



ICAO

Doc 9994

Manual on Airborne Surveillance Applications

Second Edition, 2020



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AMENDMENTS

Amendments are announced in the supplements to the *Products and Services Catalogue*; the Catalogue and its supplements are available on the ICAO website at www.icao.int. The space below is provided to keep a record of such amendments.

RECORD OF AMENDMENTS AND CORRIGENDA

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TABLE OF CONTENTS

	<i>Page</i>
Foreword	(vii)
Glossary	(ix)
Chapter 1. Automatic dependent surveillance–broadcast (ADS-B)	1-1
1.1 Overview	1-1
1.2 Interactions of ADS-B and airborne collision avoidance system (ACAS)	1-2
1.3 The limitations of ADS-B	1-3
Chapter 2. Initial airborne surveillance capabilities and in-trail procedure (ITP)	2-1
2.1 Description of the initial airborne surveillance capabilities	2-1
2.2 In-trail procedure (ITP)	2-7
2.3 Additional information for ATC	2-8
2.4 Additional information for pilots	2-9
2.5 Considerations for partial equipage environment	2-11
2.6 Stakeholders considerations	2-12
2.7 Flight planning	2-15
2.8 Validation of capabilities / applications	2-15
2.9 Architecture	2-16
Chapter 3. Specific Implementations	3-1
3.1 Cockpit display of traffic information (CDTI) assisted visual separation (CAVS)	3-1
3.2 Additional information for ATC	3-3
3.3 Additional information for pilots	3-3
3.4 Considerations for partial equipage environment	3-4
3.5 Stakeholders considerations	3-5
3.6 Validation of capabilities / applications	3-6
Chapter 4. Interval Management	4-1
4.1 Description of interval management	4-1
4.2 Operational environments for IM	4-2
4.3 Benefits for IM	4-2
4.4 Air traffic control (ATC) role	4-2
4.5 Pilot role	4-4
4.6 Considerations for partial equipage environment	4-4
4.7 Stakeholder considerations	4-4
4.8 Flight planning	4-6
4.9 Architecture	4-7
4.10 Validation	4-8

	<i>Page</i>
Chapter 5. Advanced applications	5-1
5.1 Description of advanced airborne surveillance applications (ASA).....	5-1

FOREWORD

Airborne surveillance is rapidly evolving with a number of new capabilities planned for introduction into the flight deck. The ICAO *Global Air Navigation Plan (GANP)* (Doc 9750) requires that these be interoperable in order to allow aircraft to achieve the same levels of safety and efficiency globally. Airborne surveillance represents a shift in surveillance functionality from traditional ground-based sensors to a comprehensive suite of avionics which will support a range of new, demanding surveillance capabilities and applications. Aircraft position and other airborne parameters are/will be provided by the basic airborne surveillance capability, known as ADS-B OUT. This information is/will be used directly by other aircraft equipped with an advanced capability, known as ADS-B IN, to support both existing applications, and some yet to be developed.

This manual describes several airborne surveillance capabilities such as Basic Airborne Situational Awareness (AIRB), visual separation on approach (VSA), Basic Surface Situational Awareness (SURF) and ADS-B traffic awareness system (ATAS). It also describes the in-trail procedure (ITP) application and the interval management (IM) application, which were introduced in the Aviation System Block Upgrades (ASBUs) supporting GANP.

The ASBUs contain modules which rely on ADS-B Standards, both for ADS-B OUT (ASUR-B0/1: automatic dependent surveillance – broadcast (ADS-B)) and for ADS-B IN, which are the key enablers for airborne surveillance. Their evolution is described in specific threads related to airborne surveillance applications (ASA) (CSEP-B1/1: AIRB to CSEP-B4/1: airborne separation) as well as airborne collision avoidance (ACAS-B1/1: ACAS improvements and ACAS-B2/1: new collision avoidance system).

Future airborne ADS-B IN applications which involve separation minima less than current radar separation standards may require changes in the airborne collision avoidance system (ACAS). Therefore, implementations of various airborne ADS-B IN applications may be dependent on the availability for implementation of a new collision avoidance system.

This manual also provides initial material regarding cockpit display of traffic information (CDTI) and assisted visual separation (CAVS) capabilities. CAVS is explained in Chapter 3 as specific implementation, since there are operational implementations of these capabilities only in one country as of 2020.

For surface applications, it is pointed out that SURF and SURF-IA (SURF-B1/2: Comprehensive pilot situational awareness on the airport surface and SURF-B2/3: conflict alerting for pilots for runway operations) are expected to complement A-SMGCS levels 1 and 2 and A-SMGCS levels 3 and 4.

This manual was initially developed by the Airborne Surveillance Task Force (ASTAF) that was established by ICAO in 2010 as a multidisciplinary team of experts for the timely development of ICAO provisions to ensure global uniformity and interoperability of operations based on the use of ADS-B on the flight deck. Three main objectives of this manual are as follows:

- a) to support the implementation of ASA and the initial airborne surveillance capabilities, for which some industrial solutions are already available and in operational use;
- b) to present guidance material and references related to the standards and recommended practices (SARPs), the procedures for air navigation services (PANS) and relevant industry standards documents, i.e. safety, performance and interoperability requirements (SPR) and minimum operational performance standards (MOPS);

- c) to summarize and recapitulate within an ICAO document the main results of the airborne surveillance work carried out in the air traffic management (ATM) community supported by ADS-B, which is recognized as an essential enabler of the ICAO global concept of operations as a promoter of the related ASBU threads.

The manual will be updated with the support of the Surveillance Panel (SP) to incorporate additional ASA when they are made available to the global ATM community.

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GLOSSARY

ABBREVIATIONS

ABP	Achieve-by point
ACAS	Airborne collision avoidance system
ACID	Aircraft identification
ADS-B	Automatic dependent surveillance–broadcast
AIRB	Basic Airborne Situational Awareness
ANSP	Air navigation services provider
ASA	Airborne surveillance application(s)
ASBU	Aviation System Block Upgrade
ASG	Assigned spacing goal
ASSAP	Airborne surveillance and separation assurance processing
ASTAF	Airborne Surveillance Task Force
ATAS	ADS-B traffic awareness system
ATC	Air traffic control
ATM	Air traffic management
ATS	Air traffic services
ATSA	Air traffic situational awareness
CAA	Civil aviation authority
CAVS	CDTI assisted visual separation
CDTI	Cockpit display of traffic information
CPDLC	Controller-pilot data link communications
CRM	Crew resource management
EASA	European Union Aviation Safety Agency
EUROCAE	European Organization for Civil Aviation Equipment
FIM	Flight-deck interval management
FMS	Flight management system
FUA	Flexible use of airspace
GNSS	Global navigation satellite system
GBAS	Ground-based augmentation system
HF	High frequency
HMI	Human-machine interface
ICAO	International Civil Aviation Organization
IFR	Instrument flight rules
IM	Interval management
IMC	Instrument meteorological conditions
ITP	In-trail procedure
MLAT	Multilateration (systems)
MOPS	Minimum operational performance standards
NAC	Navigation accuracy category
NIC	Navigation integrity category
NUC	Navigation uncertainty category
OEM	Original equipment manufacturer
OSA	Operational safety assessment
OTW	Out-the-window
PCP	Planned cancellation point
RA	Resolution advisory

RSI	Runway status indication
SESAR	Single European Sky ATM Research
SIL	Source integrity level (ADS-B version 2)
SIL	Surveillance integrity level (ADS-B version 1)
SOP	Standard operating procedure
SPR	Safety, performance and interoperability requirements
SSR	Secondary surveillance radar
SBAS	Satellite-based augmentation system
SURF	Basic Surface Situational Awareness
TA	Traffic advisory
TIS-B	Traffic information service—broadcast
TLS	Target level of safety
VFR	Visual flight rules
VHF	Very high frequency
VMC	Visual meteorological conditions
VSA	Visual separation on approach
WAM	Wide area multilateration

DEFINITIONS

Airborne surveillance and separation assurance processing (ASSAP). The processing of surveillance and other data in support of ASA. ASSAP function that processes surveillance data using ADS-B reports from the ADS-B receive function, and performs application-specific processing.

Airborne surveillance application (ASA). A set of operational procedures for controllers and pilots that makes use of the capabilities of airborne surveillance to meet a clearly defined operational goal.

Airborne surveillance capability. An installation into a flight deck that receives/processes surveillance data, and displays relevant information to the pilot.

Airborne surveillance system. An airborne surveillance system provides the position of participating aircraft and vehicles in the vicinities and other related information to pilots and on-board systems. In most cases, the system provides knowledge of “who” is “where” and “when”. Other information may include horizontal and vertical speed data, identifying characteristics or intent.

Airborne traffic situational awareness applications. These applications are aimed at enhancing the pilots’ knowledge of the surrounding traffic situation, both in the air and on the airport surface, and thus improving the pilots’ decision process for the safe and efficient management of their flight.

Aircraft address. A unique combination of 24 bits available for assignment to an aircraft for the purpose of air-ground communications, navigation and surveillance.

Aircraft identification (ACID). A group of letters, figures or a combination thereof which is either identical to, or the coded equivalent of, the aircraft call sign to be used in air-ground communications, and which is used to identify the aircraft in ground-ground air traffic services communications.

Assigned spacing goal. The time or distance interval between the IM aircraft and target aircraft assigned by the air traffic controller as part of the IM operation. The assigned spacing goal is determined by the air traffic controller issuing the IM clearance and the type and value(s) of the assigned spacing goal are selected to achieve the air traffic controller's goal of establishing an efficient flow while maintaining separation from all traffic.

Automatic dependent surveillance–broadcast (ADS-B) OUT. A function on an aircraft or vehicle that periodically broadcasts its state vector (position and velocity) and other information derived from on-board systems in a format suitable for ADS-B IN capable receivers.

Automatic dependent surveillance–broadcast (ADS-B) IN. A function that receives surveillance data from ADS-B OUT data sources.

Closing ground speed. The difference between the ITP aircraft's ground speed and a reference aircraft's ground speed, used to determine the reduction in ITP distance.

Closing Mach speed. The difference between the ITP aircraft's Mach speed and a reference aircraft's Mach speed, used to determine the reduction in ITP distance.

Cockpit display of traffic information (CDTI). The pilot interface portion of the aircraft surveillance applications system. This interface includes traffic display(s) and all the controls that interact with such a display.

Conflict. A predicted violation of parameterized minimum separation criteria for adverse weather, aircraft traffic, special use airspace, other airspace, turbulence, noise sensitive areas, terrain and obstacles, etc.

Essential traffic. Essential traffic is that controlled traffic to which the provision of separation by ATC is applicable, but which, in relation to a particular controlled flight is not, or will not be, separated from other controlled traffic by the appropriate separation minimum.

Free text message element. Part of a message that does not conform to any standard message element in the PANS-ATM (Doc 4444).

Ground speed. The speed of an aircraft or vehicle relative to the ground.

Hazard. Any real or potential condition that can cause injury, illness, or death to people; damage to or loss of a system, equipment, or property; or damage to the environment.

Horizontal velocity. The horizontal component of velocity relative to a ground reference.

IM aircraft. An aircraft approved by the State of the Operator that is equipped with FIM Equipment that is instructed to perform an IM Operation.

Interval. The horizontal along-path spacing between the IM and target aircraft. The interval may be specified in time or distance.

ITP aircraft. An aircraft approved by the State of the Operator to conduct in-trail procedure (ITP).

ITP distance. The distance between the ITP aircraft and a reference aircraft as defined by:

- a) for aircraft on the same track, the difference in distance to an aircraft calculated common point along a projection of each other's track; or
- b) for aircraft on parallel tracks, the distance measured along the track of one of the aircraft using its calculated position and the point abeam the calculated position of the other aircraft.

Note.— Reference aircraft refers to one or two aircraft with ADS-B data that meet the ITP criteria described in paragraph 5.4.2.7 in the Procedures for Air Navigation Services — Air Traffic Management (PANS ATM) and are indicated to ATC by the ITP aircraft as part of the ITP clearance request.

ITP equipment. All avionics which are involved in the execution of ITP functions needed to support or perform the ADS-B in-trail procedure (ITP).

ITP separation minimum. As described in 5.4.2.7.3 in the PANS-ATM, longitudinal separation between a climbing or descending ITP aircraft and reference aircraft shall be applied in accordance with paragraphs 5.4.2.7.3.1, 5.4.2.7.3.2 and 5.4.2.7.3.3 in the PANS-ATM (Doc 4444).

Own aircraft. From the perspective of a flight crew, or of the ASSAP and CDTI functions used by that flight crew, the own aircraft is the ASA participant that carries that flight crew and those ASSAP and CDTI functions.

Partial equipage. An environment where not all aircraft are equipped with avionics system which is certified to support the airborne surveillance applications / capabilities under consideration.

Performance requirements. Minimum requirements needed for the application to function properly under nominal (no fault) conditions, and are generally quantitative in nature.

Preceding aircraft. The aircraft ahead of the one performing the VSA.

Pre-formatted free text message element. A free text message element that is stored within the aircraft system or ground system for selection.

Procedural control. Term used to indicate that information derived from an ATS surveillance system is not required for the provision of air traffic control service.

Procedural separation. The separation used when providing procedural control.

Runway status indication (RSI). Runway Status Indications (RSIs) are provided if the flight crew should verify runway status prior to proceeding.

Safety requirement. A safety requirement is a risk mitigation means that when implemented will help the system meet the safety objective.

Secondary surveillance radar (SSR). A surveillance radar system which uses transmitters/receivers (interrogators) and transponders.

Separation. The generic term used to describe action on the part of ATC in order to keep aircraft, operating in the same general area, at such distances from each other that the risk of their colliding with each other is reduced.

Standardized free text message element. A message element that uses a defined free text message format, using specific words in a specific order.

Note.— Standardized free text message elements may be manually entered by the user or pre-formatted.

State (vector). An aircraft's current horizontal position, vertical position, horizontal velocity, vertical velocity, and navigational accuracy and integrity.

Succeeding aircraft. The aircraft performing VSA and maintaining own visual separation from the Preceding Aircraft.

Surveillance radar. Radar equipment used to determine the position of an aircraft in range and azimuth.

Target aircraft. A designated aircraft from which the IM aircraft achieves and/or maintains an assigned spacing goal.

Target level of safety (TLS). A generic term representing the level of risk which is considered acceptable in particular circumstances.

Track. (1) A sequence of reports from the ASSAP function that all pertain to the same traffic target. (2) Within the ASSAP function, a sequence of estimates of traffic target state that all pertain to the same traffic target.

Traffic Display. The graphical plan-view (top down) traffic display of the CDTI.

Traffic indication (TI). Traffic indications are provided by SURF-IA if there could be a collision hazard in the immediate future.

Traffic information. Information issued by an air traffic services unit to alert a pilot to other known or observed air traffic which may be in proximity to the position or intended route of flight and to help the pilot avoid a collision.

Traffic information service – broadcast (TIS-B). A function on ground systems that broadcasts an ADS-B-like message that includes current position information of aircraft/vehicles within its surveillance volume.

Note.— This technique can be achieved through different data links. The requirements for Mode S extended squitters are specified in Annex 10, Volume IV, Chapter 5. The requirements for VHF digital link (VDL) Mode 4 and universal access transceiver (UAT) are specified in Annex 10, Volume III, Part I.

Traffic symbol. A depiction on the traffic display of an aircraft or vehicle other than the own aircraft.

Vertical direction. An indication whether the traffic is climbing, descending or maintaining the altitude/level.

PUBLICATIONS

(referred to in this document)

[International Civil Aviation Organization \(ICAO\)](#)

Annex 2 — *Rules of the Air*

Annex 10 — *Aeronautical Telecommunications*,
Volume III — *Communication Systems*
Volume IV — *Surveillance and Collision Avoidance Systems*.

Annex 14 — *Aerodromes*
Volume I — *Aerodrome Design and Operations*

Procedures for Air Navigation Services — Air Traffic Management (PANS ATM) (Doc 4444)

Procedures for Air Navigation Services — Aircraft Operations (PANS OPS) (Doc 8168)
Volume I — *Flight Procedures*

Global Air Navigation Plan (GANP) (Doc 9750)

Report of the Twelfth Air Navigation Conference (Doc 10007)

Advanced Surface Movement Guidance and Control Systems (A-SMGCS) Manual (Doc 9830)

Airborne Collision Avoidance System (ACAS) Manual (Doc 9863)

Technical Provisions for Mode S Services and Extended Squitter (Doc 9871)

Aeronautical Surveillance Manual (Doc 9924)

In-Trail Procedure (ITP) Using Automatic Dependent Surveillance -Broadcast (ADS-B) (Cir 325)

Federal Aviation Administration (FAA)

Automatic Dependent Surveillance-Broadcast (ADS-B) Operations FAA AC 90-114 (latest revision)

RTCA Inc. /European Organization for Civil Aviation Equipment (EUROCAE)

Minimum Operational Performance Standards (MOPS) for Aircraft Surveillance Applications (ASA) System, RTCA DO-317A/EUROCAE ED-194

Minimum Operational Performance Standards (MOPS) for Aircraft Surveillance Applications (ASA) System, RTCA DO-317B/EUROCAE ED-194A

Minimum Operational Performance Standards (MOPS) for Aircraft Surveillance Applications (ASA) System, RTCA DO-317C/EUROCAE ED-194B

Safety, Performance and Interoperability Requirements Document for Enhanced Traffic Situational Awareness during Flight Operations (ATSA-AIRB), RTCA DO-319/EUROCAE ED-164

Safety, Performance and Interoperability Requirements Document for Enhanced Visual Separation on Approach (ATSA-VSA), RTCA DO-314/EUROCAE ED-160

Safety, Performance and Interoperability Requirements Document for ATSA-SURF Application, RTCA DO-322/EUROCAE ED-165

Safety, Performance and Interoperability Requirements Document for the In-Trail Procedure in Oceanic Airspace (ATSA-ITP) Application, RTCA DO-312/EUROCAE ED-159 and their supplement

Safety Performance and Interoperability Requirements Document for Enhanced Traffic Situational Awareness on the Airport Surface with Indications and Alerts (SURF IA), RTCA DO-323

Safety, Performance and Interoperability Requirements Document for Airborne Spacing - Flight deck Interval Management (ASPA-FIM), RTCA DO-328B/EUROCAE ED-195B

Safety, Performance and Interoperability Requirements Document for Traffic Situation Awareness with Alerts (TSAA), RTCA DO-348/EUROCAE ED-232

Safety and Performance Requirements Document for CDTI Assisted Visual Separation (CAVS), RTCA DO-354/EUROCAE ED-233

Minimum Operational Performance Standards for 1090 MHz Automatic Dependent Surveillance – Broadcast (ADS-B), RTCA DO-260/EUROCAE ED-102

Note.— This refers to ICAO Extended Squitter Version 0.

Minimum Operational Performance Standards for 1090 MHz Extended Squitter Automatic Dependent Surveillance — Broadcast (ADS-B) and Traffic Information Services – Broadcast (TIS-B), RTCA DO-260A

Note.— This refers to ICAO Extended Squitter Version 1.

Minimum Operational Performance Standards for 1090 MHz Extended Squitter Automatic Dependent Surveillance — Broadcast (ADS-B) and Traffic Information Services – Broadcast (TIS-B), RTCA DO-260B/EUROCAE ED-102A with Corrigendum 1.

Note.— This refers to ICAO Extended Squitter Version 2.

Safety, Performance Standard for Baseline 2 ATS Data Communications (Baseline 2 SPR Standard), RTCA DO-350A/EUROCAE ED-228A

Interoperability Requirements Standard for Baseline 2 ATS Data Communications, Initial Release (Baseline 2 Interop Standard)”, RTCA DO-351A/EUROCAE ED-229A

Minimum Operational Performance Standards for Flight Deck Interval Management (FIM), RTCA DO-361A/EUROCAE ED-236A.

Chapter 1

AUTOMATIC DEPENDENT SURVEILLANCE —BROADCAST (ADS-B)

1.1 OVERVIEW

1.1.1 ADS-B is recognized as one of the most important enablers of global ATM operational concept for future trajectory-based air traffic management (refer to the *Report of the Twelfth Air Navigation Conference* (Doc 10007)). ADS-B data (ADS-B OUT) is already used by some ground ATM systems and by airborne ADS-B IN systems.

1.1.2 ADS-B is a surveillance technique that relies on an aircraft broadcasting its position (latitude and longitude), altitude, velocity, aircraft identification and other information. ADS-B is dependent upon a position source (e.g. global navigation satellite system (GNSS)) of required quality and requires additional information from other on-board systems. Every ADS-B message includes an indication of the quality of the position and velocity data. This allows recipients to determine whether the quality of the data is adequate to support the intended function.

1.1.3 ADS-B supports both ground and airborne surveillance. Because ADS-B OUT information is broadcast, any suitable receiver can process the received messages. Airborne surveillance applications (ASA)/airborne surveillance capabilities require aircraft to be equipped with ADS-B IN receivers to process the data from surrounding ADS-B OUT equipped aircraft. For most of these capabilities/applications, a traffic display is used to present traffic information graphically.

Note 1.— ADS-B is supported by different techniques and frequencies, namely 1090 MHz Extended Squitter, universal access transceiver (UAT) (978 MHz) and very high frequency (VHF) digital link (VDL) Mode 4 (118-137 MHz). The requirements for Mode S extended squitters are specified in Annex 10, Volume IV, Chapter 5. The requirements for VDL Mode 4 and UAT are specified in Annex 10, Volume III, Part I.

Note 2.— ADS-B OUT can be installed on surface vehicles for certain aerodrome applications.

1.1.4 Since ADS-B messages are broadcast, they can be received and processed by any suitable receiver. As a result, ADS-B supports both ground-based and ASA. Aeronautical surveillance ground stations are deployed to receive and process the ADS-B messages. In airborne applications, aircraft equipped with ADS-B receivers can process the messages from other aircraft to determine the location of surrounding traffic.

1.1.5 The 1 090 extended squitter (ES) was developed as part of the Mode S system. The ADS-B information is broadcast in separate messages, each of which contains a related set of information (e.g. airborne position and pressure altitude, surface position, velocity, aircraft ID and type, emergency information). Position and velocity are transmitted twice per second. Aircraft ID is transmitted every five seconds. The transmission of ADS-B messages is an integral part of many Mode S transponders, although it may also be implemented in a non-Mode S transponder device as well.

1.1.6 There are currently three versions of ADS-B with different levels of performance:

- a) Version 0 provides basic ADS-B capability with position quality provided by a parameter called navigation uncertainty category (NUC). This was the initial version of ADS-B and there are a variety of Version 0 installations;

- b) Version 1 provides, among other things, separate accuracy and integrity parameters, which replace the NUC, such as navigation integrity category (NIC), navigation accuracy category (NAC) and surveillance integrity level (SIL); the Version 1 message format also provides target state and status data; and
- c) Version 2 provides, among other things, a renaming and new definition for source integrity level (SIL); includes several new message fields, such as system design assurance (SDA) and geometric vertical accuracy; removes vertical information from the NIC, NAC and SIL parameters; provides improved support of surface operations through changes to NIC encoding; supports non-diversity antenna options for smaller (general aviation) aircraft plus various other improvements.

Note.— Version 0 refers to RTCA DO-260 or EUROCAE ED-102, Version 1 refers to RTCA/DO-260A and Version 2 refers to RTCA DO-260B or EUROCAE ED-102A. The formats and update rates of each register are specified in the Technical Provisions for Mode S Services and Extended Squitter (Doc 9871).

1.1.7 The on-board architecture is discussed in sections 2.9 and 4.9. Partial equipage considerations for ADS-B OUT are discussed in section 2.5 and is also mentioned in section 2.4, with respect to Additional Information for Pilots.

Note 1.— ADS-B SARPs on 1090 MHz are in Annex 10, Volume IV. Additional guidance material on ADS-B is included in the Technical Provisions for Mode S Services and Extended Squitter (Doc 9871) and in the Aeronautical Surveillance Manual (Doc 9924).

Note 2.— For more details, refer to the Minimum Operational Performance Standards for 1090 MHz Extended Squitter Automatic Dependent Surveillance – Broadcast (ADS-B) and Traffic Information Services – Broadcast (TIS-B) (RTCA DO-260B / EUROCAE ED-102A) and Minimum Operational Performance Standards (MOPS) for Aircraft Surveillance Applications (ASA) System, RTCA DO-317B / EUROCAE ED-194A.

1.2 INTERACTIONS OF ADS-B AND AIRBORNE COLLISION AVOIDANCE SYSTEM (ACAS)

1.2.1 ACAS is an airborne system based on SSR (transponder interrogation) technology, which is independent from air traffic control (ATC) separation standards but provides a last resort safety net function. Its purpose is to prevent collision when the primary means of separation provision has failed or no ATC separation was required (e.g. visual flight rules (VFR) flights in uncontrolled airspace).

1.2.2 At the operational level, the ASA have been designed in isolation of the ACAS procedure in order to maintain the independence of the airborne safety net.

1.2.3 At the technical level, system independence of the ACAS safety net has been preserved in the definition of the ASA on board the aircraft. However, some ASA equipment makes use of ACAS positional data to enhance the information received from ADS-B sources.

1.2.4 Hybrid surveillance is a technique within the ACAS surveillance function that takes advantage of ADS-B extended squitters to reduce the number of active interrogations. This technique is specified in Annex 10, Volume IV as an optional feature for TCAS version II compliant systems and a required feature for ACAS Xa.

Note.— The Airborne Collision Avoidance System (ACAS) Manual (Doc 9863) contains operational and technical provisions on ACAS, including use of the hybrid surveillance technique.