);
- ✓ The Report on 'Free Flight' [1] by RTCA; and
- ✓ The Operational Concept Document (OCD) [4] by EUROCONTROL, which introduces limited delegation for separation responsibility in 'Managed Airspace' and autonomous aircraft operations in 'Free Flight Airspace'.

The objective of this work conducted under the auspices of Action Plan 1 of the FAA/EUROCONTROL Co-operative R&D Committee is to elaborate the 'Principles of Operation for the use of Airborne Separation Assurance Systems'. These principles are seen as essential to advance the work in this area co-operatively, taking into account US and European perspectives for global applicability.

This Principles of Operation for the use of Airborne Separation Assurance Systems takes advantage of work already done by the ICAO OPLINK (former ADS) [6] and SCRS Panels, by RTCA Special Committee 186 and by the EUROCONTROL AIRSAW Task Force. Recent work from the ATM Concept Panel on Collision Risk Management has also been taken into account.

ASAS stands for Airborne Separation Assurance Systems. ASAS applications are aimed at improving the ATM system through enhanced traffic situational awareness of flight crews and the use of new flight deck-based separation capabilities.

This document provides broad principles for ASAS applications. It is not aimed at defining the specific concepts of operations (CONOPS) related to ASAS applications.

1.2. Organisation of the Document

The document is organised into five chapters, starting with **Chapter 1** on the objectives of the document.

Chapter 2 provides an introduction to the use of ASAS by first summarising the various ATM services as currently provided by ATS Providers from an ICAO perspective. These services include flight information service, alerting service, air traffic advisory service and ATC service. This is followed by a description of the expected enhancements to the current services and potential benefits that can be derived from implementation of ASAS applications.

Chapter 3 discusses the current and future responsibility of flight crews and controllers in the provision of separation to prevent collisions. The concepts of enhanced airborne traffic situation awareness, airborne spacing, airborne separation and airborne self-separation are described. The relationship with airborne collision avoidance is also clarified.

Chapter 4 defines ASAS applications and develops in detail four major categories of ASAS applications, taking into consideration the evolutionary reallocation of responsibility and tasking between flight crews and controllers, operational procedures, human factors, aircraft systems, enabling technology, and implementation strategy. For each category of ASAS applications, this chapter discusses the principles of operation.

Chapter 5 describes the system components of ASAS, main ASAS functions, and the relationship with ACAS components and functions.

The document concludes with **Chapter 6** 'Summary and Conclusions'.

1.3. Document Terminology

In this document, certain expressions or words are given the following meaning:

- ✓ '**ATC separation**' is used to mean separation provided by an Air Traffic Service provider.
- ✓ '**Airborne**' is a qualifier for spacing or separation, meaning that it involves the flight crew and/or the aircraft systems.
- ✓ '**Clearance**' is used instead of air traffic control clearance.
- ✓ '**Controller(s)**' is used instead of Air Traffic Controller(s).
- ✓ '**Flight crew**' includes single pilot operations.
- ✓ '**Flight deck**' is used to encompass both the flight crew and the aircraft systems.
- ✓ '**Instruction**' is used instead of air traffic control instruction.
- ✓ '**Ownship**' means the aircraft under consideration, and which is equipped with an airborne separation assurance system.

Throughout the document, the authors have tried to use consistent terminology, with a preference for ICAO terminology and definitions.

2. Introduction to the Use of ASAS

2.1. Introduction

The following sections describe the current ATM system and the potential benefits from ASAS applications.

2.2. The current ATM System

In the current ATM system, Air Traffic Services (ATS) providers provide the following services:

- ✓ Flight information service;
- ✓ Alerting service;
- ✓ Air traffic advisory service; and
- ✓ Air traffic control service

The need for air traffic services is determined by considering many factors including, type of air traffic involved, the density of air traffic, the meteorological conditions and others.

Airspace is divided into classes (Classes A to G) for which air traffic services and rules of operations are specified:

- ✓ Controlled airspace corresponds to Classes A, B, C, D and E.
- ✓ Advisory airspace corresponds to Class F.
- ✓ Flight information is the only service provided in Class G.

Under the current ATM system, flight crews are responsible for the safe and efficient control and navigation of their individual aircraft in all airspace and on the airport surface.

2.2.1. Flight Information Service

Flight information service provides advice and information useful for the safe and efficient conduct of flights (Annex 2 – Rules of the Air).

2.2.2. Alerting Service

Alerting service provides notification to appropriate organisations regarding aircraft in need of search and rescue aid, and assists such organisations as required (Annex 2 – Rules of the Air).

2.2.3. Air Traffic Advisory Service

Air traffic advisory service is provided within advisory airspace to ensure separation, in so far as practical, between aircraft that are operating on IFR flight plans (Annex 2 – Rules of the Air)

2.2.4. Air Traffic Control Service

The purpose of air traffic control service is to:

- ✓ Prevent collisions;
- ✓ Expedite and maintain the orderly flow of traffic.

To prevent collisions, air traffic control units issue clearances and information (Annex 11 – Air Traffic Services – section 3.3.):

- ✓ Traffic information alerts the flight crew to other known or observed air traffic, which may be in proximity to the position or intended route of flight, and helps the flight crew avoid collisions.
- ✓ Depending on the type of flight (IFR/VFR) and the class of airspace, clearances and instructions are used to provide separation. The separation minima to be applied are established by the regulatory authority taking into account numerous factors such as the communication, navigation and surveillance capabilities and the operational procedures.

At this stage, it should be noted that:

- ✓ The provision of traffic information is essential to prevent collisions.
- ✓ Maintaining separation in accordance with applicable minima is the means for air traffic control to prevent collisions.
- ✓ Unlike controllers, flight crews have currently no specified separation minima to maintain between aircraft, other than to avoid collisions and wake turbulence. In practice, flight crews will not aim to just miss, but will maintain a trajectory that they consider safe.
- ✓ Although preventing collisions is the prime purpose of air traffic control, expediting and maintaining the orderly flow of traffic is also a priority.

2.2.5. Separation Standards

Separation by the air traffic control unit is provided by using at least one of the following:

- ✓ Vertical separation by assigning flight levels;
- ✓ Horizontal separation: longitudinal separation (time or distance) or lateral separation (different routes or different geographic areas); and
- ✓ Composite separation: combination of vertical and horizontal separation.

The applicable separation standards are defined in the ICAO documents such as Appendix 3 of Annex 2 (Tables of cruising levels), PANS-RAC (Doc 4444) and Regional Supplementary Procedures (Doc 7030). The ATS Planning Manual (Doc 9426) provides conditions governing the reduction of separation minima.

2.2.6. The Role of ACAS in the ATM System

The airborne collision avoidance system (ACAS) has been introduced in order to reduce the risk of mid-air collisions. ACAS operates independently of ground-based equipment, and provides advice to the flight crew on potential collisions with aircraft that are SSR (Secondary Surveillance Radar) transponder equipped. It is designed to operate in all airspace.

ACAS serves as a last resort safety net, irrespective of any separation standards. It has no other role in the ATM system. ICAO standards state that:

- ✓ The provision of ATS services in a given airspace shall not be based on the ACAS equipage of the aircraft [Annex 11, 2.4.2; and Doc 9426, ATS Planning Manual, 1.6.2]; and
- ✓ Air traffic control units shall provide the same services to ACAS and non-ACAS aircraft. [Doc. 4444, PANS-RAC, 19.1].

It follows that ATM procedures have to be judged safe without considering the effect of the ACAS safety net.

2.3. Enhancing the ATM System

2.3.1. Introduction

New concepts have been proposed, in which the airborne side of the ATM system (flight crews and aircraft systems) plays a different role. These concepts are based on improved flight crew knowledge of the surrounding traffic and increased involvement of the flight crew in aircraft separation.

For the basic ICAO services, the following sections (2.3.2 to 2.3.5) describe how it is possible to enhance the current ATM system using these concepts. Section 2.3.6 proposes a new approach to ATM.

2.3.2. Flight Information Service

Through airborne surveillance of the surrounding traffic, the flight crews could improve their traffic situational awareness and better understand air traffic control instructions and clearances.

2.3.3. Alerting Service

In case an aircraft declares an emergency, the surrounding traffic could provide better assistance, because they will have knowledge of the position of the other aircraft and (potentially) its emergency status. Appropriate procedures will need to be defined.

2.3.4. Air Traffic Advisory Service

Currently, within advisory airspace, ATC separation is provided, as far as is practical, between aircraft that are operating on IFR flight plans. In the future, the flight deck could play a role by introducing airborne separation as a new means to provide separation. Airborne separation means that, under specific procedures, the flight crews use dedicated tools to maintain predefined airborne separation minima from other aircraft.

2.3.5. Air Traffic Control Service

In the context of air traffic control service, separation tasks, and potentially responsibilities, could be allocated between controllers and flight crews.

For example, if the flight crew maintains a given distance or time behind another aircraft, this will help the controller manage the safe, orderly and expeditious flow of traffic. In this case the controller remains responsible for separation.

Another example is when the flight crew provides airborne separation from designated aircraft, to complement ATC separation, or even replace it. The controller is still responsible for providing separation from other traffic.

2.3.6. Future Developments - Self-separation of Aircraft

In the longer term and under the appropriate conditions, suitably equipped aircraft may fly with more autonomy, while self-separating from other aircraft. The air traffic services to be provided in this new class of controlled airspace need to be defined.

2.4. Expected benefits from the use of ASAS

2.4.1. General

Airspace users may realise different benefits according to the ASAS application and the environment in which it is used. A single application does not provide all the possible benefits listed below.

2.4.2. Safety Benefits

There are three proposed improvements that support the prevention of collisions with other traffic:

- ✓ **Situational Awareness**: This benefit should arise from presenting the flight crew with flight information concerning surrounding traffic, possibly in conjunction with a navigation display or a surface map. Situational Awareness can be provided in all airspace, in all phases of flight, and on the airport surface. It can operate in any weather condition. Some specific benefits could be:
  1. Assist flight crews with see-and-avoid duties;
  2. Assist flight crews in avoiding blunders or errors;
  3. Provide information to facilitate correct decision-making; and
  4. Provide flight crews with information consistent with that available to the controller.
- ✓ **Automation**: ASAS uses various sources of position and intent data. ASAS can support its applications without reliance on controller actions by generating guidance to the crew for safe and timely resolution of conflicts or maintenance of safe separation.
- ✓ **Guidance presented directly to flight crew**: ASAS guidance does not depend on ground-to-air communication. This should prevent the common hazard of missed or garbled radio communications.

2.4.3. User Flexibility and Flight Efficiency

Some ASAS applications could support the ability of users to fly preferred routes or trajectories, which are more fuel or time-efficient, than can be allowed with current ATC practices and traffic levels. This capability may be supported by ASAS providing a monitoring or separation function that supplements or replaces ATC separation.

2.4.4. Increased Throughput/Capacity Benefits

Some ASAS applications could support increases in aircraft throughput at an airport or passing through a volume of airspace. Arrival or departure capacities, or sector traffic limits, often cause severe bottlenecks that limit the capacity of the ATM system. It is anticipated that significant capacity benefits could result from implementation of many ASAS applications.

Many of these capacity improvements could be enabled in part by reductions in workload for controllers and, possibly, flight crews. Examples of such benefits include:

- ✓ Reduced communications between flight crews and controllers.
- ✓ Automated monitoring and alerting in the cockpit.
- ✓ Delegation of specific separation responsibilities and the transfer of the associated tasks to the flight crew.

2.4.5. Environmental Benefits

ASAS applications could support the reduction of environmental impacts in much the same ways that they support the flexibility to fly preferred profiles. The reduction of flight times and the ability to use optimum climb and descent profiles could support the reduction of aircraft exhaust emissions and noise.

3. Airborne Separation Principles

3.1. Introduction

In this section, the potential role of airborne separation is clarified by examining the relationship between the flight crew and controller, and the provision of 'separation' to prevent collisions. The use of 'spacing' by controllers to manage the efficient ordering and sequencing of traffic, which is closely related to separation, is also discussed.

3.2. The flight Crews' Responsibility to Avoid Collisions

Flight crews have an obligation to ensure the safety of flight by avoiding collisions with other aircraft. To this end they:

- ✓ Maintain traffic situational awareness;
- ✓ Follow the controller's clearances and instructions;
- ✓ See and avoid other traffic; and
- ✓ Use ACAS, if installed.

Traffic situational awareness comes from many sources: traffic information from the controller; the 'party line' effect in voice communications; the ACAS traffic display; vigilant out-the-window monitoring and the flight crew's prior experience of what tends to happen at particular places and times. Together, these help the flight crews to be aware of where they should look for collision threats. The automatic provision of flight information concerning surrounding traffic would improve the traffic situational awareness of flight crews.

Following the controller's clearances is the most effective means of avoiding collisions and, alone in this list, it is part of separation provision. Following appropriate clearances and instructions results in separation minima being maintained and thus ensuring safety. Separation minima are established such that the risk of collision is at an acceptable level.

The other processes by which the flight crews avoid collisions also contribute to reducing the risk of collision, but they do so in an unquantified way. The level of safety that is achieved, i.e. the probability of a collision, is not known for 'see and avoid'. The use of ACAS does not amount to separation provision because it provides no guarantee that the risk of collision is reduced to an acceptable level.

3.3. The Controller's Responsibility to Provide Separation

A conflict is a predicted loss of separation, defined by ICAO as a 'predicted converging of aircraft in space and time which constitutes a violation of a given set of separation minima'. (Doc 9426 – Planning Manual for Air Traffic Services, 5th Part, section 1).

Controllers when providing separation use instructions and clearances. The ICAO definitions for these words (PANS-RAC - Doc 4444) are the following:

- ✓ Air Traffic Control Clearance: Authorization for an aircraft to proceed under conditions specified by an air traffic control unit.
- ✓ Air Traffic Control Instruction: Directives issued by air traffic control for the purpose of requiring a pilot to take a specific action.

When a conflict is detected, it is necessary to act to preserve separation. This is achieved in a planned and deliberate manner by controllers and flight crews. The controller prevents collisions by using the objective knowledge at his disposal, applicable rules and procedures, and, based on these, issuing instructions to the flight crew. The flight crew has contracted to follow these instructions and, provided they do, the level of safety achieved is considered acceptable. Generally, the required level of safety (whether explicitly known or not) has determined the quantitative separation minima that are being applied.

Controllers often seek to ensure separation by maintaining a desired spacing between aircraft – a spacing in time, or distance, or any parameter that they can observe and influence. This spacing exceeds the applicable separation minimum. (PANS-RAC Doc. 4444, Part III - Area Control Service, 1.2: 'No clearance shall be given to execute any manoeuvre that would reduce spacing between two aircraft to less than the separation minimum applicable in the circumstances.') The controller monitors the possibility for conflict and leaves an adequate margin in which to observe that the desired separation is not being achieved and to take corrective action.

The controller can also use spacing to fulfil his other responsibility, to expedite and maintain an orderly flow of traffic. A desired distance or time, greater than the separation minimum, is maintained between two aircraft. This is often achieved through aircraft speed adjustments. An example might be where the controller is transferring aircraft to another ATC centre in accordance with the Letters of Agreement between the centres or with the real-time traffic flow restrictions, which could be in place. Spacing is also applied to regulate and to merge two streams of traffic landing on a single runway.

3.4. Visual Separation

'Visual separation' is used in some circumstances, in order to improve the efficiency of flight or to increase capacity. When a controller asks a flight crew to maintain visual separation from another aircraft, and the flight crew agrees, a specific and limited delegation of responsibility for separation occurs. Successive visual approaches and visual crossings (aircraft A passes behind aircraft B, maintaining visual contact) are examples.

In these visual separation procedures:

- ✓ The flight crew must see the other aircraft, and confirm to the controller that they see the other aircraft;
- ✓ The flight crew confirms that they will maintain visual contact with the other aircraft during the visual procedure; and
- ✓ The controller's clearance delegates his responsibility for maintaining separation between the two aircraft to that flight crew.

Visual separation is not merely an instance of 'see and avoid'. The controller relinquishes his separation provision obligation only when he is assured that the flight crew sees the other aircraft. The flight crew is not required to adhere to the separation minima that the controller is required to maintain, or to any other, but is still responsible for operating their aircraft in a safe manner.

Controllers sometimes use visual separation to manage aircraft in approach and aerodrome traffic patterns (Doc 4444, Part IV - Approach Control Service; and Part V – Aerodrome Control Service).

3.5. New Responsibilities for Flight Crews and Controllers in Aircraft Separation

In the future ATM system, based on a better sharing of traffic information between flight crews and controllers, there is potential for a greater involvement of the flight deck in aircraft separation.

When envisaging this more integrated ATM system, it is critical to define the responsibilities of both controllers and flight crews clearly. Three main operational concepts are identified, depending on the allocation of responsibilities and tasks:

- ✓ **Airborne spacing**: The flight crew ensures a spacing from designated aircraft as stipulated in new controller instructions for aircraft spacing. The controller remains responsible for providing separation between aircraft.
- ✓ **Airborne separation**: The flight crew ensures separation from designated aircraft as communicated in new clearances, which relieve the controller from the responsibility for separation between these aircraft. However, the controller retains responsibility for separation from aircraft that are not part of these clearances.
- ✓ **Airborne self-separation**: The flight crew ensures separation of their aircraft from all surrounding traffic. The controller has no responsibility for separation.

When airborne spacing is invoked, separation provision is still the controller's responsibility and applicable separation minima are unchanged. The flight crews are given new tasks related to aircraft spacing. The controller can use these new instructions for aircraft spacing to expedite and maintain the orderly flow of traffic, in compliance with ATC separation minima.

When airborne separation is invoked (other than relying on visual contact with the other aircraft) the flight crews assume new responsibilities for aircraft separation, and the applicable separation minima need to be defined. These new clearances for airborne separation can be seen as an extension of visual separation, using flight deck tools in place of visual acquisition.

Finally, airborne self-separation presents a new paradigm. Flight crew and controllers have new roles in aircraft separation.

3.6. Airborne Separation Minima and Safety

In considering the use of new procedures, or clearances, as a means to provide separation between aircraft, it is essential to demonstrate that these are safe, i.e. that the risk of collision is acceptably small. From that perspective, airborne spacing and airborne separation raise different issues.

For the purpose of this document, it is supposed that airborne separation will be provided and maintained by flight crews applying standardised separation minima. Therefore, the major issue is the establishment of these '**airborne separation minima'** so as to achieve safe flight operations. Optimistic views are that airborne separation minima could be much smaller than ATC radar separation minima and could thus allow for capacity increases. Other views are much more reserved and warn that they might be larger than ATC radar separation minima, while possibly smaller than procedural separation minima.

Determining the values of airborne separation minima is not envisaged to be the flight crew responsibility. These separation minima will have to be established at the ICAO level, taking into account airspace characteristics (e.g. traffic density), operational procedures, and communication, navigation, surveillance and separation capabilities available on board aircraft. These aircraft capabilities will need to be defined in Minimum Aviation System Performance Standards (MASPS) or equivalent documents.

On the other hand, airborne spacing does not require the establishment of airborne separation minima because the controller provides separation in compliance with existing ATC separation minima. Nevertheless, it should be demonstrated that the procedures adopted in implementing airborne spacing have no adverse impact on the controller's ability to provide ATC separation in all conditions. Therefore, standardised procedures should define the spacing values to be used by controllers and flight crews. The performance specifications for airborne spacing might be less stringent than those for airborne separation because the required level of safety is achieved through the provision of ATC separation.

3.7. Relationship with Airborne Collision Avoidance

The purpose of airborne collision avoidance is to prevent collisions. It is designed to detect risk of imminent collision and there are no associated separation minima. The time scales are short, and there is a need to avoid contact between aircraft. Airborne collision avoidance is a last resort function, which requires immediate action.

In normal circumstances, when separation (ATC or flight deck) is provided, airborne collision avoidance should not be necessary. Applications implementing airborne separation should achieve the approved Target Level of Safety (TLS) independently from airborne collision avoidance.

Airborne collision avoidance may not have complete information, and alerts may occur before the applicable airborne separation minimum is infringed. It is thus essential to pay particular attention to compatibility with airborne collision avoidance when designing applications implementing airborne spacing or airborne separation.

4. Principles of Operation for ASAS Applications

4.1. ASAS Application Categories

Airborne Separation Assurance Systems provide the flight crew with information regarding surrounding traffic and, in some cases, decision support tools that aid in providing separation from that traffic. This allows the flight crew to participate with controllers in providing separation from proximate traffic, and ultimately, to provide the primary, and possibly sole means for separation. The introduction of airborne separation is expected to result in improvements in the safety, efficiency and capacity of the ATM system.

The operational procedures enabled or enhanced by ASAS are referred to as ASAS applications. An ASAS application is identified by:

- ✓ Its operational goal;
- ✓ The operational procedures for controllers and flight crews;
- ✓ The requirements on aircraft systems supporting ASAS; and
- ✓ The requirements on ATC systems.

The following ASAS application definition is used in the document:

ASAS application*: A set of operational procedures for controllers and flight crews that makes use of the capabilities of Airborne Separation Assurance Systems to meet a clearly defined operational goal.*

ASAS applications encompasses applications related to traffic whether the aircraft is airborne or on the airport surface. This document defines principles of operation for all applications when ownship or traffic aircraft are airborne, and, when both ownship and traffic aircraft or vehicles are on the airport surface, but is limited to situational awareness applications in the latter case. ASAS applications related to ground movement guidance and control are beyond the scope of this document.

ASAS will not provide information on terrain, weather, aircraft performance, or status of the airspace (i.e. classes, restricted areas). However, these will be considered as constraints on ASAS applications. Of course, such information could well be provided on the flight deck, and could even be integrated with ASAS functions in practice, but consideration of these possibilities is beyond the scope of this document.

Depending on the operational goal, the following ASAS application categories can be distinguished:

- ✓ **Airborne Traffic Situational Awareness applications**: These applications are aimed at enhancing the flight crews' knowledge of the surrounding traffic situation both in the air and on the airport surface, and thus improving the flight crew's decision process for the safe and efficient management of their flight. No changes in separation tasks or responsibility are required for these applications.

- ✓ **Airborne Spacing applications**: These applications require flight crews to achieve and maintain a given spacing with designated aircraft, as specified in a new ATC instruction. Although the flight crews are given new tasks, separation provision is still the controller's responsibility and applicable separation minima are unchanged.

- ✓ **Airborne Separation applications**: In these applications, the controller delegates separation responsibility and transfers the corresponding separation tasks to the flight crew, who ensures that the applicable airborne separation minima are met. The separation responsibility delegated to the flight crew is limited to designated aircraft, specified by a new clearance, and is limited in time, space, and scope. Except in these specific circumstances, separation provision is still the controller's responsibility. These applications will require the definition of airborne separation standards.

- ✓ **Airborne Self-separation applications**: These applications require flight crews to separate their flight from all surrounding traffic, in accordance with the applicable airborne separation minima and rules of flight.

4.2. Considerations in Defining the ASAS Application Categories

In defining the above categories for ASAS applications, there are several important considerations. Primarily, the categories are defined by the amount of responsibility given to the flight crew, and thus the resulting tasks and procedures (i.e. the “operational concept”). As the flight crew’s responsibilities increase, more new procedures will be required, and eventually, new flight rules. With increasing separation responsibility, the criticality of the aircraft equipment involved in providing separation also increases, resulting in greater integrity, availability, and continuity-of-service requirements. These considerations are described in more detail below. **It should be stressed that all these considerations are important and should be seen as complementary**.

4.2.1. Conceptual Considerations

The overriding consideration in defining ASAS application categories is the level of responsibility delegated to the flight crew. Four distinct categories are immediately apparent:

- ✓ There is no fundamental change to current tasks or responsibilities. The controller is responsible for separation as in today’s airspace.
- ✓ New tasks related to aircraft spacing are given to the flight deck, but there is no change to current separation responsibilities. The controller remains responsible for separation.
- ✓ Separation responsibility is delegated to flight crews in agreed and appropriate specific circumstances, apart from which the controller remains responsible for separation.
- ✓ Flight crews have responsibility for providing separation from other aircraft.

4.2.2. Operational Procedure Considerations

Operational procedure considerations support the above ASAS category definitions by making a clear distinction between ASAS applications in which:

- ✓ No new procedures will be required between controllers and flight crews for maintaining separation, although there will likely be some phraseology changes in existing Visual Meteorological Conditions (VMC) procedures involving other traffic. Enhancements to existing procedures might be needed on the flight deck to provide for the safe and effective use of the traffic information available on board.
- ✓ New procedures will be needed for both flight crews and controllers to support the transfer of spacing tasks to the flight crews. These procedures will have to clearly define both the spacing values (either time or distance)

that the flight crews are required to acquire and maintain, and the designated aircraft.

- ✓ New procedures will be needed to support the transfer of separation tasks to the flight crew and to support both the delegation of limited separation responsibility to the flight crew, and its return to the controller as appropriate.
- ✓ New procedures will be required for the provision of separation and for manoeuvring compatibility between flight crews in maintaining this separation. Additional procedures will be required to allow for the transition to and from one class of airspace to another class. New flight rules might be required to define right of way during self-separation aircraft operations.

Positive identification by the flight crew of aircraft designated by the controller in an instruction or clearance is essential for the safe and efficient execution of ASAS applications. Prior to implementing the flight identification procedure, sufficient simulations and field tests should be conducted to ensure the procedure does not cause additional confusion for flight crews and controllers.

Some ASAS applications may require the development of contingency procedures in case of the loss of aircraft capabilities including ASAS capabilities or in case the flight crew being unable to continue to perform the tasks associated with the ASAS application.

4.2.3. Human Factors Considerations

From the perspective of both controllers and flight crews, the major differentiation between ASAS applications is in the extent of changes in their roles and responsibilities. It is important that new tasks for flight crews and controllers be supported by appropriate automation and interfaces, as well as procedures and training. Considerable research leading to additional simulation and flight trials will be needed to verify that new procedures are safe and effective.

From the flight crews' perspective, new ASAS functions must be integrated with existing flight crews' functions. The new procedures should be examined to determine whether they interfere with other duties and the pacing of standard flight crew tasks. Although specific tasks and responsibilities will be different between various ASAS applications, there should be consistency between the procedures used for the different applications to avoid high workload and confusion when more than one application is used on a single flight. Careful procedures to allow transition from one application to another (e. g. from self-separation to spacing) will be essential, as will means of identifying which application is in effect. Consistency of flight crews' procedures between aircraft operators flying ASAS applications will be equally essential. To prevent an unacceptable increase in the flight crew's workload as more separation tasks are transferred to the cockpit, the appropriate level of automation support on board will have to be defined.

From the controllers' perspective, there should also be consistency between the procedures used for the different ASAS applications to avoid high workload and confusion when more than one application is used in a particular airspace. The controller should be aware of the level of equipage, and its operational status, for all aircraft under his control. In case of delegation of separation responsibility at sector boundaries, procedures to support the transfer of this delegation between controllers will be essential. To help the controllers cope with their new role in the separation provision process, ground-based monitoring tools and back-up assistance tools may be required.

The design of ASAS applications and associated human machine interface for flight crews and controllers should respect the following principles defined in the ICAO circular 249-AN/149. Guidelines for human centred design include:

- ✓ The human must be in command;
- ✓ To command effectively, the human must be involved;
- ✓ To be involved the human must be informed;
- ✓ Functions must be automated only if there is a good reason for doing so;
- ✓ The human must be able to monitor the automated system;
- ✓ Automated systems must, therefore, be predictable;
- ✓ Automated systems must be able to monitor the human operator;
- ✓ Each element of the system must have knowledge of the other's intent; and
- ✓ Automation must be designed to be simple to learn and operate

4.2.4. Aircraft System Considerations

ASAS applications will involve different levels of aircraft and avionics capabilities, with different redundancy and integrity requirements, to support the flight crews in their new spacing and separation tasks. From the aircraft system perspective, it is worthwhile to distinguish between:

- ✓ ASAS applications in which the criticality of the aircraft equipment is low. ASAS equipped aircraft may fly alongside unequipped aircraft or aircraft with the ASAS equipment not operating. A display of surrounding traffic is likely to be sufficient for these applications. Some traffic information processing may also be required, in particular to support special display features (e.g. traffic status) or alerts pertaining to a conflicting aircraft.
- ✓ ASAS applications for which the criticality of the aircraft equipment is moderate and for which the spacing instruction may only be given to equipped aircraft. In the event of ASAS system failure, the spacing instruction is revoked and the controller manages spacing as for unequipped aircraft. Specific display features or alerts related to the spacing in time or distance from the aircraft from which airborne spacing is being maintained may be required. Automating the spacing task through the aircraft guidance and control systems is a possibility that might further raise the criticality of the function.
- ✓ ASAS applications for which the criticality of the aircraft equipment is high because ASAS system failure could result in loss of separation before the controller could resume separation responsibility. Since the aircraft trajectories will have to comply with the applicable airborne separation minima, it is highly likely that all participating aircraft will have to meet stringent redundancy and integrity requirements. A conflict detection algorithm and appropriate displays, possibly issuing conflict resolution advisories and alerts for imminent separation infringements, will probably be required for all participating aircraft.
- ✓ ASAS applications for which the criticality of the aircraft equipment is extremely high because it would be the sole means of assuring separation from other aircraft and there would be no easy fall-back option in the event of system failure. Strategic conflict detection and resolution will be required for all participating aircraft. More sophisticated aircraft guidance and control systems that account for the constraints related to conflicting traffic are possible.

These four levels of equipage support the definition of ASAS applications into the four categories outlined above.

4.2.5. Enabling Technology Considerations

Depending on the level of automation and performance, ASAS applications will use different CNS technologies to support the development of the required air/ground capabilities.

- ✓ Considering the wide spread of ASAS applications, it is anticipated that airborne surveillance will rely on ADS-B, but not exclusively. In case of partial ADS-B equipage, ground-based traffic services like TIS-B could be used as a complementary, or even the primary one, source of data for airborne surveillance.
- ✓ Some ASAS applications will also benefit from the use of data-link capabilities (e.g. air-to-air and air-to-ground) to support data exchange between controllers and flight crews or between flight crews themselves, or even explicit co-ordination between aircraft equipment.
- ✓ ASAS applications (spacing, separation and self-separation) may also require specific navigation capabilities (e.g. GNSS with/without augmentation system) to support the required navigation performance.

4.2.6. Users' Considerations

ASAS applications will have different benefits and constraints depending on the airspace and possibly type of flights. From the airspace users' perspective, it is worthwhile to distinguish between ASAS applications for which the first objective is:

- ✓ To improve safety of flights.
- ✓ To improve efficiency of flights: For these applications, some trade-offs between the benefits of the different airspace users may have to be reached.
- ✓ To improve capacity of the ATM system: For these applications, the extent of benefits for all the airspace users will accrue as more aircraft are equipped. Locally (e.g. at an aircraft operator's hub), it can be expected that the equipage of a relatively small number of aircraft may produce some benefits for the users.

For the Airborne Separation and Airborne Self-separation application categories, it will be necessary to prove that the required safety level is achieved.

4.2.7. Implementation Considerations

In considering the overall ATM system, the questions of evolution and transition are most important. In planning the various ASAS applications, aircraft should not be unnecessarily required to carry a multiplicity of CNS and ASAS equipment. In addition, for both economy and efficiency reasons, there is a need to ensure a coherent implementation around the world. Hence from the implementation perspective, it is worthwhile to distinguish between:

- ✓ ASAS applications where the first ASAS-equipped aircraft will benefit from their new capabilities provided that some other aircraft are visible to it via either ADS-B or TIS-B.
- ✓ ASAS applications (e.g., pair-wise separation) that require only participating aircraft to be equipped, but other aircraft can fly in the same airspace.
- ✓ ASAS applications that require all aircraft to be ASAS-equipped or at least made visible to ASAS. This could be done through:
    1. Mandatory equipage;
    2. Segregated airspace where only suitably equipped aircraft can operate; and
    3. The ATC system compensating for the lack of suitable equipage through, for example, TIS-B.

It is expected that various users of ASAS will implement different applications, according to their perceived benefits. Also, some applications should mature before others. The ASAS concept supports this varied usage.

In addition to the general principles already identified, the following sections will develop further the principles governing the four ASAS application categories taking into account all the above considerations.

4.3. Principles of Operation for Airborne Traffic Situational Awareness Applications

4.3.1. Definition and Scope

The Airborne Traffic Situational Awareness applications are intended to enhance the flight crews' knowledge of the surrounding traffic situation both in the air and on the airport surface, and thus improve the flight crew's decision process for the safe and efficient management of the flight. These applications will also help improve some procedures. No changes in current separation tasks or responsibility are required for these applications.

4.3.2. Objectives and Benefits

Improvements in flight management and procedures will be achieved through the capability of the flight crew to obtain more accurate and up-to-date information on their surrounding traffic environment, via better air-to-ground and air-to-air communication methods and surveillance information (e.g. traffic conditions).

Benefits of Airborne Traffic Situational Awareness applications could include the following:

- ✓ Improved co-operation between controllers and flight crews resulting from shared traffic awareness.
- ✓ Reduced risk of miss-identification by providing flight identification for traffic shown on cockpit displays.
- ✓ Improved safety through earlier anticipation of collision risks.
- ✓ Reduced voice communications through a better flight crew traffic situational awareness.
- ✓ Improved 'party-line' traffic situational awareness in a data link environment.
- ✓ Increased safety in the event of loss of voice communications or radar failure.
- ✓ Enhanced judgements of closure and encounter geometries while on approach.
- ✓ Increased efficiency of existing Visual Meteorological Conditions (VMC) procedures.
- ✓ Improved taxiway and runway occupancy awareness in airport operations, especially in low visibility conditions. This will help reduce runway incursions and collisions on the airport surface.

4.3.3. Operational Environment

Airborne Traffic Situational Awareness applications are applicable in all types of airspace. These applications are always present, either individually or contained within the more advanced ASAS applications.

4.3.4. Airborne Traffic Situational Awareness Applications

Typical Airborne Traffic Situational Awareness applications include:

- ✓ **Enhanced Visual Acquisition** (EVA): Flight crews will use the provided traffic information to supplement and enhance out-the-window visual acquisition. Flight crews will continue to visually scan out of the window while including the cockpit traffic display in their instrument scan. The information could be used to either initially detect an aircraft or to receive further information on an aircraft that was visually detected or called out by the controller. The EVA application provides a basis for the Enhanced Visual Approaches and Enhanced See and Avoid applications.

- ✓ **Enhanced Visual Approaches**: Flight crews will fly the visual approach as is done currently but they will have additional electronic traffic information available to aid in their conduct of the approach. This additional information will allow the flight crew to determine target position, spacing, flight identification, closure rate or ground speed, and ground track. The additional information available in the cockpit could also allow the controller to use flight identification during traffic call-outs, thereby reducing communications.
- ✓ **Enhanced "See and Avoid"**: This application provides a display of nearby traffic to help the flight crew "see-and-avoid" other traffic. If traffic is sighted, the flight crew must first assess the threat posed by the nearby aircraft then, if necessary, manoeuvre to avoid the other aircraft.
- ✓ **Enhanced Traffic Information Broadcast By Aircraft** (E-TIBA) in non-radar areas: TIBA is a procedure, regulated by ICAO, that is intended to permit reports and relevant supplementary information of an advisory nature to be transmitted by flight crews on a designated VHF frequency for the information of other aircraft in the vicinity. The procedure should be applied in designated airspace where:
  - There is a need to supplement hazard information provided by air traffic services outside controlled airspace; or
  - There is a temporary reduction of normal air traffic services.

  When using the TIBA procedure, flight crews have to create and maintain, by reference to information passed via voice communication, "mental 4-D" pictures of the current and future air traffic situations. One of the primary aims of this Traffic Situational Awareness application is to provide such a picture of the current air traffic situation, which contributes to a detailed context for the E-TIBA information.
- ✓ **Improved taxi and runway occupancy awareness**: This application will provide flight crews with an awareness of proximate surface traffic (both aircraft and surface vehicles) on ramps, taxiways, and runways. For the initial implementation, these tools are expected to supplement the flight crew's out-the-window visual assessment of surface targets position, direction, and speed on the airport surface.

4.3.5. Roles and Procedures for Flight Crews and Controllers

Flight crew responsibilities with regard to air traffic control will not change; however, cockpit procedures will now include flight crews' use of cockpit displays to acquire and maintain awareness of other aircraft. Flight crews can view other aircraft parameters on the traffic display and better monitor trends and space own ship appropriately.

Controller procedures are not expected to change significantly with the Airborne Traffic Situational Awareness applications. However, since flight identification is available on the flight deck, it can be used when informing flight crews of a nearby aircraft and thus reduce the need for repeated or complex traffic advisories.

4.3.6. Human Factors Considerations

Flight crews might need to perform functions such as target selection on cockpit displays. In addition, with the increased availability of traffic information, flight crew training should be provided to minimise disruptions on the ATC environment (e.g. additional flight crew queries on controller intentions).

The flight identification procedure should be designed to cause no additional confusion for flight crews and controllers.

Flight crew training must specifically address the issue of over reliance on the traffic display, and increasing head-down time, especially when not all traffic is displayed.

4.3.7. *Principles Governing the Requirements for Aircraft Systems*

The following main functions are to performed by the ASAS to support an Airborne Traffic Situational Awareness application:

- ✓ Surveillance data processing (associated principles are detailed in section 5.2.2);
- ✓ Display of traffic (associated principles are detailed in section 5.2.4); and
- ✓ Traffic Information processing (associated principles are detailed in section 5.2.5).

Since the Airborne Traffic Situational Awareness applications are intended to provide general traffic situational awareness, it is expected that the display and surveillance requirements will be less stringent than for the more advanced ASAS applications.

Since the Airborne Traffic Situational Awareness applications will supplement any available ACAS functionality, it is not foreseen that compatibility problems will arise.

4.3.8. *Principles Governing the Requirements for ATC Systems*

There may be a need for the ATC system to indicate the ASAS equipage level for individual aircraft to the controller. For example, the controller might need to know the level of equipage for the flight identification procedure.

4.3.9. *Principles for Implementation*

It's expected that the implementation of Airborne Traffic Situational Awareness applications will not take place in a single step, but rather in a phased fashion, taking advantage of the varying application availability in terms of time, technology and strategic fit. To ensure reasonable benefits, the traffic picture should be made as comprehensive as possible. Two examples of increasing the availability of traffic information are:

- ✓ The availability of incentives to ensure that a large proportion of aircraft are equipped in a regional area (e.g. aircraft operator's hub operations); and
- ✓ The introduction of TIS-B, so that traffic information could be broadcast to all appropriately equipped aircraft.

4.4. Principles of Operation for Airborne Spacing Applications

4.4.1. Definition and Scope

Airborne Spacing applications include applications where the flight crews of suitably equipped aircraft are tasked to achieve and maintain spacing from designated aircraft, as instructed by the controller. Although the flight crews are given new spacing tasks, separation provision is still the controller's responsibility and ATC separation minima are unchanged. Other than the spacing task specifically transferred to the flight crew, all other spacing is provided by the controller.

The airborne spacing (time or distance from a designated aircraft) that the flight crew is to observe must be defined, as must the procedures and phraseology for passing the spacing tasks to the flight crew and, later, back to the controller. The limits on manoeuvring in order to maintain the spacing must at all times be completely defined and unambiguous.

4.4.2. Objectives and Benefits

The objective of these applications is to provide spacing for aircraft in relatively close proximity where this can be done more effectively from the flight deck.

Presently, the actual spacing distances for passing, in trail, or parallel aircraft usually far exceed the applicable separation minima in radar airspace. This is because the controller must include a time allowance for stepped on or missed communications plus other workload when issuing spacing instructions, thus resulting in excessive or unnecessary manoeuvres relative to the separation minimum. In fact, the higher the controller's overall workload, the more he will anticipate and manage his workload by issuing early spacing manoeuvre instructions. With no change in current separation minima, significant capacity and flight efficiency gains are expected if spacing is provided from the flight deck, allowing aircraft to fly more closely to the applicable separation minimum.

Transferring spacing tasks to the flight deck is expected to reduce controller workload, possibly enabling a higher aircraft-to-controller ratio. This can allow either more aircraft in a sector, or larger sectors. In the latter case, additional benefits include a more strategic role for the controller, resulting in better flow management, and reduced sector hand-off communications.

A final efficiency benefit of these applications may be improved predictability of flight duration, resulting in improved airport arrival planning.

Although the primary objective of Airborne Spacing applications is not safety, these applications must be demonstrated to be at least as safe as the present system. Safety improvements might result from spacing being based on better position information (e.g. through ADS-B), plus eliminating the possibility of garbled or missed communications.

4.4.3. Operational Environment

The operational environment for Airborne Spacing applications is any controlled airspace. The provision of separation to avoid collisions might usually use radar or other ground-based surveillance coverage, but the applications could also take place in procedurally controlled airspace.

The applications will be limited to suitably equipped aircraft with appropriately trained flight crews. The controller will need to be assured of the aircraft equipage before transferring any spacing tasks to the flight crew.

4.4.4. *Airborne Spacing Applications*

Typical Airborne Spacing applications include:

- ✓ In-descent spacing: the flight crews maintain a time-based horizontal spacing behind designated aircraft.
- ✓ Level flight spacing: the flight crews maintain a time or distance-based longitudinal spacing behind designated aircraft.
- ✓ Lateral crossing and passing: the flight crews establish and maintain the horizontal spacing with designated aircraft as specified in the instruction.
- ✓ Vertical crossing: the flight crews establish and maintain the vertical spacing with designated aircraft as specified in the instruction.

4.4.5. *Roles and Procedures for the Flight Crews and Controllers*

The decision to initiate an Airborne Spacing application rests with the controller. The controller remains responsible for separation while airborne spacing is being performed.

Airborne Spacing applications are based on the principle of relying on the flight deck to establish and maintain a given spacing between aircraft. Simply described, the controller indicates the required spacing from a designated aircraft and the flight crew achieves and maintains this value. When the desired separation has to be established prior to maintenance, the precise manoeuvre to be used by the flight crew has to be provided by the controller before commencing this application and then executed by the flight crew. The flight crew follows the controller instruction, unless they inform the controller that they are unable to do so, as in current operations.

The key elements for Airborne Spacing applications are:

- ✓ **No obligation of use**: Airborne Spacing applications are “tools” provided to the controller, and each controller has the option to use them or not. As for any other ATC instruction, a flight crew must either acknowledge and comply with the instruction or state that they are unable to do so.
- ✓ **Upon controller initiative**: These applications can only be initiated by the controller, when he determines them appropriate and helpful.
- ✓ **Limited scope**: Airborne Spacing applications encompass only implementation and monitoring of a solution given by the controller.

The key elements for initiating, transferring, or ending such applications are:

- ✓ **Applicability conditions**: The controller must ensure that all the conditions are met before initiating such an application. He must also ensure that all the conditions remain fulfilled throughout the course of the application.
- ✓ **Interruption of application**: The controller can interrupt an application at any time by issuing an alternate instruction. The flight crew can interrupt an application if unable to comply with it.
- ✓ **Transfer to next sector**: A group of aircraft involved in an Airborne Spacing application may be transferred to the next sector without interrupting the application. There will be co-ordination requirements between controllers should the Airborne Spacing application be in effect when the aircraft cross sector boundaries.

The consequences of these applications on the controller’s practice are the following:

- ✓ **No change of responsibility**: Airborne Spacing applications do not impose any change of responsibility between controllers and flight crews. An Airborne Spacing application can be considered as an instruction based on a new flight deck capability. The controller issues an instruction that will ensure appropriate spacing and which is acceptable to the flight crew, and compatible with aircraft performance.
- ✓ **Same working practices**: Airborne Spacing applications can, and must, be used in conjunction with other current procedures.

4.4.6. Human Factors Principles

Workload should be manageable for the flight crews and controllers given the context in which the flight deck performs spacing tasks. Overall workload for the controller must be reduced when he transfers spacing tasks to the flight crew. If not, he has no motive to use the application.

The procedures must be designed to eliminate ambiguity in the transfer of spacing tasks for both flight crews and controllers. Controllers especially cannot tolerate ambiguity because it adversely impacts their workload. Even occasional repeat communications to clarify the instruction could negate any benefits of Airborne Spacing applications.

4.4.7. Principles Governing the Requirements for Aircraft Systems

Aircraft which will perform airborne spacing tasks must be suitably equipped to receive position information from any aircraft from which they will space, and to display this information to the flight crew so as to facilitate the spacing tasks. The identity of the designated aircraft should also be displayed to avoid the potential for misidentification. Depending on the application, supporting information regarding the designated aircraft may be required, such as ground track and speed or rate of closure. All surveillance data and on-board processing used to perform airborne spacing tasks should be subject to integrity monitoring and alerts provided to the flight crew in the event that the integrity requirements are not met. Such off-nominal conditions require investigation.

The following main functions are to be performed by the ASAS to support an Airborne Spacing application:

- ✓ Surveillance data processing (associated principles are detailed in section 5.2.2);
- ✓ Display of traffic (associated principles are detailed in section 5.2.4);
- ✓ Traffic Information processing (associated principles are detailed in section 5.2.5); and
- ✓ Spacing function processing (associated principles are detailed in section 5.2.6).

The acceptable range of spacing values, which will have to be greater than the applicable ATC separation minima, will be based on the CNS capabilities available on-board the aircraft and the requirements of the ASAS application.

4.4.8. Principles Governing the Requirements for ATC Systems

Before spacing tasks may be transferred to the flight crew, the controller must have reliable information that the aircraft is appropriately equipped and that the equipment is operating. Equipage information could be included with the aircraft's flight plan or received by air-ground communication and should be displayed to the controller, most likely as part of the flight data block. Operational status might either be included with the data block or communicated to the controller by the flight crew.

Before an aircraft can be designated as one from which another is to maintain spacing, the controller must have reliable information that the former aircraft is suitably equipped.

Some means of reminding the controller of the status of the Airborne Spacing application may be required. Some automation aid to assist the controller in the conformance monitoring of the spacing task may also be required.

In the very short term, the implementation and use of TIS-B might enable earlier realisation of benefits from Airborne Spacing applications and thus might encourage voluntary ASAS equipage. However, the ability of TIS-B to support such applications will depend on its surveillance quality and other factors.

In the longer term, Airborne Spacing applications might benefit from relying on air-to-ground data-link.

4.4.9. Principles for Implementation

Airborne Spacing applications rely on one aircraft using surveillance information from another to space relative to it as prescribed by the controller. Implementation and use of such applications can therefore increase gradually as aircraft equip. For a pair of aircraft involved in an Airborne Spacing application, only the one getting the application-specific instruction needs to be ASAS equipped, provided that the designated aircraft appears as an appropriate target. The information on the designated aircraft might possibly be derived from TIS-B broadcasts.

In all cases, implementation can be progressive with no need for segregating airspace, although segregating traffic through designated airspace or specific procedures could help controllers identify situations where the use of Airborne Spacing applications would be beneficial.

4.5. Principles of Operation for Airborne Separation Applications

4.5.1. Definition and Scope

Airborne Separation applications include those applications where limited separation responsibility is delegated to suitably equipped aircraft to permit those aircraft to select manoeuvres within defined limits to meet the separation minima from designated aircraft. The delegation of responsibility is limited, either in duration or distance, and does not take effect until the flight crew has accepted the clearance. Except for this specific delegation of separation responsibility, ATC retains all other separation responsibility.

The airborne separation minima (time or distance) and standards that the flight crew is to observe must be defined, as must the procedures and phraseology for delegating the limited responsibility for separation provision to the flight crew and, later, passing it back to the controller. The guiding principle for Airborne Separation applications is that this transfer of tasks and the limits of the separation clearance must at all times be completely defined and unambiguous.

4.5.2. Objectives & Benefits

The objective of these applications is to provide tactical separation for aircraft in relatively close proximity where this can be done more effectively from the flight deck.

Presently, the actual separation distances for crossing, in trail, or parallel aircraft usually far exceed the applicable separation minima in radar airspace. This is because the controller must include a time allowance for stepped on or missed communications plus other workload when issuing instructions in order to maintain separation, thus resulting in excessive or unnecessary manoeuvres relative to the separation minimum. In fact, the higher the controller's overall workload, the more he will anticipate and manage his workload by issuing early manoeuvre instructions. With no change in current separation minima, significant capacity and flight efficiency gains are expected if tactical separation is provided from the flight deck, allowing aircraft to fly more closely to the separation minimum.

Additionally, airborne separation minima might in future be smaller than the current ATC separation minima used by the controller in the same circumstances since the communication time budget is eliminated, and because, in some circumstances, more recent or more accurate data are available on the aircraft.

The clearest potential for a reduction in separation minima exists where ATC procedural separation can be replaced by ASAS based airborne separation. However, a reduced separation minimum is not necessarily the only motive, and is not a requirement for these applications.

Transferring tactical separation tasks to the flight deck is expected to reduce controller workload, possibly enabling a higher aircraft-to-controller ratio. This can allow either more aircraft in a sector, or larger sectors. In the latter case, additional benefits include a more strategic role for the controller, resulting in better flow management, and reduced sector hand-off communications.

Allowing the flight crew to select an appropriate manoeuvre to maintain separation (for instance, either speed or heading change) might improve both flight efficiency and flexibility.

A final efficiency benefit of these applications might be improved predictability of flight duration, resulting in improved airport arrival planning.

Although the primary objective of Airborne Separation applications is not safety, these applications must to be demonstrated to be at least as safe as the present system. Possibly safety improvements may result from separation being based on better position information (e.g. through ADS-B), plus eliminating the possibility of garbled or missed communications.

4.5.3. Operational Environment

The operational environment for Airborne Separation applications is any controlled airspace. The provision of separation to avoid collision might usually use radar or other ground-based surveillance coverage, but the applications could also take place in procedurally controlled airspace.

The applications will be limited to suitably equipped aircraft with appropriately trained flight crews. The controller will need to be assured of the aircraft equipage before making any delegation of separation to the flight crew.

4.5.4. Airborne Separation Applications

Typical Airborne Separation applications include:

- ✓ In-descent separation: the flight crews maintain a time-based horizontal separation behind designated aircraft.
- ✓ Level flight separation: the flight crews maintain a time or distance-based longitudinal separation behind designated aircraft.
- ✓ Lateral crossing and passing: the flight crews insure that horizontal separation with designated aircraft is larger than the applicable airborne separation minimum.
- ✓ Vertical crossing: the flight crews insure that vertical separation with designated aircraft is larger than the applicable airborne separation minimum.
- ✓ Paired Approaches in which the flight crews maintain separation on final approach to parallel runways.

4.5.5. Roles and Procedures for the Flight Crews and Controllers

The roles of flight crews and controllers are clear and have an analogy in present rules for the delegation of separation to aircraft on instrument flight plans. Under visual separation rules for IFR aircraft, the controller asks the flight crew to report a designated aircraft in sight; once they have done so, the controller clears the flight crew to maintain separation from, or to follow, the designated aircraft. The flight crew does not have to report the traffic in sight, and may thus avoid the visual separation clearance, and consequent separation responsibility. However, once they have accepted that responsibility, they must maintain both visual contact and separation.

Similarly, under airborne separation, the controller will ask the flight crew to indicate ASAS has acquired the subject traffic. When they do so, the controller will give a clearance to the flight crew indicating that they are responsible for separation from that aircraft, and the nature of, and limits upon, the manoeuvre they are to make. For instance in the case of a crossing, the controller might issue the clearance: "Pass behind XXX, maintain separation, maintain present altitude, report clear". The controller does not resume responsibility until the procedure is completed, and the applicable ATC separation minimum is achieved. Throughout the procedure, the controller remains responsible for the aircraft's separation from other traffic. Unlike the visual separation example, airborne separation will involve airborne separation minima.

The intent of these applications is that the controller retains strategic control of his airspace, but transfers tactical tasks consistent with that strategy and at his discretion. The controller identifies the situation for which delegation of separation responsibility is appropriate, and determines the nature and constraints of the solution. Clearly, the controller should not attempt to delegate responsibility for separation in a situation with imminent loss of separation, nor should the flight crew accept the clearance in such a situation. Other hazards that might interfere with the flight crew implementing a safe and efficient solution, such as weather or restricted airspace, must be considered before the clearance is offered or accepted.

The Airborne Separation applications are based on the principle of relying on the flight deck to establish and maintain a separation between aircraft. Simply described, the controller indicates to the flight crew which aircraft they have to provide separation from. The flight deck selects flight parameters to maintain the applicable airborne separation minima. The controller is not required to monitor the separation between the aircraft involved.

The key elements for Airborne Separation applications are:

- ✓ **No obligation of use**: Airborne Separation applications are “tools” provided to the controller, and each controller has the option to use them or not.
- ✓ **Upon controller’s or flight crew’s initiative**: These applications may either be initiated by the controller, or may be requested by the flight crew, when found appropriate and helpful. In the latter case, the controller must still offer the delegation of responsibility in order to initiate the application.
- ✓ **Flight crew’s acceptance**: As for any other clearance, the flight crew may either accept or decline the delegation of responsibility for separation.

The key elements for initiating, transferring, or ending such applications are:

- ✓ **Applicability conditions**: The controller and the flight crew must ensure that their respective conditions are fulfilled for initiating and completing these applications. The procedures for the application must account for contingency situations, such as the flight crew finding they are unable to sustain the required separation.
- ✓ **Interruption of delegation**: The application procedures should enable the controller to interrupt an application at any time by issuing an instruction or an alternate clearance. The flight crew can interrupt an application in case of emergency or if some required condition cannot be maintained.
- ✓ **Transfer to next sector**: A group of aircraft involved in an Airborne Separation application may be transferred to the next sector without needing to interrupt the application. There will be coordination requirements between controllers should the delegation of separation be in effect when the aircraft cross sector boundaries.

The consequences of these applications on controller’s practice are the following:

- ✓ **Delegation of responsibility**: Airborne Separation applications impose a significant change of responsibility between controllers and flight crews. With the assistance of ASAS equipment, the flight crew becomes responsible for maintaining separation, in lieu of the traditional monitoring and control practised by controllers. It is expected that the flight crew of the designated aircraft from which separation must be maintained does not need to authorise the procedure.

- ✓ **New working practices**: Airborne Separation applications will require changes to traditional working methods.

4.5.6. *Human Factors Principles*

Workload should be manageable for the flight crews and controllers given the context in which the flight crews accept separation responsibility. From the controller's perspective, overall workload must be reduced when he delegates separation responsibility to the flight crew. If it is not, he has no motive to delegate. From the flight crews' perspective, if the workload is not acceptable, they have no motive to accept the clearance even if it would have resulted in a more efficient route for the flight.

The procedures must be designed to eliminate ambiguity in the delegation and end of separation responsibility for both flight crews and controllers. Controllers especially cannot tolerate ambiguity because it adversely impacts their workload. Even occasional repeat communications to clarify the clearance could negate any benefits of delegating separation responsibility.

4.5.7. *Principles Governing the Requirements for Aircraft Systems*

Aircraft from which separation tasks are to be performed must be suitably equipped to receive position information from any aircraft from which they will separate, and to display this information to the flight crew so as to facilitate the separation tasks. The identity of the designated aircraft should also be displayed to avoid the potential for misidentification. Depending on the application, supporting information regarding the designated aircraft may be required, such as ground track and speed or rate of closure. All surveillance data and on-board processing used to perform separation tasks should be subject to integrity monitoring and alerts provided to the flight crew in the event that the integrity requirements are not met.

The following main functions are to be performed by the ASAS to support an Airborne Separation application:

- ✓ Surveillance data processing (associated principles are detailed in section 5.2.2);
- ✓ Display of traffic (associated principles are detailed in section 5.2.4);
- ✓ Traffic Information processing (associated principles are detailed in section 5.2.5); and
- ✓ Separation function processing (associated principles are detailed in section 5.2.6).

The airborne separation functions are directly associated with airborne separation minima. These may differ from ATC separation minima, with values based on the different forms of surveillance data used for ASAS, the tasks performed by flight crews, and the removal of ground-to-air communications from the control loop. The separation minima will be based on the CNS capabilities available on-board the aircraft and the requirements of the ASAS application.

4.5.8. *Principles Governing the Requirements for ATC Systems*

Before separation tasks may be transferred to the flight crew, the controller must have reliable information that the aircraft is appropriately equipped and that the equipment is operating. Equipage information should be included with the aircraft's flight plan and should be displayed to the controller, most likely as part of the flight data block. Operational status may either be included with the data block or may be communicated to the controller by the flight crew.

Before an aircraft can be designated as a target from which another is to separate from, the controller must have reliable information that the aircraft is equipped to act as a target.

Should the flight crew of an aircraft equipped to perform separation tasks choose not to perform those tasks, the aircraft may still act as a target from which others may provide separation.

In the very short term, the implementation and use of TIS-B might enable earlier realisation of benefits from Airborne Separation applications and thus could encourage voluntary ASAS equipage. However, the ability of TIS-B to support such applications will depend on its surveillance quality and other factors.

In the longer term, Airborne Separation applications might benefit from relying on air-to-ground data-link.

Depending on the specific Airborne Separation application, ground-based monitoring of the airborne surveillance data might be required. Ground-based monitoring might serve as a potential means of redundancy that raises the integrity and safety of the application.

4.5.9. Principles of Implementation

Airborne Separation applications rely on one aircraft using surveillance information from another to manoeuvre relative to it as prescribed by the controller. Implementation and use of such applications can therefore increase gradually as aircraft become equipped. For each Airborne Separation application, analysis must be performed to determine if the application is sufficiently safe when only the one aircraft of a pair getting the application specific clearance is ASAS equipped, so that the designated aircraft is visible to it, but the latter is otherwise not equipped. The information on the designated aircraft may possibly be derived from TIS-B.

In all cases, implementation might be progressive with no need for segregating airspace, although segregating traffic through designated airspace or specific procedures could prove to help controllers identify situations where the use of Airborne Separation applications would be beneficial.

4.6. Principles of Operation for Airborne Self-separation Applications

4.6.1. Definition and Scope

Airborne Self-separation applications require flight crews to ensure that their flights remain separated from surrounding traffic, in accordance with applicable airborne separation standards. These applications require suitably equipped aircraft and apply for specific conditions and in specified airspace.

In a new class of controlled airspace, flight crews will have authority to self-separate from other aircraft and fly their preferred trajectories, thereby enabling controllers to focus on management of traffic flow.

Note: In this section the terms ‘ATC-controlled airspace’ is a synonym of ‘controlled airspace’ (Class A, B, C, D and E) as distinct from the new classes of controlled airspace, which need to be defined to introduce some Airborne Self-separation applications.

4.6.2. Objectives and Benefits

In collaboration with the ground ATM component, Airborne Self-separation applications are anticipated to provide many benefits over current centralised air traffic management. Potential benefits include increased safety, increased airspace capacity and flight efficiency, and increased flexibility for the airspace users:

- ✓ **System Capacity and User Efficiency**: Centralised ground-based traffic separation applications do not scale linearly with the anticipated growth of air traffic. By raising the aircraft-to-controller ratio and even removing the need for a controller under some circumstances, Airborne Self-separation applications provide the potential to grow proportionately with an increase in throughput. Much higher traffic throughput levels may be attainable before limits are reached. Capacity in airspace that is characterised by poor or non-existent radar coverage is increased through a reduction of applicable separation minima. Airspace users gain efficiency by applying their goals and preferences directly to flight management rather than relying on a controller either to make assumptions about user preferences or to accommodate user requests.
- ✓ **Flexibility**: Increased user flexibility results from the removal of restrictions that are based on the capabilities and availability of controllers to separate aircraft, and from the ability of the flight crew to react more appropriately to conflicts.
- ✓ **Safety**: Airborne Self-separation applications remove the dependence on a single controller team for the provision of separation. The applications enable the flight crews of all aircraft involved in a conflict to have the capability and authority to resolve it, thereby enabling an increase in redundancy. This redundancy has the potential to be used as an additional tool in an overall approach to achieving the required TLS.

4.6.3. Operational environment

Airborne Self-separation applications may require the development of specific new classes of airspace, specific rules for airspace access, standards for airborne separation minima and possibly specific flight rules. All these aspects are expected to require standardisation at the international level in order to allow aircraft operators to obtain the expected benefits worldwide, and minimise impediments to global interoperability:

- ✓ **Airspace considerations**: Airborne Self-separation applications could be applied within different airspaces:
  - En-route airspace in low traffic-density areas with good weather and away from major terminals. In such airspace, traffic should not be affected by traffic management constraints or other highly dynamic localised constraints.
  - En-route airspace characterised by dynamically changing regions that are either restricted or contain hazards to air traffic, transitional airspace that contains aircraft affected by flow constraints into terminal areas, or capacity-constrained terminal airspace. These airspaces are considered as more challenging environments for aircraft to self-separate.
  - Oceanic airspace in lieu of procedural control that is currently applied. There is a significant potential for a reduction of the applicable separation minima in such an environment, but this reduction precludes any separation provision by ATC. Under these circumstances, airborne self-separation will require all aircraft to be equipped.
- ✓ **Airspace Access**: Two modes of operations can be envisaged:
  - <u>Segregated environment</u>: This mode of operation makes use of the concept of 'Free Flight Airspace' [4]: a segregated airspace region where the flight crews are fully responsible for separation from the surrounding traffic from the entry to the exit points of the airspace. Flight crews are aware of all traffic because the access to this segregated airspace is restricted to suitably equipped aircraft. Such airspace would most likely be defined as en-route airspace above a specified flight level. One of the main issues is the management of the traffic density and complexity inside that airspace, as well as the management of the transition between that airspace and the adjacent ATC-controlled airspace. In particular, the traffic acceptance rates and restrictions imposed by adjacent controlled airspace will have to be taken into account.
  - <u>Mixed-equipage environment</u>: Where it is imperative to minimise the equipment required for airspace access and allow for a mix of avionics capability in individual aircraft. An alternative approach to achieving self-separation benefits for those users who choose to equip their aircraft is to distribute capability and responsibility for traffic management between aircraft and ground-based air traffic control. Such 'mixed equipage environment' would enable operational benefits to be achieved in transitional and terminal environments, where capacity is often limited, by allocating separation responsibility for aircraft not equipped for self-separation to controllers. However, such a mode of operation may increase the risk of confusion over responsibility for separation.
- ✓ **New Rules of Flight**: Airborne Self-separation applications may require specific flight rules to resolve ambiguities and prevent potential conflict disputes. As a conflict develops, flight crew goals and their resolution strategies change as a function of the time to the point of separation loss. If this time is large, co-operative resolution strategies involving explicit co-ordination among flight crews may be used. At some pre-specified time, the aircraft might be required to follow predetermined rules for resolving a conflict. These rules dictate which aircraft must manoeuvre ('priority rules') and the manoeuvre degrees of freedom ('manoeuvre rules'). They could be based on extensions of visual flight rules.
- ✓ **Shared Flight Intent Information**: Research is needed to determine the appropriate international standards regarding content and format of messages that must be exchanged between aircraft, and possibly between aircraft and ground systems. These message content standards will impact flight crews' ability to self-separate, their workload, their ability to monitor traffic conformance with intent, and surveillance system requirements. All of

these issues in turn impact feasibility and viability of the applications. Several factors must be considered when determining these standards:

- The need for flight crews and controllers to be aware of traffic intent, and the level of such information that will be required to prevent missed or false alerts must be determined. Intent content currently under consideration for exchange includes one or more trajectory change points and constraints, and flight mode indicators to convey information about additional trajectories that might result from off-nominal conditions.
- The need for adequate information transfer must be balanced with bandwidth limitations of available communication technology. Proposals to address bandwidth concerns include reduced update rates for intent exchange and broadcasting intent only if it changes. These solutions might limit feasibility of some Airborne Self-separation applications. Application concept and feasibility research should be integrated with communication technology development to achieve solutions that meet both bandwidth and application requirements
- Format standards for the exchanged intent information will impact the design of surveillance data processing, communication processing and self-separation functions. They also impact the capability to retrofit existing aircraft equipage with capabilities to self-separate

✓ **Airborne Separation Minima**: As discussed in section 3.6, one major issue will be the establishment of airborne separation minima to be applied by the flight crew during the Airborne Self-separation applications, so as to achieve safe flight operations.

4.6.4. Airborne Self-separation Applications

Typical Airborne Self-separation applications include:

✓ Airborne Self-separation in ATC-controlled airspace.
✓ Airborne Self-separation in segregated en-route airspace.
✓ Airborne Self-separation in mixed-equipage en-route airspace.

4.6.4.1. Airborne Self-separation in ATC-controlled airspace

A controller can delegate full responsibility for self-separation to the flight deck of suitably equipped aircraft through a new clearance. For the flights so cleared, separation by controllers is provided only once the clearance limit is reached. This clearance can be seen as an extension of ‘own separation while in VMC’ (as defined in PANS-RAC Doc 4444 Part III). Depending on the airspace, the provision of traffic information may be required. In case of an airborne separation minimum lower than the separation minimum applicable by ATC, the other flights may constitute essential traffic in relation to the flight cleared to maintain airborne self-separation. Accordingly, all essential traffic might have to be provided with information in order to enhance the safety of such procedures.

4.6.4.2. Airborne Self-separation in segregated en-route airspace

This application requires the flight crews to self-separate from other traffic inside that airspace without ATC support. Airborne self-separation provision during autonomous aircraft operations encompasses the identification of conflict (potential loss of separation with involved aircraft) and solutions, the implementation of the solution and monitoring at different time horizons.

To allow safe and efficient autonomous aircraft operations in segregated en-route airspace, it is envisaged that only suitably equipped aircraft and qualified flight crews will have access to that airspace. In particular, the flight crews must be provided with adequate information related to the surrounding traffic and dedicated decision support tools for conflict management based on the available information from other aircraft. It is anticipated that airborne surveillance will rely on Automatic Dependent Surveillance-Broadcast, but not exclusively. In case of a partial ADS-B equipage of the fleet, ground-based traffic information services could be used as a complementary source, or even the primary one, of surveillance data for airborne surveillance. Nevertheless full radar coverage is not a requirement.

In case of conflict situations, there is a need to ensure compatibility between the manoeuvres engaged by the participating aircraft through the application of pre-defined rules of flight or even some exchange of information for co-ordinating manoeuvres in real-time.

The traffic flow management in segregated en-route airspace is a relevant aspect, which should address the traffic density issue. It will have to balance demand and capacity and manage the global traffic density and as far as possible the local traffic density, at a level compatible with the flight deck capabilities. The ATS provider may have to play a role in that traffic flow management, over a wide range of time horizons.

The transition of traffic flows from/to the segregated en-route airspace represents a fundamental issue of this concept: rules and procedures will have to be defined to ensure compatibility and smooth transition of traffic flows between the different airspace. One of the key elements that will influence the transition will be the relationship between separation minima applicable in the two adjacent airspaces. Another key element to be taken into account will be the compatibility between the constraints related to the route structure in controlled airspace and the freedom of flight given to the airspace users in the segregated en-route airspace.

4.6.4.3. Airborne Self-separation in mixed-equipage en-route airspace

While in the en-route airspace, appropriately equipped aircraft (referred to as “autonomous aircraft”) are given the authority, capability, and procedures needed to execute user-preferred trajectory changes without requesting ATS provider clearance to do so. Along with this authority, the flight crews assume the responsibility to ensure that the active trajectory is conflict free and trajectory changes do not generate near-term conflicts with other aircraft in the vicinity. The trajectory change must also conform to any active local traffic flow management constraints, which are imposed by the ATS provider. Causes for these constraints include current or predicted severe convective weather, active special use airspace, airspace congestion, and arrival metering/spacing.

The ATS provider is responsible for separation provision for lesser-equipped aircraft (referred to as “managed aircraft”) through the provision of trajectory clearances. The controller may also monitor autonomous aircraft operations and provide advisories when able. Ground-based decision support automation assists the controller. Depending on the outcome of operation research and controller acceptability studies, the controller may act on behalf of managed aircraft when they are in potential conflict with autonomous aircraft. Procedures, flight rules, and new airspace designs may be incorporated to provide incentives for aircraft to equip for autonomous operations.

4.6.5. Roles and Procedures for Flight Crews and Controllers

Airborne Self-separation applications will significantly change the roles of flight crews and controllers. The operational procedures must precisely define these roles and flight crews’ and controllers’ responsibilities for aircraft separation.

In addition to their current role in managing their flight in a safe and efficient manner, the flight crews will be responsible for detecting potential losses of separation with other aircraft, and deciding on the means by which separation will be preserved. When manoeuvring, the flight crew must comply with airborne separation standards and applicable flight rules.

Controllers will no longer be required to provide separation for the aircraft involved in airborne self-separation. In a mixed-equipage environment, controllers will continue to provide separation between pairs of managed aircraft, and depending on the outcome of feasibility and human operator acceptability studies, between managed and autonomous aircraft.

Controllers will focus on managing the efficient flow of traffic by establishing flow constraints and ensuring that traffic density and complexity remain at a level compatible with the flight deck capabilities to perform airborne self-separation. They might also provide flight information to the aircraft involved, depending on the services provided within the airspace.

Depending on the application, it may remain the responsibility of controllers to clear flight crews to perform airborne self-separation operations.

The aircraft operators may play a role in the management of their fleet as part of Airborne Self-separation applications. The aircraft operator under some circumstances may share the strategic planning component of the flight crew's role.

4.6.6. Human Factors Principles

Airborne Self-separation will introduce the most significant departure from conventional tasks for flight crew and controllers. Consequently, this category of applications will require the most thorough research and investigation of human factors issues. In particular, the flight crews must remain in control of the decision loop, in which they can determine the separation provision actions to be taken. Even more than for other ASAS categories, there is a need to insure that proper automation support is provided to the flight crew. New rules and procedures will be needed to address the issues of communication, co-ordination and priorities between flight crews involved in airborne self-separation operations. The provision of intent information to flight crew should be evaluated.

In a mixed-equipage environment, new rules and procedures will be needed to avoid confusion over roles and responsibilities for separation provision between flight crews and controllers.

4.6.7. Principles Governing the Requirements for Aircraft Systems

The following main functions are performed by the ASAS to support Airborne Self-separation applications:

- ✓ Surveillance data processing (associated principles are detailed in section 5.2.2);
- ✓ Display of traffic (associated principles are detailed in section 5.2.4);
- ✓ Traffic Information processing (associated principles are detailed in section 5.2.5);
- ✓ Self-separation function processing (associated principles are detailed in section 5.2.6); and
- ✓ Air Traffic Management function processing (associated principles are detailed in section 5.2.7).

4.6.8. Principles Governing the Requirements for ATC Systems

State and intent information exchanged between aircraft may also be received by ATC systems to support the mission of the ATS provider. The ATS provider may in turn uplink this information to all aircraft, thereby enabling aircraft to have access to information outside the range of their aircraft receivers. As with the aircraft systems, the ATC systems will need continuous updating of position and intent information from each aircraft equipped for airborne self-separation provision. ATC systems will also require information regarding the capabilities of each aircraft, including the state of operation of on-board navigation and surveillance systems. Winds and temperatures aloft information may also be useful to ATC systems to develop accurate wind-field information and broadcast it back to the aircraft to enable them to plan for accurate and efficient compliance with traffic management constraints.

Depending on the application, the ATS provider may require decision support automation as well. This automation includes tools that assist controllers in establishing constraints to expedite the flow of traffic, such as required times of arrival at specified locations or required sequencing and spacing between aircraft. The tools may also establish constraints that determine airspace access, based on traffic density or situation complexity; they may support controllers in issuing clearances to aircraft that must be managed by ATC systems; or they may enhance controller situation awareness during monitoring activities.

For Airborne Self-separation applications, ground-based monitoring of the airborne surveillance data might be required. Ground-based monitoring might serve as a potential means of redundancy that raises the integrity and safety of the application.

Ground-based monitoring could be also necessary to verify that aircraft operations are conducted in accordance with the applicable standards and rules of the air.

4.6.9. Principles for Implementation

4.6.9.1. Implementation Considerations

The notion of separation responsibility is very important in air transport activities due to the regulatory aspects, and the legal implications that can be derived from it. Therefore, there is a need for an internationally approved operational concept allowing such delegation of separation responsibility from the ground to the air as envisaged for Airborne Self-separation applications.

These ASAS applications will be accepted only if they achieve a required TLS. Therefore a full risk assessment, including assessments for the aircraft segment and for the ground ATC segment, has to be performed following recognised methodologies prior to their implementation.

For benefits to justify the cost of equipping, Airborne Self-separation applications may be required to apply not only to low-density airspace, but also to dense and complex airspace. Therefore, there is a need to determine the operational viability of these applications in all anticipated environments prior to implementation.

In order to support a transition phase to full ASAS equipage it will be important to encourage early equipage, and be able to demonstrate the benefits of early equipage to airspace users. During the transition phase - when there is a mixed population of non-equipped and suitably equipped aircraft - it will be necessary to consider which Airborne Self-separation applications are feasible to implement.

4.6.9.2. Military Considerations

In addition to the implications for Civil Aviation, the Airborne Self-separation applications might have an impact on the equipage required for military operations. However, military organisations need access to all airspace and might need to control their aircraft at any time, regardless of equipage. From that perspective, the implementation of some Airborne Self-separation applications could be an issue and will have to be considered by individual States.

5. Airborne Separation Assurance Systems

5.1. ASAS Definition

The following ASAS definition is used in the document:

Airborne Separation Assurance System (ASAS)*: An aircraft system that enables the flight crew to maintain separation of their aircraft from one or more aircraft, and provides flight information concerning surrounding traffic.*

Note 1: This definition differs from the SCRS Panel definition. The document proposes to divide the SCRS Panel ASAS definition into an ASAS definition more focused on the system (see above) and an ASAS application definition related to the intended operational goal and the associated operational procedures (see section 4.1).

Note 2: The provision of flight information is an essential part of airborne separation provision. Systems that provide only flight information are deliberately encompassed by the definition, because a proliferation of notional 'systems' would be confusing. However, the term 'ASAS' would normally relate to more capable systems.

Note 3: The word 'assurance' is confusing for many people because it is often associated with a verification process. When speaking of separation the word 'provision' was preferred throughout this document.

Note 4: A suggestion has been made to revert to the original acronym 'Airborne Separation Assistance System' which was proposed to SICASP Working Group 2 in 1995 [2]. The word 'assistance' seems to better cover the functions provided by the system that assists the flight crews in providing separation between aircraft (i.e. visual separation, or airborne spacing, or airborne separation).

ASAS is a system. The installation of ASAS onboard an aircraft might impact existing systems (e.g. FMS) or equipment (e.g. displays) and may also require new equipment depending on the required aircraft architecture.

5.2. ASAS Functions

5.2.1. Introduction

An ASAS installation may support any number of the applications discussed in Section 4. To do so, ASAS must perform several functions. These could be categorised as follows:

1. Airborne surveillance function
2. Other data-link communications
3. Display of traffic information
4. Traffic information processing
5. Airborne spacing and separation functions
6. ATM functions

A specific ASAS installation will not necessarily perform all of these functions. The most basic equipment might perform only functions in categories 1, 3, and 4, while more advanced equipment might perform all the functions. The definition of each application will impose functional and performance requirements on ASAS equipment. As a result of Operational Safety Assessments for each application, additional requirements can be allocated to equipment and procedures to assure conformance with safety objectives. Examples of such requirements include design assurance levels or redundancy.

Regardless of the degree of shared functionality, ASAS functions must be integrated with all cockpit functions and must not impair them.

5.2.2. Airborne Surveillance Functions

ASAS performs airborne surveillance of surrounding traffic. The primary means for this surveillance is normally ADS-B; other means are discussed below. With ADS-B, other aircraft periodically broadcast their own position, velocity, and certain other information. This other information can include the aircraft identification (flight number or aircraft registration number), aircraft type, capability, and near-term intended flight path. Additional information may also be broadcast, and might be necessary for some applications. Such information includes winds and temperatures aloft, navigation uncertainty and integrity categories, and the state of operation of on-board navigation and surveillance systems.

All this information is received passively by ASAS, that is, without its making interrogations. Because of interference and other probabilistic phenomena, every report may not be received. This is taken into account in designing the rate of broadcasting ADS-B reports and the other parameters of the communication link. Reception range requirements must be established for each application.

The position information, which could come from any of a number of navigation sources, also includes information describing its accuracy and integrity limits. For example, some targets could determine their position using augmented GNSS; others with basic GNSS, and still others using less accurate navigation sources. Also, a given GNSS position can vary in accuracy or integrity depending on such factors as the number and geometry of the satellites it uses. The accuracy and integrity must be known to determine a target’s eligibility for some applications.

The surveillance function tracks each aircraft. An ADS-B report contains a technical identification that enables association of an aircraft’s report with its previous reports. The surveillance function can determine the time since an update was received, and can extrapolate an aircraft’s position during a reasonable interval of missing updates. In so doing, the ASAS tracker also must expand the uncertainty about the aircraft’s tracked position, since the aircraft may have manoeuvred since the last update.

Another source of traffic data is from Traffic Information Service – Broadcast (TIS-B) messages. TIS-B is a system that can be implemented at locations on the ground to provide traffic information to aircraft. It uses ground-based surveillance to construct reports that resemble ADS-B reports, and broadcasts these to aircraft within a defined service volume of airspace.

Since the source of TIS-B surveillance is different than aircraft navigation sources (e.g., radar rather than onboard GNSS), it is likely that its reports’ accuracy and integrity values will differ from those of equipped aircraft. Studies must be performed to determine which applications could be supported by TIS-B surveillance.

The primary purpose of TIS-B is to enable ASAS-equipped aircraft to receive information for nearby traffic that is not equipped with ADS-B. A ground TIS-B station might provide reports for only such traffic. It does so by receiving equipped aircraft broadcasts and correlating these with its own tracks, in order to not broadcast their information. This approach has the advantages of conserving bandwidth, since fewer reports are broadcast, and also of relieving ASAS surveillance of most correlation of ADS-B and TIS-B reports for aircraft, and of recognising (and ignoring) TIS-B reports for their own position.

Since ASAS may receive surveillance inputs from more than one source, it must correlate inputs to avoid creating duplicate tracks for targets. This may be done using aircraft identity, if provided, or using position. The surveillance function also must either select a single source of input, or can fuse data from the various sources, taking the accuracy, integrity, and time of applicability into account.

5.2.3. Other Data-link Communications

Some ASAS applications may require air-to-air or air-to-ground data-link communications that do not fall within the airborne surveillance information described in 5.2.2.

- ✓ **Air-to-air:** This information would be transmitted by one aircraft participating in an ASAS operation and addressed to another aircraft, rather than being broadcast to all. This data could include information on the current or planned trajectory (i.e., intent) that is only considered useful to the addressee. For the example of an airborne conflict resolution, these communications could co-ordinate the proposed resolution manoeuvres between the participating aircraft.
- ✓ **Air-to-ground**: Air-ground data-link communications may also be used to perform ASAS functions such as the ATM functions described in section 5.2.7.

Note: These examples are intended only to illustrate conceptual uses of addressed communications. The applications cited have not been developed and it is not yet known if they will use these data.

5.2.4. Display of Traffic Information

All uses of ASAS are envisioned as involving some display of traffic information to the flight crew. Most work to date has involved a graphical Cockpit Display of Traffic Information (CDTI). Other means are possible, including textual, aural, head-up, or others. This section will describe display functions, and an equivalent function would need to be demonstrated for other media.

The Display uses inputs from airborne surveillance processing, inputs from ownship navigation (and possibly own FMS), and control inputs from the flight crew. These are described as part of the Display function, since they primarily would control display features.

An ASAS display could be unique or shared with other onboard functions (e.g. navigation/FMS display or weather radar). Various factors, including functionality, cost, reliability, priority of function, availability, and common-mode failures, must be considered for an individual installation.

A CDTI is normally implemented for depiction of traffic information relative to own-ship. Using a convenient orientation (e.g., track-up, heading-up, or North-up), target symbols are located relative to an own-aircraft reference. If traffic is shown in plan view, data tags may be located near to the symbols, showing altitude, identity, and other information useful to the application. Target velocity may be depicted, e.g., by extending a vector from the traffic symbol.

The information depicted may vary according to the application in use. The display scale also may vary by application or phase of flight, to enable accuracy of interpretation and to minimise clutter. Other controls may be used to suppress the display of extraneous targets or information.

The display may provide additional textual or graphical information related to an ASAS application. These are discussed in the following sections.

When alerts are generated in connection with an ASAS application, some combination of aural and visual cues can be provided.

Airborne Self-separation applications might require the display of equipage level and/or capability to self-separate for each target aircraft, and a confidence level associated the information provided. A vertical display may also be necessary for some applications to provide information regarding climb and descent profiles of traffic aircraft, and to enhance decision making for conflict detection and resolution.

5.2.5. Traffic Information Processing Functions

These functions are associated with Airborne Situational Awareness applications. They support the display of information that assists the flight crew in knowing the surrounding traffic situation and in visually acquiring traffic. These functions may operate both in the air and on the airport surface.

As described in section 5.2.4, the traffic symbol depicts the location of a target. The display also may depict the uncertainty associated with this position, so as to prevent flight crews from overestimating the accuracy of the displayed position.

The flight crew may use a control input to designate a particular target of interest, e.g., with a special symbol. This can help crews to quickly identify the same symbol after looking away. Also, the crew may elect to display additional information about the target (e.g., aircraft type, ground speed) that is normally not shown to avoid display clutter, or may reduce the number of targets displayed to further reduce clutter.

These applications may involve alerts to signify proximate traffic, determined by comparison to ownship navigation position and velocity. Display features, e.g., colour, could identify the target(s) causing the alert.

On the airport surface, targets and ownship symbol can be displayed on a surface map. Different symbols can distinguish airborne targets from those on the ground; or either type can be suppressed.

5.2.6. Airborne Spacing and Separation Functions

5.2.6.1. General principles

Additional functions are required to perform Airborne Spacing, Airborne Separation or Air Self-separation applications. In addition to the functions and features described in section 5.2.5, functions are needed to:

- ✓ Give the flight crews guidance in achieving or maintaining a designated time or distance between target and ownship or an applicable separation minimum.
- ✓ Issue alerts, possibly accompanied by specific guidance, indicating a loss of separation or other hazardous or non-nominal conditions.

The spacing and separation functions are likely to require higher equipment criticality levels than situational awareness functions, since unavailable or misleading information could lead to loss of separation.

A wide range of automation options might be possible, ranging from a manual solution, wherein the flight crew will modify the aircraft trajectory in order to meet the required spacing or the applicable separation minima, up to the most automated option through FMS trajectory modification. This latter implementation may raise the criticality of the application.

5.2.6.2. Spacing and Separation Functions

At the basic level, the calibration of the display scale allows crews to estimate distances. However, the ASAS automation determines distances and times with far greater accuracy than can be depicted graphically. For these applications, crews may prefer a textual display of current or projected range from a selected target. For crossing/passing applications, a projection of flight paths can graphically show the closest point of approach as lying within or without a desired threshold.

Spacing functions should allow the flight crew to conduct the spacing tasks, including merging manoeuvres, by supporting the establishment and maintenance of the desired spacing. Speed and turn guidance could be useful. Received ADS-B data provides ASAS with immediate updates of a target's speed. The processing could provide guidance to the flight crew for maintaining spacing within desired tolerances.

Separation functions should allow the flight crew to conduct the separation tasks, including crossing or merging manoeuvres, by supporting the establishment and maintenance of the applicable separation minima. For separation and self-separation applications, conflict detection and resolution decision aids will detect the potential loss of separation and alert the crew to enable them to take corrective action. The conflict detection function must analyse one or more potential trajectories of ownship and traffic aircraft to detect traffic hazards over a specified time horizon. The function must continuously check for changes to the ownship trajectory, which may be input from the flight crew to resolve the conflict manually, and possibly monitor conformance of traffic to broadcast intent. The time horizons must be established based on traffic environments that are found to be worst-case for a specified application. In high traffic-density environments characterised by traffic flow management constraints, these time horizons may be large.

Flight crew decision support automation might also provide conflict resolution advisories, and might co-ordinate the resolution among the aircraft involved.

5.2.6.3. Alerting functions

For some applications, ASAS processing must monitor tracks and projections in order to issue alerts in a timely manner when action is required. The design must achieve an acceptable balance between the protection of these alerts and minimising unnecessary alerts.

For spacing applications, the function should provide alerts/alarms to the flight crew for the purpose of maintaining spacing safely and efficiently. Examples of alerts include conditions where spacing is too close or too far from the spacing value given in the spacing instruction.

For separation applications, this function should provide alerts/alarms to the flight crew for the purpose of maintaining separation safely and efficiently. Examples of alerts include conditions where separation is too close or too far, and conditions where the delegated aircraft is approaching/passing the point where the procedure is terminated.

Alerts/alarms should be compatible with other cockpit alarms (e.g. terrain avoidance, flight envelope alerting). More generally, all alerts should conform to existing standards and prioritisation.

ATC monitoring and alerting functions are separate but should be compatible with aircraft monitoring and alerting functions.

5.2.7. ATM Functions

Some ASAS applications address the ATM function of aircraft separation, beyond the separation or spacing from a designated aircraft. These applications detect and resolve conflicts between ownship and any other traffic known to ASAS. The ASAS processing continually monitors all tracks and compares current and predicted separations to the applicable separation minima.

Crew decision support automation might also provide conflict resolution guidance, and might co-ordinate the resolution among the aircraft involved. Some applications might employ strategic resolutions to solve conflicts, which determine trajectory changes necessary to meet the objective of the free-conflict flight plan. The flight crew might also be provided with interactive tools, enabling them to supplement the automated conflict-resolution process with manual "what-if" manipulation of the trajectory to meet the preferences or goals of the flight crew or the aircraft operator.

A trajectory planning capability and crew decision aids might be needed for some Airborne Self-separation applications. These include some that are characterised by real-time flight management that accounts for complex traffic and airspace constraints, schedule requirements, and other user-defined goals. A capability to receive addressed uplink of constraints from ground-based airspace management systems may be needed for these applications. Conflict resolution functions might use a hazard resolution strategy consistent with user flight management goals and, potentially, the capabilities of other involved aircraft. Various methods for reducing ambiguity, such as intent inference, might be necessary where the state-vector information does not match the intended trajectory as broadcast. A prioritisation of several simultaneous traffic hazards might also be necessary for some applications.

These ATM functions are likely to require higher equipment criticality levels than the functions discussed in the previous sections.

5.3. Relationship between ASAS Functions and ACAS

5.3.1. Introduction

ACAS has been developed and implemented as a back up to an acceptably safe ATM system. It provides the flight crew with an alert and manoeuvre advisory when it detects a potential for imminent collision with another aircraft. The ICAO definition for Airborne Collision Avoidance System (ACAS) (Annex 2 – Rules of the Air) is the following:

> "*An aircraft system based on secondary surveillance radar (SSR) transponder signals which operates independently of ground-based equipment to provide advice to the pilot on potential conflicting aircraft that are equipped with SSR transponders.*"

Since ACAS is required for certain classes of aircraft, it is probable that some aircraft will be equipped with both ACAS and ASAS. It is also probable that aircraft equipped with only one system will be in threat situations with aircraft equipped with only the other. This section outlines principles for the relationship between ACAS and ASAS where both are installed on the same aircraft, and for situations where differently equipped aircraft may threaten one another.

As discussed is section 3.7, ASAS applications must be complete and proven safe without relying on ACAS. For example, it would be unacceptable to rely on invoking the ACAS safety net when an ASAS procedure is aborted.

5.3.2. ASAS and ACAS Surveillance

ASAS must not be based on ACAS surveillance. The **principled reason** for this is that doing so might undermine the ACAS function. The more practical consideration is that the ACAS surveillance is of little value because of the restrictions placed on it to limit interference between ACAS SSR interrogations. This results in not all proximate aircraft being tracked by ACAS in all situations.

The ACAS SARPs [5] describe a hybrid surveillance technique based on using the Mode S extended squitter (i.e. the 1090 MHz implementation of ADS-B). The purpose of this particular scheme is only to reduce the frequency of active interrogations by ACAS, not to produce a composite surveillance picture suitable for more than ACAS.

5.3.3. Shared Use of the Traffic Display

ACAS does not require a traffic display. However, when a display is provided for ACAS, it may share that display with ASAS (and probably other functions, see section 5.2.4). Only one target should be displayed for each tracked aircraft. If both ASAS and ACAS are tracking a target, and the ASAS software can associate the tracks, then the ASAS target should be the one displayed. If either ASAS or ACAS is tracking a target that is not tracked by the other system, the CDTI must show a target, and it must be apparent which system has produced the target.

ASAS applications must be based on ASAS surveillance and should not be performed on targets based on ACAS alone (other than any general situation awareness gained from a shared traffic display). ASAS manoeuvres on targets that are based solely on ACAS surveillance are not permitted.

5.3.4. ASAS and ACAS Alerts

Where aircraft are equipped with both ACAS and ASAS, alerts should be clearly distinguishable, so that the flight crew are aware of which system is providing the alert.

As a matter of general design, ASAS conflict warnings should occur well in advance of any potential ACAS alert. However, situations in which both occur may happen when both are active. Conflicting resolution advisories must be avoided.

Situations where a beneficial ASAS application (for example, approaches to closely spaced parallel runways) has been shown to be acceptably safe, but ACAS would provide unacceptable nuisance alerts, are possible. Not implementing demonstrably safe ASAS applications because of unacceptable ACAS nuisance alerts is unreasonable. Either ACAS alerts must be suppressed while the ASAS application is being performed, or some other technical solution allowing implementation of the ASAS application should be sought. The circumstances under which either system is suppressed in favour of the other require very careful attention. The guiding principle is that safety should not be compromised by suppression of either system, although in practice, this may be very difficult to determine.

Additionally, threat situations between ASAS and ACAS equipped aircraft must be considered to ensure appropriate resolution. In this case, ASAS should be aware of the resolution advisory provided to the ACAS equipped aircraft, and propose a complementary avoidance manoeuvre.

5.3.5. Other Shared Components

Any components shared between ACAS and ASAS should have sufficient availability and integrity to be acceptable as a common point of failure.

6. Summary and Conclusions

This document was developed under the auspices of Action Plan 1 of the FAA/EUROCONTROL Co-operative Research and Development Committee. Its objective is to elaborate the ‘Principles of Operation for the use of Airborne Separation Assurance Systems’.

The main guiding principle is that Air Traffic Services can be enhanced through greater involvement of flight crews and aircraft systems in co-operation with controllers and the Air Traffic Management system. The concepts of ‘airborne spacing’ and ‘airborne separation’ are used to support this argument.

Taking into account various considerations (conceptual, operational procedures, human factors, aircraft systems, enabling technologies, users’ perspectives and implementation), four ASAS application categories have been defined. For each ASAS application category, principles of operation have been further developed including the relationship to airborne collision avoidance. Where it was not possible to develop firm principles, specifically for the Airborne Self-separation applications, guidance based on the current knowledge and research has been given.

When defining an ASAS application, its category (Airborne Traffic Situational Awareness, Airborne Spacing, Airborne Separation or Airborne Self-separation) should be carefully selected because categories are associated with different principles. The wrong selection of the application category could lead to the misuse of that application and have major impact on the safety of flight.

ASAS applications involving major reliance on aircraft systems and changes to present responsibilities and procedures to ensure aircraft separation will require rigorous safety analysis and validation before implementation. This analysis will need to demonstrate conclusively that the ASAS application meets or exceeds the required Target Level of Safety, including consideration of equipment failure and human error. Methodologies and guidelines for these analyses will need to be agreed at the international level.

This document is not an approved policy for ASAS applications and does not provide an implementation road map. It was not its objective to develop operational and technical standards and many identified issues need to be resolved.

Nevertheless, **it is hoped that this document will be used as guidelines by the research community, at the international level (ICAO Panels), at the national level (Airspace Authorities, ATS Providers and Certification Authorities), at the technical standardisation level (RTCA, EUROCAE). It seeks to focus the work necessary prior to the implementation of any ASAS application.**

Appendix A - References

[1] Report of the RTCA Board of Director's Select Committee on Free Flight, January 1995

[2] SICASP/WG2/WP489 – Airborne Separation Assistance System – The ASAS Concept, Sydney, March 1995

[3] SICASP6/WP44 – Report on Agenda Item 6 - The ASAS Concept, February 1997

[4] Operational Concept Document (OCD) from EUROCONTROL, March 1997

[5] ACAS SARPs - International Standards and Recommended Practices, Aeronautical Telecommunications, Annex 10 to the Convention on International Civil Aviation, Volume IV - Surveillance Radar and Collision Avoidance Systems, Chapter 4 – Airborne Collision Avoidance Systems, 2nd edition, July 1998.

[6] ADSP5/WP61 - Report on Agenda Item 4 – Appendix B – Information relevant to the use of a system to increase traffic situational awareness and provide airborne separation assurance, October 1999

[7] SICASP7/WP27 - Report on Agenda Item 6 – Appendix A - ASAS Circular, September 2000