Managing Criticality of ASAS Applications

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Abstract

What must happen to assure that some aspects of separation services can safely be performed in the cockpit?

The ASAS concept proposes the transfer of responsibility for maintaining aircraft separation from the ground to the airborne side under specific conditions. With the emergence of an operational requirement for ASAS applications, their safety issues need to be addressed as soon as possible. MITRE and CENA, which have been involved in ASAS and safety studies for many years, are particularly interested in doing so.

This paper presents the results of safety assessment work performed to date towards the prospect of developing and certifying ASAS applications, and indicates the direction foreseen for continuing work aimed at completing and introducing ASAS for useful operational service. Illustrative examples of criticality assessment of ASAS, including assessment for the aircraft segment and for the ground ATC segment, are presented using the Operational Safety Assessment (OSA) methodology developed by a joint committee of RTCA and EUROCAE.

Introduction

The aviation community is paying close attention to the prospect of using airborne traffic display devices for many new purposes. With the concurrent development of ADS-B air-to-air broadcast technology, in addition to ground-to-air data-link technologies like TIS or TIS-B, the ability is close at hand to receive and display position and additional information for nearby traffic. This has obvious application to enhancing safety, as it improves the aircrew's traffic situational awareness. Moreover, numerous concepts are being proposed and developed which would make use of this data in the cockpit in giving the flight crews some further abilities and responsibilities related to aircraft separation. ICAO has named this ASAS, Airborne Separation Assurance Systems [1].

At present, aircraft separation is a well-defined function performed by ATC that plays a basic role in assuring the safety of flight. Any time a change in its operation is considered, it is always studied closely to ensure that no degradation of safety results and all essential or critical factors are known and safeguarded. This process is intensive when studying just a single system onboard an aircraft or on the ground, or for considering a procedural change. It could be ever so much more complex for systems that communicate amongst aircraft and multiple air traffic services.

With this concern in mind, a joint committee of RTCA SC-189 and EUROCAE WG-53 has developed a methodology for performing Operational Safety Assessment (OSA) of CNS/ATM systems that span multiple institutions [2]. Within the prospect of developing and certifying ASAS applications, this methodology is an excellent candidate for performing a full risk assessment, spanning the pertinent aspects of the aircraft segment and the ground ATC segment. This paper describes the work performed to date in this area and indicates the direction foreseen for continuing work aimed at completing and introducing ASAS for useful operational service.

The OSA methodology is first described within the context of ASAS safety assessment. Then, the operational safety assessment process is illustrated through some pertinent examples from several ASAS applications. The allocation of safety objectives and requirements for ASAS procedures and systems is discussed, as well as the role of ATC and Airborne Collision Avoidance System (ACAS) during ASAS operations. Ongoing ASAS simulations and trials, and their role in the criticality assessment process, are also mentioned.

Operational safety assessment of ASAS

The ICAO SICASP Panel has determined that ASAS consists of equipment, protocols, airborne surveillance and other state data, and flight crew and ATC procedures. Thus, these elements must be considered as a whole in determining the safety and criticality of each candidate application. The OSA methodology performs the following steps, which are described in the context of evaluating ASAS:

1. Operational Environment Definition (OED)

   The OED describes how and in what context an application of ASAS is expected to operate. It includes the responsibilities of the flight crew and ATC, when and how the application begins and ends, the basic information that supports the conduct of the application, resulting displays and alerts, and communications and decisions that are routinely part of the application.

   The OED also describes the environment for this use of ASAS. This identifies the type of airspace for which the application is intended, including the degree to which the aircraft population is expected to be equipped with ASAS and any other pertinent equipment, the nature of ATC service, any requirement for radar surveillance, and any other special characteristics of the airspace (e.g., track system, air routes).

2. Operational Hazard Analysis (OHA)

   The OHA enumerates operational hazard events that could pertain to the application described in the OED. At this level, the OHA is not concerned with how an operational hazard could occur, but only focuses on its effects. The OHA describes the worst-case effect and assigns a level of severity to this effect. This step also lists mitigating factors which support safety even in the presence of the hazard event.

   The hazard classification matrix in Figure 1, derived from that already proposed in the OSA methodology, provides a scheme for the severity assignment of each hazard depending on its effects on ASAS operations.

1 **Catastrophic**	2 **Hazardous**	3 **Major**	4 **Minor**	5 **No Effect**
Complete loss of safety margin	Large reduction in safety margins	Significant reduction in safety margins	Slight reduction in safety margins	No effect on safety margins
An operational hazard that has the potential for one or more catastrophic accidents. Complete loss of separation from another aircraft, terrain, objects, or obstacles. Operational hazard results in a complete loss of flight control. No independent source of mitigation, such as ATC intervention and/or flight crew procedures could reasonably be expected to prevent a catastrophic accident Many fatalities and/or hull loss.	An operational hazard that has the potential for one or more aircraft to deviate from their cleared route of flight such that collision or terrain avoidance maneuvers are required to avoid a catastrophic accident. Large reduction in separation as for example in a near mid-air collision. Small number of fatalities, numerous severe injuries, and/or major aircraft or system damage.	An operational hazard that has the potential for one or more aircraft to deviate from their cleared route of flight such that surveillance and communication combined with ATC or flight crew procedures provide the capability to detect and correct the deviation. Significant reduction in separation between aircraft. Minor injuries and/or minor damage to aircraft or systems.	An operational hazard that in itself has no direct impact on the safety of flight operations but has the potential to affect safety either indirectly or in combination with other hazards, for example, by increasing the workload of the controller, flight crew, or by degrading a functional capability needed in the provision of an Air Traffic Service used in the mitigating string for an operational hazard. Slight reduction in separation. Physical discomfort and/or negligible damage to aircraft or systems.	An operational event that can result in no hazardous condition, that is, has no potential for direct or indirect impact to the safety of flight operations.

Figure 1: Hazard classification matrix for ASAS applications

At this stage, it is important to consider all feasible hazards, so that adequate protection may be explicitly given during the development process. In the final operational system, some protection against hazards may be provided by equipment or procedural design.

It is important to consider the severity separately from the event's likelihood of occurrence (the step below). The severity depends only on the effects that the hazard could cause and upon the presence or absence of mitigating factors.

3. Likelihood of Occurrence

   A translation is performed between each hazard's severity level and the maximum likelihood of occurrence permitted for that hazard. There is a standard, qualitative relationship illustrated in Figure 2 that gives the greatest likelihood allowed for each level of severity (naturally, the more severe the hazard, the less frequently it is tolerated).

   Analyses of each hazard, taking account of trials data where it exists, must determine whether its likelihood conforms to the allowed maximum level. If it does not, steps must be taken either to mitigate its severity or to reduce its likelihood (or possibly both factors).

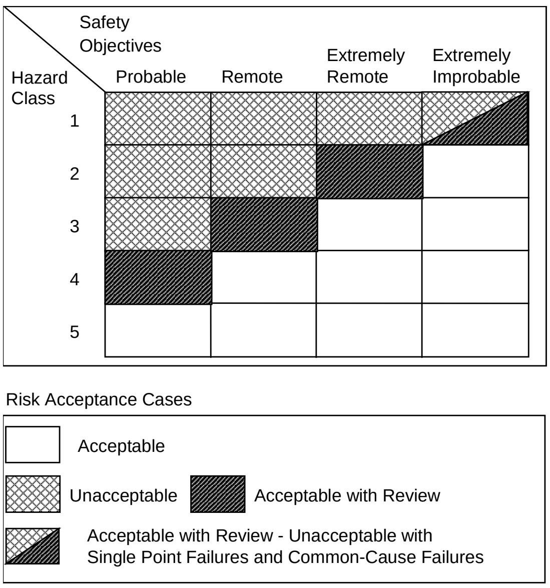

Figure 2: Relationship between hazard classification and likelihood of occurrences

4. Allocation of Safety Objectives and Requirements (ASOR)

   Quantify the level of operational safety that is sought. From examination of the hazards and their mitigations, develop a list of functions to be performed by equipment, flight crews and ATC required to achieve safe ASAS operations. This allows designers to determine the elements of the application that assure safety.

5. Ongoing Design and Development

   Designers investigate the specific causes of hazardous events, both technical and human, and provide sufficient safeguards in equipment and procedures to satisfy the safety objectives allocated to them. Test and evaluation activities provide assurance that these objectives are met and that the OHA has not overlooked key elements bearing upon safety.

6. Certification and Entry into Operational Service

   Approval authorities ascertain that safety and performance requirements are met. Equipment and operational approvals should reflect any limits of use that are requisite to safety goals.

7. Monitor Operational Performance

   Continued monitoring is desirable to assure that the application is performing as was anticipated during earlier analysis. Lessons learned should be fed back in order to refine the OHA and, if necessary, the equipment and procedures.

These steps are not required to be performed in serial order. It is more practical to work on several of them in parallel, and it is useful to feed results back to the preceding steps. In many respects, the order is not critical. For example, safety objectives and mitigating factors may be known well before hazards have been enumerated. Depending on the development stage of the application of ASAS, the different steps can be used to refine or validate the operational procedure, and the functional and technical characteristics of the ASAS system.

Operational environment of ASAS applications

ASAS applications range from modest increments that supplement present operations with information, to more ambitious ventures that could change ATC functions in significant ways [3]. At ATM-98 the authors presented several papers discussing useful classification schemes for applications and various steps in developing and evaluating them so as to achieve some benefits in the near-term and progress towards potentially more complex uses [4], [5].

Traffic situational awareness

Some examples of simple applications fall in the category of “Traffic Situational Awareness.” These provide the flight crew with information about the surrounding traffic, but no delegation for separation responsibility from the ground to the airborne side is envisaged. Thus, these applications can be defined within the scope of existing ATC practices. An interesting example is aimed at increasing safety for mixed-use VFR/IFR traffic. Indeed, because of the increasing speed of aircraft, the poor external visibility in modern cockpits and pilot’s workload in some phases of flight, the limits of the ‘see and avoid’ principle have been reached.

Delegation of separation assurance

Many applications are proposed in the category of “Co-operative Separation.” For these, flight crews will be expected to act upon information provided by ASAS, in the context of specific, new procedures. In so doing, the flight crew could accept some aspect of aircraft separation responsibility that has traditionally been provided by ATC alone. The purpose is to alleviate ATC constraints by involving the flight crew in the separation assurance process, where they may be able to exploit better information. Also, it may be possible to reduce the applicable separation minimums. Actually, the determination of the airborne separation minimums is a complex process which needs to take into account various criteria, including the operational procedure and communication, navigation and surveillance capabilities.

One example application in this category is the ASAS Crossing Procedure initially presented at ATM-97 [6]. This procedure would enable the pilot flying under IFR within en-route controlled airspace, to assure his separation from another traffic in accordance with airborne separation minimums. This is analogous to the Oceanic In-Trail/Lead Climb or Descent, which can allow vertical maneuvers in an oceanic track system at closer longitudinal spacing than previous rules allowed. While a version based on TCAS already is used in some Flight Information Regions, ASAS should alleviate some potential hazards.

A more ambitious co-operative application is for independent Closely Spaced Parallel Approaches in IMC. Instead of requiring ATC to closely monitor separation, ASAS would detect departures from standard approach paths and alert flight crews when an evasive maneuver was required. This application clearly has a significant set of hazards that involve its own alerting logic, as well as the potential for undesirable interactions between ASAS and ACAS.

Airborne self-separation assurance

Another complex application is for Conflict Detection and Resolution at longer look-ahead times than are used by ACAS. This capability is proposed as an enabling capability for user-preferred trajectories and free flight. The concept of ASAS-provided separation in lieu of ATC involves issues that surpass the other applications. The OSA will be crucial to the definition and development of such a capability.

Operational hazards and mitigating factors associated with ASAS

While the OED descriptions of ASAS applications continue to be developed, progress also is being made on hazard analyses. These hazards should address the functions, interfaces and procedures associated with ASAS. The hazards related to non-ASAS functions or procedures which might be affected by an ASAS event would also be investigated.

Operational hazard identification

The operational hazards should be identified by considerations including airborne or ground system failures, human failure to respond appropriately to system failures, human error or omission during normal ASAS operations. These system failures or human-mode errors may concern an aircraft involved in the ASAS procedure or another. Additionally, system failures that are detected or not by the flight crews or the air traffic controllers may result in different hazards. The timing of these operational events (e.g. prior, during or after the ASAS procedure, different phases of flight) may also have to be considered.

Some aspects common to most ASAS applications include concerns about aircraft lacking proper equipage, or whose equipment has failed. Erroneous information, from identification, position or velocity reports, or for other pertinent data such as intent, clearly must be considered. Also, human factors analysis must address the potential for errors by the flight crew in interpreting ASAS displays or following ASAS procedures.

Other hazards depend on the intended use of ASAS. Interactions between ASAS and ACAS are more pertinent for aircraft that are close enough for ACAS to act.

Hazard severity assignment

The same operational hazard may be caused by different single operational events, or by a combination of events. It is important to classify the operational hazards depending on their effects on ASAS operations, so as to decide on the risk mitigation strategy that can be developed based on the elements of the operational environment.

As illustrated in Figure 3 for one hazard, the mitigating factors may either be systems/infrastructure characteristics or procedure/operating practices elements.

Operational Hazard	**Effects on ASAS operations**	**Severity**	**Mitigating Factors** **A) Infrastructure / systems** **B) Procedures / operating practices**
ASAS crossing procedure			
Incorrect identification of target aircraft at the procedure initialization	Potential loss of separation since the pilot (of own aircraft) may accept the ASAS procedure with respect to a wrong aircraft (in close proximity) and not execute the required separation maneuver with respect to the correct target aircraft	Major	A) CDTI features enhance pilot's situational awareness about surrounding traffic Traffic Advisory provided by ACAS / TCAS as conflict increases between own aircraft and correct target aircraft If airborne and ground separation minimums are compatible, Short Term Conflict Alert raised to ATC between aircraft involved in the procedure B) Procedural requirement for the pilot to report any change in altitude, direction or speed during the procedure

Figure 3: OHA table for ASAS applications

The role of the controller will influence the definition and disposition of some hazards. If ASAS is supplementing ATC, the ASAS likely is not critical, whereas if it replaces ATC, criticality falls mainly on the ASAS. More precisely, the criticality required for an ASAS equipment and procedure depends on the level of delegation for separation assurance. In case of full delegation to the flight crew, the highest criticality needs to be considered for the ASAS application.

When aircraft are in close proximity, the effect of an error may be more severe since there is little time to achieve separation in an alternate way.
This level of severity could be mitigated if the ground system supports contingency procedures as a back-up, for example through ground surveillance. In that case, the criticality of airborne separation assurance is highly dependent on the comparison between the ground and airborne separation minimums. In particular, higher criticality could be expected in airspace where procedural control is applied, if the airborne separation minimums are made much smaller than current procedural separation minimums.

Depending on the operational environment, some risk mitigations may not apply or may be limited. For instance, ACAS may not fully operate in some phases of flight (e.g. below 1000 feet altitude), or may be inhibited in some applications based on intentional close proximity. Another example is the ATS surveillance that does not apply, or is limited to ADS, outside radar coverage. Finally, the use of ADS-B for both the airborne and ground surveillance may constitute a common point of failure, not compatible with the level of safety required for ASAS operations.

Hazard likelihood analysis

The likelihood of occurrence of each hazard highly depends on the considerations and assumptions made when defining the operational environment of ASAS operations, and in particular, on the required equipment and CNS functions that support the conduct of the ASAS procedures by the flight crew and ATC.

The determination of an operational hazard likelihood of occurrence requires the identification of its possible causes (either system failures or malfunctions, human errors or omissions). Indeed, the avoiding factors contributing to reduce the likelihood of each hazard depend on the operational events or combination of events leading to the hazard.

The table in Figure 4 illustrates the relationship between operational hazards and their causes, and the necessity to distinguish between them when analyzing whether their likelihood conforms to the maximum allowed for the hazard's severity level.

Operational hazard	Incorrect identification of target aircraft at the ASAS procedure initialization					
Possible causes	Corrupted ADS identification report by other aircraft	Corrupted track correlation by own airborne surveillance	Corrupted aircraft identification displayed in the cockpit of own aircraft	Air traffic controller error when initializing the ASAS procedure	Pilot (from other aircraft) error when entering aircraft identification transmitted through ADS	Pilot error when identifying target aircraft on the CDTI
Likelihood of occurrences						
Avoiding Factors **A) Infra-structure / systems** **B) Procedures / operating practices**	A) Integrity requirement for ADS report (RCP), and Consistency check of ADS identification report by the ground surveillance system (either manually or automatically)	A) Integrity requirement for airborne surveillance (RSP) B) Procedural requirement for the use of target identification in conjunction with a traffic information for consistency check by the pilot	A) Integrity requirement for cockpit display B) Procedural requirement for the use of target identification in conjunction with a traffic information for consistency check by the pilot	B) Procedural requirement for the use of target identification in conjunction with a traffic information for consistency check by the pilot	A) Consistency check of ADS identification report by the ground surveillance system (either manually or automatically) B) Cross-check procedure within the cockpit	A) Ease-of-use of CDTI and highlighting of aircraft identification of selected target B) Cross-check procedure within the cockpit

Figure 4: Hazard likelihood analysis for ASAS applications

Allocation of safety objectives and requirements for ASAS applications

Safety objectives for ASAS operations

Safety objectives for ASAS operations need to be agreed at the policy level. They should be compatible with the Target Level of Safety (TLS) normally required for air traffic control, i.e. $1x10^{-9}$ mid-air collision per flight hour. However, depending on the airspace characteristics, this TLS could correspond to an unacceptable number of collisions per year in specific areas, typically in high traffic density areas in continental airspace.

Airborne separation in collision risk management

For ASAS applications where the flight crew is required to assure some airborne separation, mid-air collision would result from the combination of an ASAS failure (i.e. loss of airborne separation) and the inability of the backups to avoid the collision. Moreover, in case of a complete loss of airborne separation without any possible ATC or flight crew intervention, the collision risk increases with higher traffic density and lower airborne separation minimums. The establishment of appropriate separation minimums will be an essential product of the overall safety assessment of ASAS operations.

As long as there is no common mode of failure between ASAS and its backups, and no induced risk of collision due to the backups when the ASAS performs correctly, it would be possible to allocate specific safety objectives for the ASAS systems and procedures, independently from the backups. These safety objectives, expressed in terms of losses of separation per flight hour, would be more easily monitored during the entry into operational service of ASAS. Furthermore, the reduction in collision risk expected through ATC backup or ACAS II intervention, would have to be defined and assessed from the initial ASAS development stages, in order to validate that the overall TLS is achieved.

ACAS II safety contribution

The world wide ACAS mandate was not based on an assessment of the absolute level of collision risk with and without ACAS II, but only on theoretical analysis and practical experience that ACAS II reduces the collision risk. In 1989, SICASP/4 expected a reduction of collision risk of $1x10^{-1}$ collision per flight hour with the introduction of ACAS II [7]. More extensive simulations led SICASP/6 to adopt performance-based standards for ACAS that specifically focus on the risk reduction. It still has not been demonstrated that these objectives were met.

Furthermore, the ACAS II safety contribution is mainly based on its independence from the primary means of surveillance. Therefore, ACAS II must remain independent from these primary means, wherever the separation assurance is performed from the ground as it is currently, or in the air as it is envisaged with ASAS. Otherwise, the reduction of collision risk achieved by ACAS II and its supposed contribution to the overall safety objectives would have to be reconsidered.

Finally, it is currently accepted that the ACAS carriage by aircraft shall not be a factor in determining the need for air traffic services (see ICAO Annex 11). This statement would have to be revisited if ACAS II is used in the risk management strategy within ASAS operations.

Safety requirements for both airborne and ground segments

From the analysis of operational hazards, their possible mitigating and avoidance factors, the elements required to achieve the acceptable level of safety of ASAS operations need to be explicitly identified. These elements include all the equipment and procedural requirements for both the airborne and ground segments of the CNS/ATM system, but also, the required communications (RCP), navigation (RNP) and surveillance (RSP) performances.

This allocation of safety requirements is illustrated in Figure 5 for representative hazards in several applications.

Hazard Description	**Consequences**	**Avoidance Factors** **A) Infrastructure / systems** **B) Procedures / operating practices**	**Mitigating Factors** **A) Infrastructure / systems** **B) Procedures / operating practices**
ASAS Crossing Procedure			
Incorrect identification of target aircraft at the procedure initialization	Potential loss of separation since the pilot may accept the ASAS procedure with respect to a wrong aircraft	See Figure 4	See Figure 3
Enhanced Visual Approach			
Pilot misjudges in-trail spacing or closing speed	Loss of separation	A) CDTI features displaying range and closing speed B) Pilot training and procedures	A) ASAS alert to pilot B) ATC monitors spacing and may issue warning
Conflict Detection & Resolution			
Pilot receives incompatible instructions from controller and from ASAS	Pilot unable to comply with both. Potential loss of separation with original threat or with another	B) Procedures must govern the responsibility for resolving conflicts	B) Procedures must resolve this situation
Pilot receives simultaneous ASAS resolution and ACAS Resolution Advisory	Pilot may be unable to comply with both. Potential loss of separation	A) ASAS design should ensure issuing its conflict resolution prior to ACAS RA, and should defer to ACAS when it generates RA	A) ASAS must remove its resolution or change to one compatible with the RA. B) Pilot training and procedures establish reliance on ACAS

Figure 5: ASOR table for ASAS applications

ASAS equipment characteristics and performances

Airborne surveillance is one major component of ASAS equipment, and required surveillance performances will have to be defined for each ASAS application. The ASAS equipment also includes the processing of the airborne surveillance data and navigation data, for airborne separation assurance.

During the overall safety analysis, the suitability of ADS surveillance data for ASAS needs to be considered carefully [8]. In particular, the accuracy, availability, integrity of the navigation and surveillance data, update rate and surveillance range validation, need to be assessed with respect to the safety requirements.

It is anticipated that airborne surveillance will rely on ADS-B, but not exclusively. Air-air data-link and air-ground data-link such as TIS-B are also envisaged. The minimum operational performances of the correlation and fusion of data from different sources need to be defined.

When active procedural use of information displayed on the CDTI by the flight crew is invoked, the criticality of some hazards related to airborne separation assurance may require the development of alerting system for airborne separation monitoring. The reliability and adequacy of such alerts would have to be assessed in further safety analysis.

Role of ATC in ASAS operations

For co-operative ASAS applications, one major issue that needs to be addressed during the safety analysis is the sharing of separation responsibilities between ATC and the flight crew. Indeed, misunderstanding or incorrect implementation of these responsibilities could lead to unsafe situations incompatible with the overall safety objectives.

Besides, depending on the relationship between the airborne separation minimums applicable by the flight crew and the ground separation minimums used by ATC, different risk mitigation strategy for ATC intervention may be developed. If applied airborne separation is lower than ground separation minimums, the ability for ATC to maintain the safety margins may be compromised, particularly in case of high traffic density. Otherwise, contingency procedures based on ATC back-up could be developed with slight increase in controller workload.

Role of ACAS II in ASAS operations

ACAS II is an airborne system based on Secondary Surveillance Radar (SSR) technology, which acts as a last resort safety function when the primary means of separation assurance has failed. However, current TCAS II equipment is not designated as critical equipment (The Minimum Equipment List specifies that a failed ACAS II equipment shall be fixed within 10 days). Therefore, the use of ACAS II as a mitigating factor for some hazards during ASAS operations needs to be considered carefully, and may require further investigation. Any such requirements allocated to ACAS may not be fulfilled by the present generation of equipment.

Another limitation for the reliance on ACAS II mitigation will be the compatibility between the airborne separation minimums and the collision avoidance logic. This issue is particularly crucial for ASAS applications, like the Closely Spaced Parallel Approaches, where a significant reduction in aircraft separation is expected to occur.

Despite the fact that ACAS and ASAS are independent by nature, they might share some components of the airborne architecture. In particular, the safe combination of ACAS and ASAS features needs to be investigated when designing a Cockpit Display of Traffic Information. Nevertheless, the loss of the ASAS functions must not be detrimental to the ACAS function. This is necessary for ACAS to remain the last resort for collision avoidance in case of navigation failure or separation assurance failure.

Similarly, the use of ACAS data for airborne surveillance purposes could also compromise the ability for ACAS to act as an independent safety net during ASAS operations, and this issue needs to be addressed when designing the ASAS equipment for airborne surveillance.

ASAS simulations and trials

Some aspects of the system and applications have begun to be demonstrated through simulations and flight testing. At MITRE, laboratory simulations have explored the feasibility of procedures and displays used in enhancing visual acquisition, enhanced visual approaches, and In-Trail Climb and Descent. The NLR has demonstrated a form of Conflict Detection and Resolution. The Eurocontrol Experimental Center has conducted real-time simulations of various Co-operative Separation applications, in both en-route and terminal airspace [9]. CENA has investigated the interest in applying the ASAS Crossing Procedure using simulations on the basis of French radar data [4]. NASA has simulated independent Closely Spaced Parallel Approaches.

Operational trials in Europe have given airlines some experience in situational awareness. Within the NEAN (North European ADS-B Network) Update Program, CENA is involved in experiments for enhanced 'see and avoid' between VFR (light aircraft and helicopters) and IFR flights, at the second major French airport. An OED has been developed, including procedures mainly dedicated to airspace classes D and E, and should be used for an operational hazard analysis to be performed before the end of year 2000. The FAA and Cargo Airline Association conducted an experiment in which 24 aircraft conducted enhanced visual approaches and a variety of other applications. While most of these are quite preliminary, the experience with line flight crews provides data useful for validating performance relevant to some hazards. Further trials are planned for 2000 in the Ohio Valley and in Alaska.

Conclusions and future work

Some safety analyses of ASAS applications have been initiated, but studies are still required, to validate that the relationship between the airborne separation assurance systems, the associated procedures and safety nets will ensure that the overall required safety objectives are achieved.

This ongoing work developing operational safety assessments is an essential part of the development process of ASAS applications. The objective is to highlight the major criticality issues, and also the possible mitigations, that need to be taken into account to support safe ASAS operations.

Using the recognized OSA methodology, continuing work is required:

- to refine the definition of the operational environment of the selected ASAS applications including the air/ground CNS facilities, the ASAS equipage and the airborne and ground separation minimums;
- to validate the ASAS procedures through the identification of the hazards and their mitigations, and constructively contribute to the development process. These procedures should define all the flight crew and ATC actions required to satisfy the safety requirements; and
- to refine the functional and technical characteristics of the ASAS systems used to perform these ASAS procedures while taking into account the safety objectives.

As this work proceeds, various test and validation activities will refine technical and procedural details and will develop user community confidence in the new uses of cockpit information. We can foresee the need for computer simulation to evaluate certain hazards, particularly where alerting logic plays a critical role in maintaining separation. This may resemble the work performed to evaluate ACAS logic.

The need for standardization provides a sound basis for coordinated efforts among developers, users and Air Traffic Service providers.

Author Biographies

Dr. Andrew D. Zeitlin is Principal Engineer for ATM/Avionics at MITRE/CAASD. He has been a leading developer of cockpit-based traffic warning and display systems since 1975. He has conducted numerous safety studies for TCAS and related applications. He is a member of SICASP Working Group 2 and its ASAS Subgroup, RTCA Committees SC-186 (ADS-B and ASAS), SC-147 (ACAS), and SC 189/EUROCAE WG-53 (ATS Safety and Interoperability Requirements).

Béatrice Bonnemaison is an ACAS & ASAS specialist within CS-SI, working for CENA since 1995. She has been involved in the development of ACAS simulation tools, and supports the French ATS Authority (SCTA) in charge of the TCAS II events analysis. She has conducted many studies about the concept of ASAS operations and ACAS/ASAS logic performances. She has been a member of the Eurocontrol AIRSAW (Airborne Situational Awareness) Drafting Group, and also participates to the ASAS Subgroup of SICASP/WG 2.

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Acronyms

ACAS	Airborne Collision Avoidance System
ADS	Automatic Dependant Surveillance
ADS-B	Automatic Dependant Surveillance Broadcast
ASAS	Airborne Separation Assurance System
ATC	Air Traffic Control
ATS	Air Traffic Services
ATM	Air Traffic Management
CDTI	Cockpit Display of Traffic Information
CNS	Communications, Navigation and Surveillance
EUROCAE	European Organization for Civil Aviation Equipment
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
IMC	Instrument Meteorological Conditions
OED	Operational Environment Definition
OHA	Operational Hazard Analysis
OSA	Operational Safety Assessment
RCP	Required Communication Performance
RNP	Required Navigation Performance
RSP	Required Surveillance Performances
SICASP	SSR Improvements and Collision Avoidance System Panel
SSR	Secondary Surveillance Radar
TCAS	Traffic alert and Collision Avoidance System
TIS	Traffic Information Service
TIS-B	Traffic Information Service Broadcast
TLS	Target Level of Safety
VFR	Visual Flight Rules