Airborne Separation Assistance System Thematic Network 2
(ASAS-TN2)

Work Package 3

ASAS application maturity assessment

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Document coordinator	Chris Shaw / Bill Booth
Company	EUROCONTROL Experimental Centre, Brétigny-sur-Orge, France
Contact details	firstname.lastname@eurocontrol.int

Change history

Version	Date	Sections/Pages Affected	Reasons for change
1.0	27th March 2006	All	Initial publication
1.1	19th December 2006	Text added to all main sections except Airborne separation. Maturity levels changed for: ATSA VSA ASPA S&M SSEP MAS SSEP FFT New section added "Summary of changes from March 2006 to February 2007"	Draft annual update (2007) preparation. Initial changes from ASAS-TN2 authors

1.2	8th January 2007	Updated following sections: ASAS spacing cluster ASAS separation cluster Applications maturity summary (new ASEP-S&M diagram) Summary of changes from March 2006 to February 2007 (including adding ASEP S&M to histogram)	Draft annual update (2007) preparation. Changes from ASAS-TN2 authors and NASA Langley
1.3	22nd January 2007	Refinements to all chapters of document Added chapter 4.3 ADS-B equipage status for Hong Kong, China	Draft annual update (2007) preparation - Changes arising from group ASAS-TN2 review held 18th January 2007
2.0	9th March 2007	Refinements to structure and contents of all chapters of document. Addition of summary and conclusion.	Annual update (2007) external release - Changes arising from ASAS-TN2 plus external reviewers from: NASA Langley, AENA (Spain), Rockwell Collins (Netherlands), QinetiQ (UK), Airbus (France), Air Services Australia, Boeing (Seattle), Thales Air Systems (France), and MITRE (US).
2.1	7th January 2008	Updated all sections	Draft annual update (2008) preparation. Initial changes from ASAS-TN2 authors
2.2	18th January 2008	Updated sections: Summary, Chapter 1,2,4,5&6. Main changes:updated ADS-B coverage statistics; reduced some airborne separation application maturity scores; and referenced material in CASCADE validation report, v1.0, 11th Jan 2008	Changes from review on 14th January 2008. Comments from: NLR, LFV,EEC
2.3	5th February 2008	Added new section to introduction 1.4 Plans for ASAS in Europe and US. Small changes to several chapters Added text to section 4.7.6 to explain trends in figure 12	Changes from: review meeting at EEC, 29th January 2008; new contributions from QinetiQ and NASA Ames on SESAR/NextGen
3.0	7th March 2008	Updated ADS-B coverage statistics with Jan 2008 data. Updated scores of ADS-B surveillance (RAD & NRA), Airborne traffic situational awareness (AIRB) and Airborne separation (S&M)	Changes from peer review: comments from Airbus, Boeing and Air Services Australia

Summary

The global maturity of nineteen applications based on Automatic Dependent Surveillance Broadcast (ADS-B), has been assessed by the European Commission sponsored Airborne Separation Assistance System (ASAS) Thematic Network 2 project. A group of twelve European operational and technical ASAS specialists from industry, service providers and research (BAE Systems (UK), ENAV (Italy), LFV (Sweden), NLR (The Netherlands), Thales Air Systems (France), Thales Avionics (France) and EUROCONTROL) judged maturity based on a set of commonly agreed metrics and their experience in the field.

For each application, maturity scores in the range 0 to 4 were assigned for each of the following metric types: (i) Operational concepts, (ii) Benefits and constraints, (iii) Safety, (iv) Procedures and human factors, (v) Systems, HMI and technology and (vi) Transition issues. The maturity assessment was reviewed externally by peers in Europe, USA and Australia. This is the third annual assessment since 2006.

In the period October 2006 to January 2008, the percentage of European flights sampled that were Mode-S equipped increased from 95.3 % to 97.0 %. ADS-B Extended Squitter indicated capability as a percentage of Mode-S equipped flights increased from 57.3% to 78.3%.

Results indicate that one of the most mature applications is ‘ATC surveillance in non-radar areas’ with a total score of 23.0 out of a possible 24 (operational daily in Bundaberg, Australia since 2007). The airborne traffic situational awareness applications ‘In-trail procedure in procedural airspace’ and ‘Enhanced visual separation on approach’, and the Airborne spacing application ‘Sequencing and merging’ also seem to have made progress with total scores of 19 and above. The applications judged to be relatively immature are ‘Aircraft derived data for ground tools’ (ADS-B surveillance category) and ‘Vertical crossing and passing’ (Airborne separation category) with total scores less than 7.

Over the year from March 2007 to February 2008 the maturity scores of fourteen out of nineteen applications increased (compared with fifteen the previous year) including a new application In-trail Merge (Airborne separation category). ‘Sequencing and merging’ (Airborne spacing category) showed the greatest annual change in total score from 17 to 20.5 after FAA gave UPS/ACSS operational approval in December 2007.

Over the two year period from March 2006 to February 2008 the maturity scores of seventeen out of nineteen applications increased. The total maturity score of the airborne spacing application ‘sequencing and merging’ increased the most over the two year period from 15.5 to 20.5. The two applications with the lowest scores also matured at the slowest rate over the two year period: ‘Aircraft derived data for ground tools’ (ADS-B surveillance category) and ‘Vertical crossing and passing’ (Airborne spacing category) did not change maturity score. . The lack of change in score of Aircraft derived data for ground tools over the three year period implies the application needs to be revisited in the context of SESAR and NextGen.

When grouped in order of increasing ASAS functionality, the maturity tends to decrease on average. The relatively high initial airborne self-separation scores given in 2006 can perhaps be explained by the free flight research initiatives in the US and Europe during the previous decade with airborne separation category applications catching up more recently.

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1. Introduction

1.1. Purpose and scope

This report provides an assessment of the global maturity of Airborne Separation Assistance System (ASAS) applications. The purpose of this part of the ASAS Thematic Network 2 (ASAS-TN2) is to provide an annual assessment of the progress and necessary steps in the development of ASAS applications. This report is the second annual update of the initial report version 1.0 issued on 27th March 2006.

1.2. ASAS-Thematic Network

ASAS-TN2 is a three-year project that is primarily a communication activity. ASAS-TN2 is sponsored by the European Commission (Directorate General Research). It is a stand-alone project, following on from the work of its predecessor project ASAS-TN1. The scope has now increased to address applications beyond ADS-B (Automatic Dependent Surveillance Broadcast) Package 1. ASAS-TN1 arose out of the ASAS work within the programme of Co-Operative Actions of Research & Development (R&D) in EUROCONTROL (CARE-ASAS). It is organised within the work programme for Competitive and Sustainable Growth of the European Community, Key action 4, New Perspectives in Aeronautics, Target Platform 4, “More Autonomous Aircraft in the Future Air Traffic Management System”.

The main objective of the ASAS Thematic Network is to accelerate the implementation of ASAS applications in European airspace taking into account global applicability in order to increase airspace efficiency, capacity and safety.

More specifically the ASAS-TN2 tasks include the following:

- Reviewing R&D work on ASAS/ADS-B applications including validation/safety/human factors work – in particular work performed in ASAS-related projects;
- Reviewing the development of operational standards;
- Reviewing the development of technical standards;
- Reviewing of the achievement of early implementations; and
- Developing guidelines and recommendations to accelerate implementation of ASAS/ADS-B applications

The deliverables of the ASAS-TN2 are threefold:

- Host five ASAS workshops and a final seminar
- Provide web-based related documentation including ASAS-TN2 reports; and
- Reporting annually on the status and maturity of ASAS application development.

This report concerns the third bullet above. It is the last report of three aiming to summarise, in a concise and graphical format, the advancements of ADS-B/ASAS applications towards implementation

ASAS-TN2 is managed by a consortium led by EUROCONTROL that includes BAE Systems (UK), ENAV (Italy), LFV (Sweden), NLR (Netherlands), Thales Air Systems and Thales Avionics (France).

In addition to the above organisations, ASAS-TN2 involves a very wide range of organisations (e.g. ATM stakeholders, universities) including pilot and controller professional associations (ATCEUC (Air Traffic Controllers European Union’s Coordination), IFATCA (International Federation of Air Traffic Controllers’ Associations), IFALPA (International Federation of Air Line Pilots’ Associations) and ECA (European Cockpit Association)).

1.3. Automatic Dependent Surveillance – Broadcast (ADS-B)

1.3.1. ADS-B definition

An Automatic Dependent Surveillance – Broadcast (ADS-B) transmitter allows an aircraft to broadcast its identification, position, velocity and intent information (not in current standards) over a range of the order of 100 nautical miles. Aircraft equipped with an ADS-B receiver can then process and present this surrounding traffic information to pilots on a cockpit display of traffic information (CDTI). This gives rise to a set of potential new applications based on what is referred to as an airborne separation assistance system (ASAS). ADS-B receivers on the ground can also supply enhanced traffic information to air traffic controllers.

1.3.2. ADS-B equipage status

1.3.2.1. Core Europe 1090 Extended Squitter

The following statistics were taken from the Airborne Monitoring Project ADS-B Monthly Report, January 2008 of the EUROCONTROL CASCADE project (Co-operative Air Traffic Services through Surveillance and Communication Applications Deployed in the European Civil Aviation Conference area).

The results are generally based on information collected by: France (Charles de Gaulle), Germany (Dusseldorf), The Netherlands (Schiphol, Woensdrecht), The United Kingdom (Pease-Pottage), Belgium (Bertem/St. Huber) Czech Republic (Pisek) and Switzerland (Geneva) consolidated by EUROCONTROL.

Number of recorded flights: 699745
Recording duration: 3,822 hours
Percentage of flights that are Mode-S equipped: 97.0 %
ADS-B Extended Squitter capability as percentage of Mode-S equipped: 78.3% (compared with 57.3% in October 2006 and 39.8% in January 2006)

Extended Squitter data statistics (Com-B Data Selector 1.7)	Jan 2006 % of flights	Oct 2006 % of flights	Jan 2008 % of flights	Trend over first 10 month period (% change)	Trend over second 15 month period (% change)
ES Airborne position set to 1 (bds 0.5)	53.5	66.5	81.0	+24	+22
ES Ground position set to 1 (bds 0.6)	38.4	59.0	78.1	+54	+32
ES Status set to 1 (bds 0.7)	54.8	69.3	81.3	+27	+17
ES type and id set to 1 (bds 0.8)	65.0	74.2	84.1	+14	+13
ES Airborne velocity set to 1	56.0	69.9	79.9	+25	14
ES Even driven set to 1	0	0	0.04	0%	+

Table 1 Statistics for Extended Squitter capable flights in Europe

Note:
1) ADS-B transmissions are generally not certified for operational use. A detailed statistical analysis of data collected (from France, Switzerland and UK) indicates that about three quarters of ADS-B capable transponders declared they were broadcasting a position.

2) Statistics refer to flights rather than aircraft. The same aircraft could be used for several flights**.**

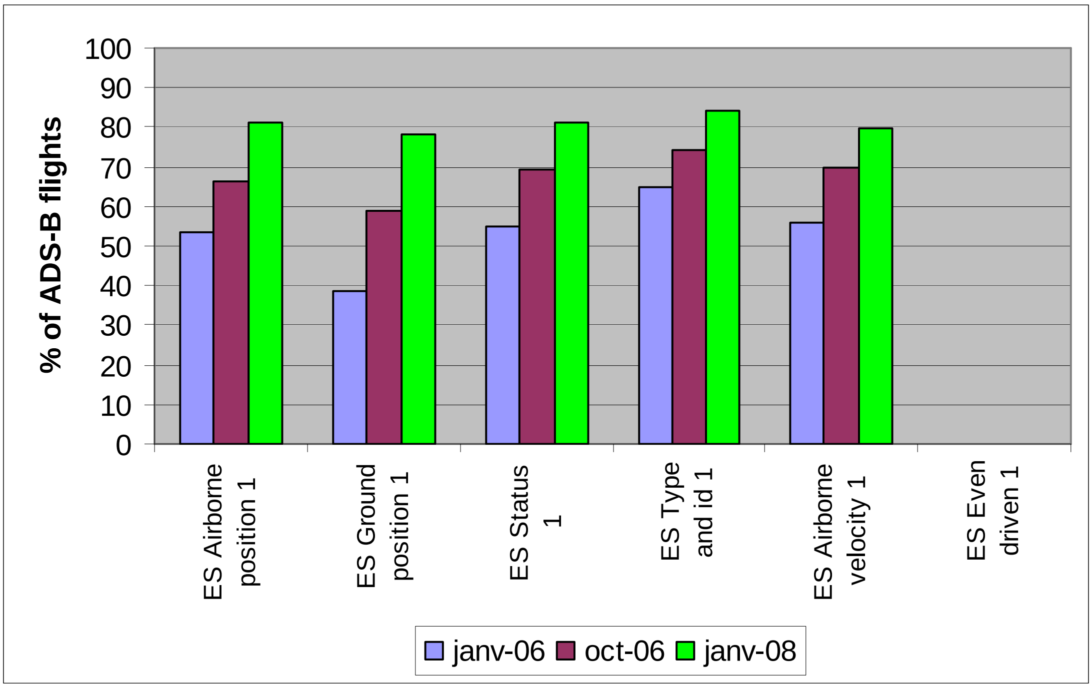


Figure 1 Statistics for Extended Squitter capable flights

1.3.2.2. Regional European VDL/4 ADS-B

The following statistics are based on information collected by LFV (Sweden) in the 18-month period from May 2005 to November 2006.

LFV is recording data from the newly deployed ADS-B network with ground stations in Malmö, Arlanda and Umeå. These stations are the three first in a series of 12 stations that will provide nation wide ADS-B coverage.

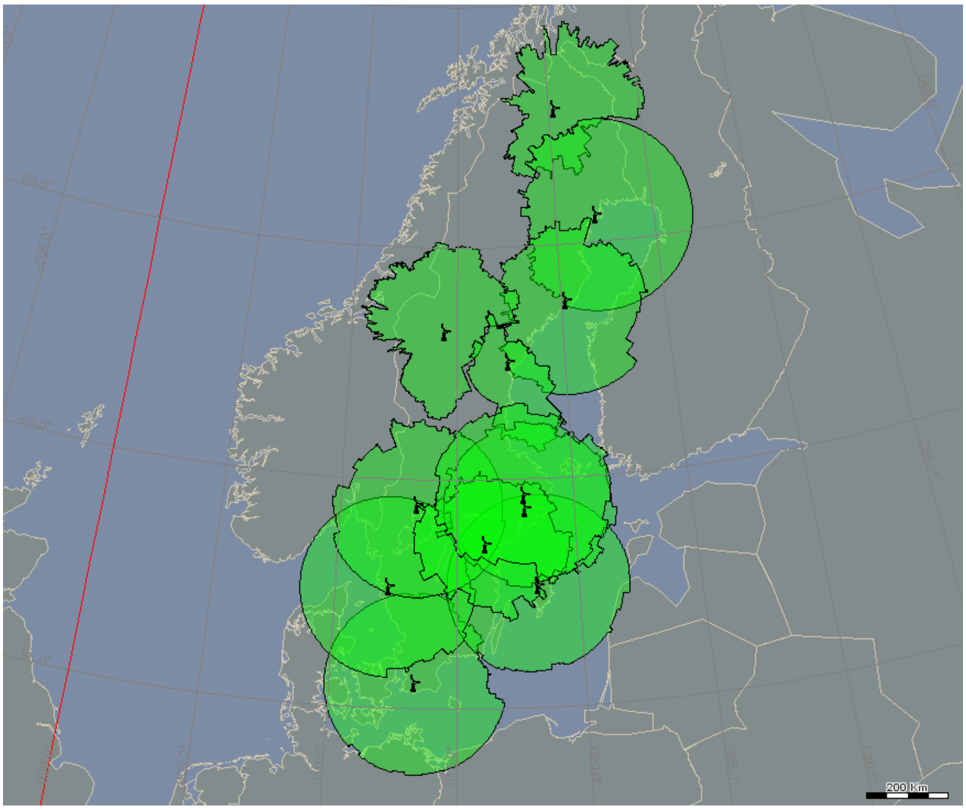


Figure 3 Estimated coverage at 10,000 ft above Mean Sea Level for the Swedish ADS-B network when all 12 ground stations are deployed (Analysis done using EUROCONTROL CAPT tool)

The current installation gives en-route coverage over the Swedish airspace from Malmö to Umeå, where the regional airlines, Malmö Aviation and Skyways operate.

The total recorded duration of VDL Mode 4 equipped flights is approximately 3,000 hours of flight time (GA and commercial operators). The surface vehicles at Arlanda airport generate in excess of 300 hours of surface movements recorded each day.

1.3.2.3. Hong Kong, China

Since November 2004, Hong Kong Civil Aviation Department has collected statistics on ADS-B equipage of the aircraft flying close to Hong Kong International Airport. The following statistics were presented to the 5th ICAO meeting of ADS-B study and implementation task force in New Delhi, India, 5-7th April 2006.

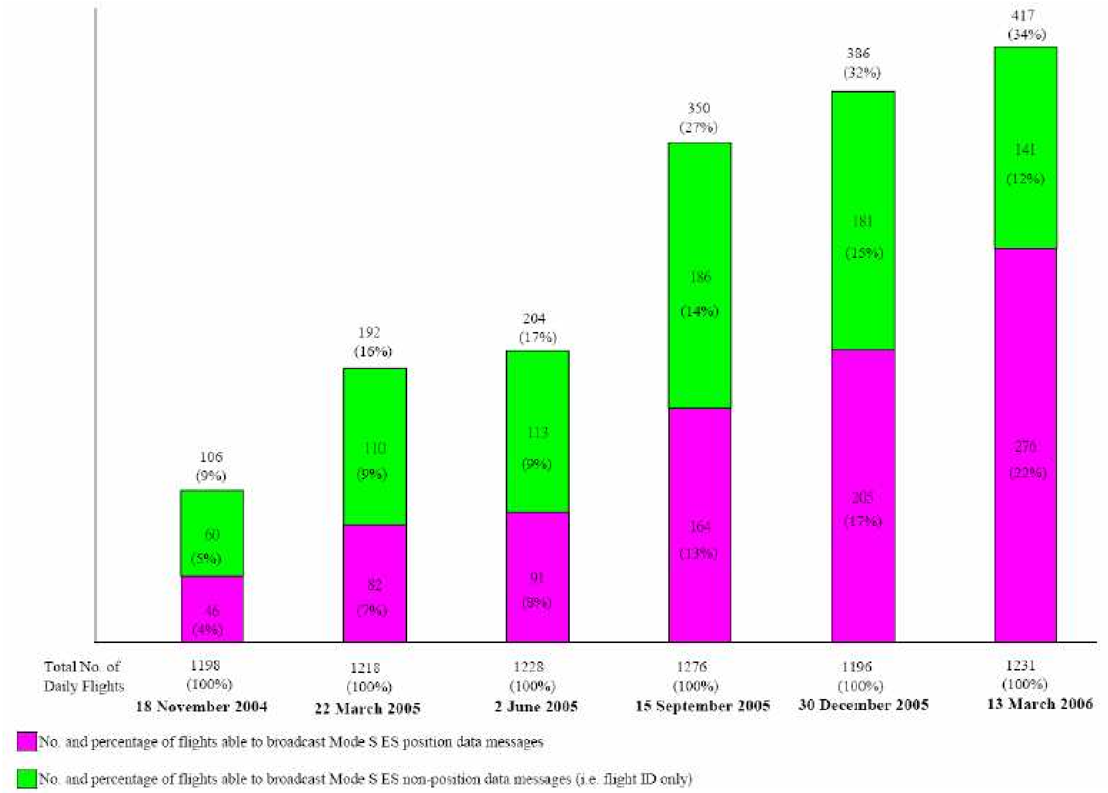


Figure 4 Quarterly survey of Mode S extended squitter (ES) equipage, Hong Kong, China

1.4. Plans for ASAS in Europe and US

1.4.1. Future of ATM

The SESAR and NextGen projects are developing plans for the future development of ATM in Europe and the USA respectively. Both projects base their concepts of operations on trajectory management methods. The trajectories are developed and approved cooperatively, in an environment where all parties have access to and share all the information they require The objective is to enable the airspace user to follow the trajectory that most meets the user's needs within the essential constraints.

In both concepts, the normal method for providing separation is to deconflict the trajectories long before the aircraft reach the point of conflict. Ground systems (rather than controllers) detect conflicts and calculate the minimal adjustments that are required to maintain separation. Again, changes in trajectory are developed cooperatively.

In this context, both concepts also envisage the use of ASAS to enable flight crew to act as their own separator in some circumstances, or in some airspaces. In general, there is no inconsistency between trajectory management techniques and the use of ASAS, and the use of ASAS in circumstances where flight crew is best placed to provide separation while flying an agreed trajectory will improve overall efficiency and ensure closer adherence to the desired trajectory. [AP23: "The Operational Role of Airborne Surveillance in Separating Traffic"] A trajectory management environment more naturally provides opportunities for the constructive use of ASAS to provide separation (or a desired spacing) than does the traditional environment.

1.4.2. SESAR (Europe)

The SESAR concept introduces the notion of the "business trajectory", which is owned by the airspace user. This trajectory is negotiated and becomes the Reference Business Trajectory (RBT), which is the trajectory that the airspace user agrees to fly and the ANSP and Airport agrees to facilitate. The RBT is authorised by controllers in a series of successive clearances to the flight crew. These may take the form of either Precision Trajectory Clearances (PTC) exploiting aircrafts capability to fly precise 2D, 3D or 4D trajectories or may include delegation of separation responsibility to flight crew using ASAS procedures. The concept also introduces the notion of "ATM capability levels", which show the symbiotic development of trajectory management and ASAS capabilities over the next two decades.

- Level 1 provides ADS-B, avionics with 2D-RNP, vertical constraint management, a single RTA and event reporting and intent sharing.
- Level 2 (2013 onwards) provides basic ASAS (ADS-B/IN) and avionics enabling airborne spacing – "Sequencing and Merging", and Link 2000+ applications.
- Level 3 (2020 – SESAR requirements) provides Trajectory Sharing with ATM, Vertical Navigation Performance capability; multiple RTA and Airborne Separation capability
- Level 4 (2025 onwards) provides Air-Air Trajectory Sharing Air-Air, Avionics with Longitudinal Navigation Performance Capability (4D Contract) and Airborne Self-Separation.

(Note that these capability levels refer to SESAR D3 (2007) and may change in D5)

Queue management will provide a safe, orderly and efficient flow of traffic towards a constrained resource – normally a runway. The emphasis of SESAR in queue management is to reduce environmental impact, particularly by absorbing delay at high altitude prior to a continuous descent approach. In an airborne queue, ASAS can be used to provide tactical fine spacing. Trajectory management can ensure an optimum arrival sequence, then ASAS techniques can merge arrival streams, facilitating cost effective and environmentally beneficial Constant Descent Approaches, and to provide precise approach spacing yielding increased consistent runway utilisation.

On the airport surface, ASAS will improve safety by providing greatly enhanced awareness of the airport layout (the moving map) and the position of other aircraft. In particular, it is part of a range of measures to greatly reduce the risk of runway incursion.

The SESAR separation modes include airborne separation and airborne self-separation, based on ASAS. Airborne separation can be used to enable one aircraft to overtake another; the overtaking aircraft calculating the manoeuvre using airborne separation, and then sharing the new trajectory providing the controller with assurance that the situation is resolved. The controller could also authorise an aircraft that is climbing to execute its RBT by climbing through the flight level of one or more blocking aircraft by providing airborne separation from those two aircraft. It is considered that self-separation may be feasible in a relatively short time-scale in very low-density high altitude airspace, providing the freedom for aircraft to cruise climb.

The SESAR concept includes mixed airspace in which some, well-equipped, aircraft may self-separate from ALL other aircraft, while less well equipped aircraft continue to receive a separation service from an ANSP. In this case, controllers would be responsible only for separating the less well equipped aircraft from each other. While this is perhaps the most challenging aspect of the SESAR concept, it is not a new idea and there has been some research. [references from NASA]

1.4.3. NextGen (US)

Trajectory-Based Operations and ASAS applications are central to the ATM transformation proposed by NextGen. NextGen introduces the notion of Performance-Based Services, in which preferential access to scarce resources is given to more capable aircraft that place lower demand on the ATM system than less equipped traffic. Although there is no direct analogy to the SESAR concept of aircraft capability levels, an equivalent range of aircraft capability is implicit in NextGen provisions for accommodating all aircraft, from today's diverse fleet, to aircraft fully capable of airborne self-separation. NextGen explicitly differentiates between trajectory-based operations for aircraft capable of exchanging datalinked trajectories, and operations similar to today's operations for aircraft lacking this capability. NextGen's expected segregation of airspace is in marked contrast to SESAR.

NextGen introduces the term "Delegated Separation" to refer to a broad range of ASAS capabilities, from allowing two aircraft to manage a simple encounter, to delegation of separation responsibility to several proximate aircraft for an extended period. An example of the latter is the NextGen concept of "Flow Corridors" in which traffic travels near parallel routes, achieving high density while leaving much airspace available for other traffic. Flow corridors are segregated from crossing traffic and must lie within trajectory-based airspace. Aircraft use ASAS for entering or leaving the corridor, for overtaking within the corridor and for longitudinal spacing between aircraft on the same track. Flow corridors might well be used when available en route airspace is restricted due to widespread convective weather, a common summer occurrence in parts of the US.

Delegated separation is expected to be the operating norm for trajectory-based operations, but NextGen emphasises that the ANSP delegates separation responsibility to capable aircraft at its discretion and thus retains control of overall traffic flow. NextGen also proposes segregated self-separation operations for certain airspace to reduce the need to provide trajectory management in this airspace and thus reduce service costs.

Whenever weather conditions permit in the United States, IFR traffic routinely conducts visual approaches to parallel, converging and single runways. NextGen proposes to maintain runway throughput irrespective of ceiling and visibility through ASAS-enabled closely-spaced approaches and in trail spacing operations. For the busiest airports at peak times, "Super-Density" operations are proposed, in which ASAS capabilities are combined with precise 4D trajectory management to maximize runway throughput.

2. Applications of ADS-B

Eighteen ADS-B applications were selected for this maturity assessment. They are grouped in five categories depending on whether they can be characterised as ADS-B surveillance or by the four ASAS categories: Airborne traffic situational awareness, Airborne spacing, Airborne separation and Airborne self-separation. The applications per category are described as follows:

2.1. ADS-B surveillance

2.1.1. Airport surface surveillance (ADS-B-APT)

This application will provide a new source of surveillance information for ATC for safer and more efficient ground movement management at airports. Equipped ground vehicles could also be displayed.

2.1.2. ATC surveillance in radar airspace (ADS-B-RAD)

The ADS-B-RAD application will apply to en-route and terminal phases of flight in airspace classes (A to E) where radar surveillance currently exists (note that non-radar area cases are covered by ADS-B-NRA).

An example is the case of surveillance in areas where single radar coverage presently exists; ADS-B surveillance could be considered as enhancing the quality (i.e. accuracy, integrity, availability, etc.) of surveillance information and may also be used as back up in case of radar failures. Another example is where multi-radar presently exists but a radar is to be de-commissioned in future and the radar replacement costs are not justified.

2.1.3. ATC surveillance in non-radar areas (ADS-B-NRA)

The ADS-B-NRA application will provide enhanced air traffic services in areas where radar surveillance currently does not exist.

Examples of use of this application are remote areas (including offshore, oilrig and small island environments), which, due to the level of traffic, location or the cost of the equipment, could not justify the installation of radar. This application may also be useful in areas where there are gaps in the radar coverage, (e.g. due to obstacles, mountainous terrain, shadowing etc). as well as areas where existing radar is to be de-commissioned and the replacement costs are not justified.

2.1.4. Aircraft derived data for ground tools (ADS-B-ADD)

This application will provide additional aircraft derived data through ADS-B to be used by the ATC ground system for developing or enhancing ATC tools like displays, MTCD (Medium Term Conflict Detection), AMAN (Arrival Manager), DMAN (Departure Manager) and ground based safety nets. Collaborative Decision Making (CDM) applications will also share the benefits. It should be noted that this application does not encompass the ground tools themselves; it only provides additional input data for these tools.

2.2. Airborne traffic situational awareness

2.2.1. Enhanced traffic situational awareness during flight operations (ATSA-AIRB)

ATSA-AIRB is the basic application. It provides flight crews with information about nearby traffic including at least the aircraft identifier and its position. This display supplements verbal traffic information provided either by controllers or other flight crews, as well as normal out-the-window visual scans.

ATSA-AIRB can be used in all visual conditions and therefore is relevant to both Instrument Meteorological Conditions (IMC) and Visual Meteorological Conditions (VMC) operations. It is also applicable to all flight rules, i.e. Instrument Flight Rules (IFR) and Visual Flight Rules (VFR), and to all types of aircraft, though the allowable crew reactions vary with the rules.

The objectives of this application are to improve flight safety and efficiency in all airspace.

This Airborne surveillance application contains two sub-applications, which aim at enhancing some current procedures. They are defined by the operational goal and the airspace involved with the associated services provided by ATS. The two sub-applications are:

- Enhanced visual acquisition for see-and-avoid: in airspace where separation service is not provided by ATC, it aims at making the visual acquisition task easier and more reliable by the addition of an appropriate on-board traffic display.
- Enhanced TIBA (Traffic Information Broadcast by Aircraft): in airspace where TIBA is applied it improves the current TIBA procedure by the addition of an appropriate on-board display of surrounding traffic to provide surveillance additional to listening to the TIBA VHF frequency.

2.2.2. Enhanced traffic situational awareness on the airport surface (ATSA-SURF)

This application provides the flight crews with information on the surface traffic that supplements out-the-window observations and see-and-be-seen procedures. The goal is to reduce the potential for conflicts, errors and collisions (e.g. runway incursion) by providing enhanced situational awareness to the flight crew operating an aircraft on or near the airport surface.

2.2.3. In-trail procedure in procedural airspace (ATSA-ITP)

This application permits a “climb-through” or “descend-through” manoeuvre to pass a “blocking” aircraft, using a distance-based longitudinal separation minimum with the blocking aircraft prior to the ITP manoeuvre. This distance-based longitudinal separation minimum is less than the standard separation minimum applied in procedural airspace. The goal is to enable aircraft that desire flight level changes in oceanic and remote airspace to achieve these changes on a more frequent basis, thus improving flight efficiency and safety. Note that the procedure is designed so that there is no requirement to know the distance between the aircraft during the manoeuvre (the ITP tools could fail on the aircraft and the manoeuvre can still be completed).

2.2.4. Enhanced visual separation on approach (ATSA-VSA)

This application helps crews to achieve the visual acquisition of the preceding aircraft and then to maintain visual separation from this aircraft. The goal is to allow an increased use of visual separation on approach in order to provide an optimum flow of traffic.

2.3. Airborne spacing

2.3.1. Sequencing and merging operations (ASPA-S&M)

The objective is to redistribute tasks related to sequencing (e.g. in-trail following) and merging of traffic between the controllers and the flight crews. The controllers will utilise a new set of instructions allowing them, for example, to instruct the flight crews to establish and to maintain a given time or distance in trail from a designated aircraft. The flight crews will perform these new tasks using a suitable human-machine interface. One anticipated benefit is increased capacity through better adherence to the ATC-requested spacing.

2.3.2. Enhanced crossing and passing operations (ASPA-C&P)

The objective is to provide the controller with a new set of procedures to solve conflicts directing, for example, the flight crews to cross or pass a designated traffic aircraft while maintaining a given spacing value. The flight crews will perform these new tasks using a human-machine interface. The main expected benefit is increased efficiency through the reorganisation and streamlining of tasks.

2.4. Airborne separation

2.4.1. Lateral crossing and passing (ASEP-LC&P)

ASSTAR is currently defining a “Lateral Crossing” procedure allowing an aircraft (the “clearance” aircraft) to cross or pass a “target” aircraft using ASAS. Responsibility for separation from the target aircraft is delegated to the flight crew of the clearance aircraft, although ATC remain responsible for separation of the clearance aircraft from all other aircraft. This responsibility is limited in time, space and scope for the duration of the Lateral Crossing procedure. Except in these limited specific circumstances where the flight crew takes responsibility for separation, ATC retains all other separation responsibility.

2.4.2. Vertical crossing and passing (ASEP-VC&P)

The ASEP-VC&P application will consist of scenarios such as Pass Above or Pass Below, in which an aircraft will be able to climb or descend two or more flight levels relative to a blocking aircraft such that during the vertical manoeuvre, the aircraft do not approach closer than some specified horizontal distance, until the vertical separation is recovered. There also exists RVSM to non-RVSM transition scenarios which will support flight level transitions in the presence of opposing traffic when flying from RVSM to non-RVSM airspace.

2.4.3. In-trail procedure (ASEP-ITP)

ASEP-ITP is the In Trail Procedure defined as an Airborne Separation application, as opposed to an Airborne Traffic Situational Awareness application as currently being defined by the RFG. ASEP-ITP is currently subject of work in the ASSTAR project.

The ASEP-ITP application is designed for use en-route in a procedural environment. The main objective is to increase efficiency. This will be achieved by allowing climbs or descents with temporarily reduced longitudinal separation minima. For ASEP-ITP, a limited transfer of separation responsibility between the controllers and aircrews is assumed (i.e. for the duration of the ITP climb or descent). The flight crew has to monitor and maintain spacing to specific aircraft during the manoeuvre.

The ITP criteria for ASEP-ITP will most likely differ from the ITP criteria for ATSA-ITP to enable a further reduction in longitudinal separation minima during the ASEP-ITP manoeuvre.

Within ASSTAR, there are six ITP climb or descent manoeuvres, as follows:

- Following Climb.
- Following Descent.
- Leading Climb.
- Leading Descent.
- Combined Leading-Following Climb.
- Combined Leading-Following Descent.

2.4.4. In-trail follow (ASEP-ITF)

The ASEP-ITF application is currently being studied in ASSTAR which uses the MFF Operational Concept as the basis for defining the ASEP-ITF application.

The application is designed for use en-route in a procedural environment. The objective is to reduce controller workload and to increase capacity and flight efficiency. This will be achieved by redistributing tasks and separation responsibility related to the in-trail following of traffic between the controllers and the aircrews.

Both procedural and radar controllers will be provided with new ATC procedures directing, for example, the aircrew to establish at the oceanic entry point and to maintain a given time or distance from a designated aircraft. The aircrews will perform these new tasks using new aircraft functions (e.g. airborne surveillance, display of traffic information, spacing functions). Within the context of ASSTAR, the use of ASEP-ITF procedures will replace most of the controller's use of the sliding Mach technique to separate traffic in the NAT Organised Track System, or more general in NAT (and similar) airspace for traffic flying the same route.

2.4.5. Sequencing and merging operations (ASEP-S&M)

The application is designed to delegate the tasks related to merging of traffic from the controllers to the flight crews. The controllers will utilise a new set of instructions allowing them to delegate the responsibility for maintaining separation from a designated target (lead aircraft) to the flight crew for a limited duration and under specific conditions. The flight crews will perform these new tasks using a suitable human-machine interface. The expected benefits are increased flight predictability, airspace throughput and the enabling of more efficient flight profiles.

2.4.6. In-trail Merge (ASEP-ITM)

Following a presentation by NATS at the ASAS-TN2 workshop 3 (11th-13th September 2006 in Glasgow), a proposal was developed to use a variant of ASEP-ITF (which became known as Airborne Separation In Trail Merge) to allow for the re-routing of eastbound traffic within the Shanwick Oceanic Control Area, to improve flight flexibility and manage European domestic airspace congestion.
The current situation for eastbound traffic during the duration of the eastbound OTS is that traffic is often following a routing which is not optimum in terms of flow management from an overall ATC point of view. ASEP-ITM enables the re-routing of aircraft to another oceanic exit point, after 20 West, to reduce ATM complexity, and/or improve the remaining route towards destination.

2.5. Airborne self-separation

2.5.1. Self-separation in segregated free flight airspace (SSEP-FFAS)

The "Airborne Self Separation" concept, also referred to as "Free Flight", is where aircrews are allowed to select their trajectory freely in real-time, at the cost of acquiring responsibility for conflict management. EUROCONTROL defines Free Flight as the flight through 'Free Flight Airspace' (FFAS) (see ATM2000+ Strategy), where, suitably equipped aircraft are able to fly user-preferred routings and responsibility for separation assurance from other aircraft operating in the same airspace will rest with the aircrew. Figure 5 shows the possible location of FFAS with respect to Managed Airspace (MAS).

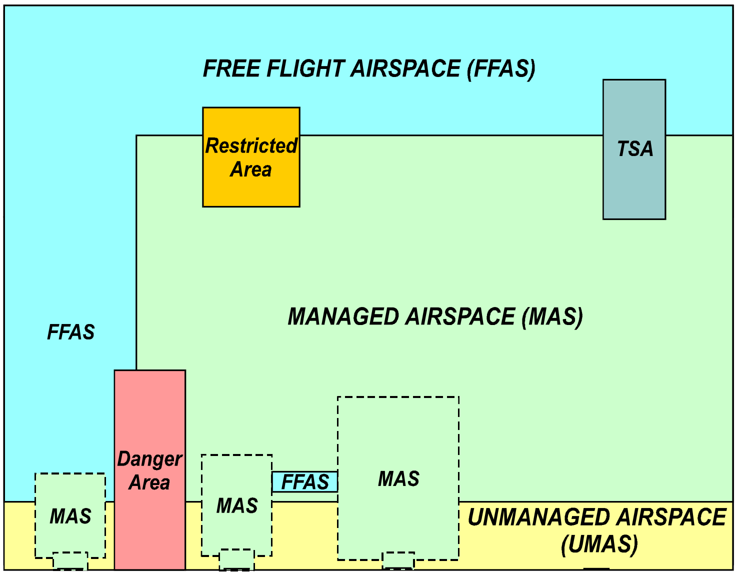


Figure 5 Possible locations of FFAS and MAS.

2.5.2. Self-separation in managed airspace (SSEP-MAS)

The SSEP-MAS concept is slightly different from the definition as provided by EUROCONTROL. In the SSEP-MAS concept, equipped aircraft are allowed to freely choose their trajectory in Managed Airspace, provided that they avoid the non-equipped aircraft in MAS which are conventionally controlled by ATC.

2.5.3. Self-separation in an organised track system (SSEP-FFT)

The SSEP-FFT concept is a variation of the SSEP-FFAS concept, although more restricted. The concept assumes equipped aircraft to be flying on a designated track within the oceanic Organised Track System (OTS), segregated from the non-equipped aircraft. The crew is able to choose their trajectory freely, albeit with some limitations in the horizontal direction. This concept is expected to be a first implementation towards SSEP-FFAS.

3. Method

3.1. Approach

The approach to the ASAS-TN2 ASAS application maturity work is based on a simple assessment and scoring system to report the maturity of ASAS applications, in order to produce a lightweight and accessible summary of the level of maturity of ASAS applications in a few pages.

Within the scope of the project it was considered that we could not address each ASAS application individually and that an analysis at the level of the ASAS packages was at too high a level. Indeed, the content of ADS-B packages 2 and 3 at the time of writing is still under definition. Therefore intermediate groupings were defined for analysis corresponding to whether the applications were a type of ADS-B surveillance or an ASAS category:

- ADS-B surveillance (ground and airborne)
- Airborne traffic situational awareness
- Airborne spacing
- Airborne separation
- Airborne self-separation

3.2. Metrics

Each application within each group was assessed by a team of experts for maturity from several aspects:

- Operational concepts
- Benefits & constraints
- Safety assessment
- Procedures and human factors
- Systems, HMI & technology
- Transition issues

Each maturity level is scored as follows:-

Operational concept:

1 - Problem statement, identify solutions, concept generation (concept of operations)
2 - Preliminary Operational Concept Description (R&D Operational Service and Environment Description (OSED))
3 - Draft OSED in development (e.g. feedback from R&D OSEDs, trials and experiments, initial Requirements Focus Group (RFG) OSED) – in review and close to approval by appropriate internationally recognised body.
4 - Consolidated OSED (demonstrating integration in ATM system, feedback from Operational Safety Assessment (OSA) – some validation activity) - Published

Benefits & constraints:

1 - Benefits expectations & constraints survey
2 - Qualitative assessment of benefits
3 - Quantitative assessment of benefits (e.g. by means of fast-time simulations)
4 - Confirmation of benefits by means of large-scale data collection (real-time simulations, flight trials, etc.)

Safety assessment:

1 - Safety expectations
2 - Identification of hazards & risks, leading to Operational Hazard Analysis (OHA).
3 - Stable OSA. Allocation of safety objectives to the aircraft/aircraft operators and (Air Navigation Service Providers) ANSP. Standardisation activities.
4 - Approval for operations.

Procedures and human factors:

{There are two elements to address, air and ground. The score will reflect the lowest level of maturity - appropriately weighted}

1 - Role of actors, philosophy of automation defined
2 - Functional model of information presentation and operator interaction enabling high-level assessment of Human Factor (HF) risks and human performance
3 - Task analysis, derivation of cognitive model, investigate human factors risks and human performance, training needs analysis
4 - Mitigate risks in human performance and HF and validate task analysis and cognitive model. Identify training needs.

Systems, HMI & technology:

{There are two elements to address, air and ground. The score will reflect the lowest level of maturity - appropriately weighted}

1 - Functional design
2 - R&D, mock-up/part-task evaluation with humans-in-the-loop
3 - Industry-led system simulations, including human-in-the-loop simulations for Human Machine Interface (HMI). Shadow-mode/flight trials.
4 - Manufacturer(s) commit to full system development

Transition issues (All benefit dependant; Benefits high – just do it! Benefits proven low – forget it?):

1 - Issues identified
2 - Options identified (mixed equipage/airspace)
3 - Impact assessed
4 - A solution has been shown feasible and agreed upon

The evidence for scoring will be based on the projects, programmes and activities to be reviewed listed in the references section of this document. The list is not in any way exhaustive and will be updated during the course of ASAS-TN2.

This version of the document marks in brackets any differences in maturity scores since the previous version last year.

4. Results

4.1. ADS-B surveillance

4.1.1. Progress overview

4.1.1.1. Airport surface surveillance (ADS-B-APT)

This application is or has been addressed by European R&D projects such as:

- North European ADS-B Update Programme (NUP-1)
- NUP-2
- NUP II+
- EMMA and EMMA 2 (European Airport Movement Management by A-SMGCS)

In Europe, the work towards implementation of this application is co-ordinated by the EUROCONTROL CASCADE programme. This includes the standardisation work (e.g. RFG) as well as validation trials (named CRISTAL) throughout Europe. A draft OSED has been developed by RFG addressing A-SMGCS level 1 and “ADS-B only” environments. Progress on this application will benefit from the ADS-B out monitoring and validation trials initiated in the context of CRISTAL.

In the USA, Safe Flight 21 (SF21) addressed ADS-B APT. However, it must be emphasized that SF21 started earlier than RFG and that the scope of the applications considered within SF21 might not exactly match those developed by RFG and reviewed in this document. In addition, the US FAA has launched a country wide ADS-B implementation program that is going to include various applications, including surveillance on airports. There is no indication today whether the application considered by the FAA for this program matches the one addressed by RFG.

In the Asia Pacific Region, a number of countries are implementing A-SMGCS systems with ADS-B capability:

- Australia in Sydney, Brisbane and Melbourne;
- Republic of Korea in Seoul;
- Kazakhstan in Almaty;
- …

Note that many recent A-SMGCS installations include a multilateration system that can also receive ADS-B signals, directly providing the ADS-B ground receiver function required for ADS-B-APT.

4.1.1.2. ATC surveillance in radar airspace (ADS-B-RAD)

ADS-B RAD is or has been addressed by European R&D projects such as:

- NUP-1
- NUP-2
- MEDUP (Mediterranean Update Programme)
- SEAP (Large Scale European ADS Pre-implementation Programme)

In Europe, the work towards implementation of this application is co-ordinated by the EUROCONTROL CASCADE Programme. This includes the standardisation work (e.g. RFG) as well as validation trials (named CRISTAL) throughout Europe (e.g. Mediterranean, Netherlands, Sweden, UK,…)

In particular, the CRISTAL MED (Co-opeRative ValidatIon of Surveillance Techniques and AppLications of Package I Mediterranean) project (started in late 2005) addresses the use of this application in Portugal, France, Italy, Malta, Greece, Cyprus and Turkey.

RFG standardisation of ADS-B-RAD will benefit from the work done on ADS-B-NRA and from the validation of ADS-B-out undertaken in CASCADE / CRISTAL trials. ADS-B-RAD is one of the three first priority applications in the RFG now that work on ADS-B-NRA / ED126 has been completed.

In the USA, ADS-B-RAD has been investigated by Safe Flight 21. The recent contract award by the FAA to implement ADS-B nationwide is significantly accelerating the investigation, validation and certification process for this application.

In the context of the Australian Upper Airspace Programme,
- Australia is already using ADS-B operationally in Bundaberg Queensland in a radar environment

- Australia has purchased and now received additional ADS-B ground stations to be installed at existing civil enroute radar stations and at some Defence radar locations

- In addition, Australia has contracted a supplier to update the ATC system to process and fuse ADS-B data with radar (including ModeS DAPS) into a system track. This capability will be deployed at all enroute and all existing terminal area consoles.

- The Australian implementation may differ from the RFG RAD application because it will not require the transmission of Mode A SSR codes in ADS-B messages because the ATC automation is capable of managing without Mode A, including inter centre co-ordination.

4.1.1.3. ATC surveillance in non-radar areas (ADS-B-NRA)

This application has been addressed by several European R&D projects: NUP-1, NUP-2, MEDUP, and SEAP.

In Europe, the work towards implementation of this application is co-ordinated by the EUROCONTROL CASCADE Programme. This includes the standardisation work (RFG) as well as validation trials (named CRISTAL) throughout Europe (e.g. CRISTAL Austria, Ireland, Mediterranean, Netherlands, Sweden).

CASCADE/CRISTAL is running an extensive “ADS-B out” validation programme across 12 European countries to monitor ADS-B out 1090 MHz Extended Squitter signals broadcast by aircraft. The programme develops statistics on the percentage of aircraft equipped and actually broadcasting ADS-B, but also analyses in more detail whether the aircraft broadcast the correct set of data with the right accuracy and quality indicators. This work benefits all ADS-B enabled applications.

Three ground stations have been installed on the island of La Reunion in the Indian Ocean by DSNA (France) and are currently used for operational validation. Operations will start in 2008, first providing a situation display in support of procedural separation, then to support separation.

ADS-B-NRA OSED, SPR and INTEROP material developed by the RFG was accepted by the EUROCAE and RTCA early 2007 and published as ED-126/D0-303. This is the basis for the relevant certification material: A Notice of Proposed Amendment-NPA was published by EASA in 2007 and the Acceptable Means of Compliance-AMC is expected in 2008.

Airbus has certified the A380 (with Do-260A) and A330/340 families (with Do-260) for Non Radar Operations ED-126. Certification is ongoing for the A320 family (with Do-260). In this context, CASCADE has launched the ADS-B Pioneer Airlines project, which aims at the airworthiness approval of 1090 ES equipped aircraft for ADS-B NRA, using the ED-126 EASA certification material. 17 airlines are participating for a total of about 500 aircraft.

In the USA, the application is operational since January 2001 as part of the Capstone programme, in Alaska. However, due to the very specific nature of the Capstone program, it is not sure to what extent the content of the application is in line with the European definition, as described in the OSED. The recent contract award by the FAA to implement ADS-B nationwide includes the provision of ADS-B-NRA services in some areas e.g. Gulf of Mexico.

In Australia, Airservices Australia has decided to deploy a network of ADS-B ground stations providing nationwide coverage in the Upper Airspace (above FL300, with coverage to the ground in the vicinity of the ground stations). Daily operation of ADS-B-NRA started in 2007. Eleven stations are operational and data is presented to controllers today. In the scope of this program, the Australian regulator (CASA) has approved 5NM separation between two aircraft equipped with approved ADS-B avionics. Over 500 airframes (most DO-260 equipped) have been approved for use in this program including many international carriers.

In Canada, NavCanada is implementing ADS-B to provide surveillance over the Hudson Bay. Ground Stations are installed and operations are expected to start late 2008.

4.1.1.4. Aircraft derived data for ground tools (ADS-B-ADD)

ADS-B ADD has been addressed by European R&D projects such as: NUP 2, DADI 2, MEDUP, ADD Safety Now project due to start by ENAV

4.1.2. Maturity assessment

Differences in maturity scores since previous year are marked in brackets.

4.1.2.1. Operational concepts

Application	Maturity level	Notes
ADS-B-APT	2	The OSED is being drafted by RFG
ADS-B-RAD	3 (+0.5)	The OSED is being drafted by RFG. This is one of the three priority applications of the RFG in 2008.
ADS-B-NRA	4	The OSED, SPR (Safety Performance Requirements) and Inter-operability (Interop) documents were published by RTCA/EUROCAE (European Organisation for Civil Aviation Equipment) early 2007. Australia participated in this RFG activity and brought significant inputs.
ADS-B-ADD	1	The operational concept for this application is not at a mature stage. Currently the only inputs provided are from NUP-2.

4.1.2.2. Benefits and constraints

Application	Maturity level	Notes
ADS-B-APT	2	Expected benefits include the improvement of the surveillance of movements on the airport surface. ADS-B complements Surface Movement Radar at a low cost, extending effective coverage to areas previously affected by shadows, obstacles, …etc and facilitating track labelling and correlation to flight call-signs. It also allows tracking and identifying airport vehicles. ACSS working on benefits assessment.
ADS-B-RAD	2.5	Benefits are expected through the improvement of the radar coverage in terms of continuity. In some cases, such as when a target is far from the radar, the ADS-B position could be considered instead, which will improve the global assessment of the air situation. If ADS-B is approved to be equivalent to radar surveillance, then multiple radar coverage could be simplified, with the consequence of reducing the cost of the ground infrastructure. FAA have developed a positive business case for this application in their national context. Improved velocity vector information will benefit automated alerts.
ADS-B-NRA	3.5	Expected benefits range from improvements through efficiency, cost saving for airlines through the provision of reduced separation compared to procedural control. 5NM radar-like separation is currently operational 24 hours per day / 7 days per week in Bundaberg, Australia. Other benefits also include support to Search and Rescue. Constraints are that ATC centres must be upgraded to address the application. Maximum benefits will be accrued only when a significant number of aircraft are equipped, although some benefits can be provided to early participants (e.g. User Preferred Routes, radar-like safety nets).
ADS-B-ADD	1	The expected benefits are improved and new ground tool performance, in term of efficiency and accuracy e.g. for trajectory prediction or safety nets.

4.1.2.3. Safety assessment

Application	Maturity level	Notes
ADS-B-APT	2	Safety analysis underway at RFG
ADS-B-RAD	3 (+1)	Safety analysis underway at RFG - almost ready for FRAC
ADS-B-NRA	4 (+1)	This application has been completed by RFG, and some states are willing to implement it in the short / medium term. An initial ASOR (Allocation of Safety Objectives and Requirements) /PSSA (Preliminary System Safety Assessment) was conducted by the RFG. (Publication ED126/D0303)
ADS-B-ADD	1	Will be analysed by RFG

4.1.2.4. Procedures and human factors

Application	Maturity level	Notes
ADS-B-APT	1	Initial assessment carried out in the scope of OSED development
ADS-B-RAD	1.5	Initial assessment carried out in the scope of OSED development
ADS-B-NRA	4 (+1)	An in-depth analysis of human factor risks and human performance was carried out in Australia to enable ADS-B based separation
ADS-B-ADD	1	Initial assessment carried out in the scope of OSED development

4.1.2.5. Systems, HMI and technology

Application	Maturity level	Notes
ADS-B-APT	3.5	Technology available for airports; the impact of ADS-B on the HMI will be to be capable of displaying an appropriate symbol so the controller knows what source of positional data is being used
ADS-B-RAD	3.5	Ground and airborne systems available; the impact of ADS-B on the HMI will be to be capable of displaying an appropriate symbol so the controller knows what source of positional data is being used
ADS-B-NRA	4 (+0.5)	Ground and airborne systems available; the impact of ADS-B on the HMI will be to be capable of displaying an appropriate symbol so the controller knows what source of positional data is being used.
ADS-B-ADD	1.5	

4.1.2.6. Transition issues

Application	Maturity level	Notes
ADS-B-APT	1	Tracking of ADS-B equipped ground vehicles will provide full benefits as soon as equipment is installed. ADS-B is one mechanism to provide secure labelling of ground movements, suitable for ground vehicles including aircraft. Secure labelling will enable A-SMGCS level 1. Secure labelling from ADS-B combined with Surface Movement Radar will provide benefits even from a partial equipage
ADS-B-RAD	3 (+1)	Transition issues not investigated yet, although Australian experience indicates that ground and airborne systems suitable for NRA will support RAD..
ADS-B-NRA	3.5	Reduced separation can be provided between two equipped aircraft. User Preferred Routes could be cleared to ADS-B equipped aircraft.
ADS-B-ADD	1	Transition issues not investigated yet.

4.1.2.7. Summary

ADS-B-APT provides the potential to improve ground surveillance on the airport surface, providing an additional highly accurate sensor source to manage ground movements with or without an A-SMGCS. There may be some issues with GPS performance in airport environments. In most cases, ADS-B is used as an additional source of surveillance data for A-SMGCS systems. Some systems are already ADS-B-APT capable typically, multilateration based systems that can also receive ADS-B.

ADS-B-RAD provides the potential to improve ATC service particularly in areas where single radar coverage is available or to become a cost-effective replacement for some of the secondary radars. The challenge here is the demonstration and validation of the separation service when a layer of radar surveillance is replaced by ADS-B (Safety Case). Progress has been made by the RFG on this subject and the FAA's decision and contract award for nationwide deployment of ADS-B will further accelerate the process.

ADS-B-NRA is mature. Initial applications of ADS-B-NRA have been tested through pre-operational trials in Australia, Alaska and Europe and a full-scale deployment is well underway in Australia. The main challenge in ADS-B-NRA is the demonstration and validation of the separation service using radar-like minima (e.g. 5nm) with the target architecture (Safety Case). Ensuring consistent ADS-B-out equipage is also a transition issue to be overcome (see related issue of DO260/DO260A in next section).

ADS-B-ADD remains less mature than the other GS applications and requires further analysis of the corresponding ADD parameters and of their performance requirements.

4.1.3. Critical path and blocking issues

The critical path for ground surveillance applications is mainly to ensure adequate and consistent aircraft equipage for the ADS-B-out function. Due to the European mandate on Enhanced Surveillance (EHS), Mode S transponders have been upgraded to address this new function. Avionics manufacturers agreed with the main airframe manufacturers (Airbus, Boeing) to include the 1090 Extended Squitter (ES) function as part of the upgrade. Since early 2003 the fleet capable of transmitting ADS-B reports on 1090 ES is steadily growing.

Initially, the ADS-B out function was certified only on a non-interference basis i.e. the transponder was allowed to broadcast ADS-B messages but the ADS-B messages were not certified to any level of performance. In addition there are avionics issues relating to the DO-260 vs 260A standards (especially with regard to integrity and accuracy quality indicators such as NIC, NAC, SIL, etc.). However a number of recent regulation decisions (refer to details in 4.1.4) supported by regional initiatives/projects will significantly improve the situation. In particular the Eurocontrol Pioneer Airlines project involves a number of aircraft types including Boeing and Airbus airliners, business jets and regional transport aircraft, and will significantly contribute to fixing any remaining incorrect configurations for air transport aircraft.

Another issue is to deal with mixed fleet equipage and transition to full equipage. Solutions may vary depending on the particular application considered and local solutions may exist where traffic is dominated by a small number of operators.

Constraints are related to the upgrade of the ATC system to receive and process ADS-B reports for ADS-B NRA, ADS-B RAD and ADS-B APT (especially A-SMGCS).

4.1.4. Current implementation and plans

Significant implementation plans are now in progress in various parts of the world and related regulation steps are taking place.

In 2007, ICAO defined and published documents to support the implementation of ADS-B:

- ADS-B amendments to **PANS-ATM** effective starting 22 Nov 07;
- ADS-B based **5 NM separation criteria** published as **Circular 311**.

Australia is implementing ADS-B for Upper Airspace Surveillance with DO-260 (accepts 260A as well). To support the 5 Nm ADS-B based separation, CASA published in June 2007 an amendment to 'Civil Aviation Order 20.18' requiring aircraft flying in Australian airspace to comply with an approved ADS-B Out equipment configuration. The ATLAS project, which is currently the subject of consultation, would go a step further towards mandating ADS-B for enroute separation, including in airspace currently surveilled by en-route radars.

In Europe, EASA plans to publish in 2008 the ‘AMC 20-24’ document to support operational implementation of ADS-B surveillance. This document is expected to refer to DO-260A but to allow DO-260 equipment for initial operation.

A NavCanada programme to develop ADS-B based separation services over the Hudson Bay is well underway. In this context, Transport Canada published AIC 18/07 which requires mandatory carriage of either DO-260 or DO-260A ADS-B out equipment over the Hudson Bay by November 2008.

A wide-scale implementation project is underway in the USA that includes ADS-B surveillance in both radar and non-radar airspace, as well as at the airport. In this context, the FAA published a Notice for Proposed RuleMaking (NPRM 29305) that will require mandatory carriage of ADS-B out equipment by all types of aircraft flying under IFR rules. The final rule is expected to be published in 2009 for mandatory carriage by 2020. Infrastructure expected to be in place by 2013.

4.2. Airborne traffic situational awareness

4.2.1. Progress overview

4.2.1.1. Enhanced traffic situational awareness during flight operations (ATSA-AIRB)

In Europe, the work towards implementation of this application is co-ordinated by the EUROCONTROL CASCADE Programme. This includes the standardisation work (RFG) as well as validation trials (e.g. CRISTAL Sweden, CRISTAL ATSAW).

4.2.1.2. Enhanced traffic situational awareness on the airport surface (ATSA-SURF)

In Europe, the work towards implementation of this application is co-ordinated by the EUROCONTROL CASCADE Programme. This includes the standardisation work (RFG) as well as validation trials (e.g. CRISTAL Sweden, CRISTAL ATSAW).

The NUP II+ project includes ADS-B operational tests at Stockholm-Arlanda airport in Sweden. In autumn of 2007 tests on runway incursion services were performed. In these tests a SAS 737NG and various ground vehicles were involved. VDL-4 was used as the ADS-B medium. The Aircraft was equipped with a Rockwell-Collins VMMR and dual Electronic Flight Bags(EFB). Cautions and warnings were generated by algorithms internally in the EFB thus assuring their independency and were visually presented on the EFB in the trial aircraft. In the future cautions and warnings will be complemented by aural callouts. The results were very encouraging and confirmed that the service performed exactly as planned.

Mobiles equipped with ADS-B out/in and a CDTI/EFB on board will also be able to display all surrounding traffic via direct ADS-B complemented by TIS-B transmissions. One B737NG and two vehicles will initially be fully equipped during these trials. Plans are to equip additionally three SAS 737NG with VMMR and EFB.

ACSS and UPS received airworthiness and operational approval for a similar application, based on 1090 MHz, in 2007.

RFG will begin work on ATSA-SURF in 2008.

4.2.1.3. In-trail procedure in procedural airspace (ATSA-ITP)

ATSA-ITP trials are conducted by EUROCONTROL CASCADE (CRISTAL ITP involves NATS, ISAVIA, Airbus and Alticode). Real time simulations have been conducted in Shanwick, Reykjavik and Toulouse, some of them interconnecting ATC and aircraft simulators. Flight tests are expected by end of March 2008.

ICAO APANPIRG/ADS-B task force is currently investigating the potential use of ATSA-ITP in the Asia-Pacific region. Air Services Australia has conducted simulations of ATC procedures associated with ITP, and is preparing ATSA-ITP operational evaluation flights and support for NASA. ICAO’s Separation & Airspace Safety Panel (SASP) is currently considering ITP, including collision risk modelling by the Mathematics Sub Group (MSG).

4.2.1.4. Enhanced visual separation on approach (ATSA-VSA)

This application has been investigated in the US during the Ohio Valley ADS-B trials and for Frankfurt during the FALBALA (First Assessment of the operational Limitations, Benefits & Applicability for a List of package I AS applications) project.

ACSS and UPS received airworthiness and operational approval for this application (in a specific environment) in 2007.

4.2.2. Maturity assessment

4.2.2.1. Operational concepts

Application	Maturity level	Notes
ATSA-AIRB	2	RFG has developed draft OSED. The concepts are quite stable.
ATSA-SURF	3 (+1)	RFG has developed draft OSED. No major issues identified.
ATSA-ITP	3.5 (+0.5)	RFG has developed draft OSED. The concepts are quite stable. Feedback from preliminary results of the OSA process. The SPR is near completion.
ATSA-VSA	3.5 (+0.5)	RFG has developed draft OSED. The concepts are quite stable. Feedback from preliminary results of the OSA process.

4.2.2.2. Benefits and constraints

Application	Maturity level	Notes
ATSA-AIRB	2.5 (+1.5)	Benefits are identified and qualitatively assessed in Airbus flight tests.
ATSA-SURF	3 (+1)	Benefits are identified not assessed but deemed sufficient for a first implementation (ACSS has certified Safe Route for UPS, and UPS has received operational approval for it)
ATSA-ITP	2.5	Benefits are identified. NASA studies identify benefits. Procedure has been refined. ICAO is now considering ITP. Airbus identified benefits but communication of results pending agreement from NAT IMG. Results expected from CRISTAL ITP (NATS) 2008/9.
ATSA-VSA	2.5	Benefits are identified. Basic assessments have been made (UPS use in Louisville) but no modelling. Issues of aircraft identification remain.

4.2.2.3. Safety assessment

Application	Maturity level	Notes
ATSA-AIRB	1	No OHA document by RFG (on-going)
ATSA-SURF	1	No OHA document by RFG
ATSA-ITP	3.5 (+1.0)	Safety and Performance Requirements to be published soon (EUROCAE ED-159). ICAO Separation and Safety Panel (SASP) officially decided to consider ATSA-ITP and Mathematics sub-group (MSG) currently conducting safety analysis.
ATSA-VSA	3	OSA performed. UPS CDTI certified for a very similar application.

4.2.2.4. Procedures and human factors

Application	Maturity level	Notes
ATSA-AIRB	4 (+1.0)	Procedures are defined in OSED. Human factor analysis performed.
ATSA-SURF	3	Procedures are defined in OSED. Procedure validation is ongoing but it is straightforward: do not manoeuvre with CDTI as sole source of information.

ATSA-ITP	2.5	Procedures are defined in OSED. Procedure simulations are performed within CRISTAL ITP, as well as by NASA and Airservices. Encouraging feedback from ICAO SASP.
ATSA-VSA	3	Procedures are defined in OSED. No change in current procedures.

4.2.2.5. Systems, HMI and technology

Application	Maturity level	Notes
ATSA-AIRB	4 (+1)	Already used by UPS. Airbus is certifying ATSA-AIRB.
ATSA-SURF	4 (+1)	In operational use at UPS. Real time simulations have been performed
ATSA-ITP	4 (+1)	Airbus is certifying ATSA-ITP.
ATSA-VSA	4 (+1)	Already Used by UPS. Airbus is certifying ATSA-VSA.

4.2.2.6. Transition issues

Application	Maturity level	Notes
ATSA-AIRB	2	Rely on current procedures.
ATSA-SURF	3	Rely on current procedures. Mixed fleet equipage is probably acceptable.
ATSA-ITP	3	Derived from current procedures. Mixed fleet equipage is acceptable.
ATSA-VSA	3	Rely on current procedures. Mixed fleet equipage is acceptable.

4.2.2.7. Summary

FAA have certified (airworthiness and operational) the ACSS/UPS SafeRoute system, including ATSA-SURF and ATSA-VSA (or very similar) applications.

ATSA-AIRB -Concept, procedures and systems/HMI well advanced
Certifications are ongoing.

ATSA-SURF - Concept, procedures and systems/HMI well advanced
Work needed on safety, benefits and transition.

ATSA-VSA - Concept, procedures and systems/HMI well advanced. Certifications are ongoing.
ATSA-ITP - Concept, procedures, systems/HMI and benefits well advanced. Certifications are ongoing.

4.2.3. Critical path and blocking issues

The definition and validation effort has to continue.
Modifications of some ICAO documents will be necessary: for most applications phraseology has to be slightly modified; ITP and E-TIBA will require changes of Annex 11 or Doc 4444; ITP separation has been evaluated by the Separation and Airspace Safety Panel (SASP). The approval authorities will have to be involved.

In pair wise operations:

> The manoeuvring aircraft has to be ATSAW equipped. All the applications require ADS-B-in equipage corresponding to ATSA-AIRB, though performance requirements may vary between applications.
>
> The other aircraft has to be ADS-B-out capable. This will become more frequent because a growing part of the worldwide fleet will be ADS-B-out equipped. Note however that DO-260 and DO-260A are only 'pipes'. An important issue is the navigation source and whether the transponder ADS-B out function is qualified. For ATSAW applications, correlation with Mode-S active interrogations might provide sufficient integrity. Airbus has already taken the decision to launch ATSAW based on internal cost benefit analysis. ITP and VSA are the main drivers.

The decision to equip aircraft for ATSAW capability relies on the identification of operational and economic benefits that would trigger the decision of airframe manufacturers or avionics manufacturers to offer the modification, and aircraft operators to take it up.

No blocking issue has been identified mainly because the different ATSA applications aim at improving existing procedures. Studies may be required regarding the impact of ATSA on the ground ATC, although for ITP these have been started by Eurocontrol and Airservices.

Studies have been conducted by DSNA about the impact of ATSA on the ground ATC (See CRISTAL ATSAW Report).

4.2.4. Current implementation and plans

An important milestone is the decision from an airframe manufacturer to offer ATSA applications. It has to be combined with the decision of Regulator/ANSPs to implement ATSA operations in their airspace.

EUROCONTROL's CASCADE programme is co-ordinating activities, including local implementations, for ATSA-AIRB, ATSA-SURF, ATSA-VSA and ATSA-ITP (CRISTAL ATSAW validation projects has been launched).

Target date for certification of ATSAW in the air on Airbus aircraft is 2009. Validations on simulator have been performed under the umbrella of Eurocontrol CASCADE CRISTAL.

LFV conducted a live trial at Arlanda during the 4th quarter of 2006 to assess flight crew benefits of ATSA-SURF. The trial targeted one flight crew on the calibration aircraft. During these trials initial verification of a runway incursion detection algorithm where conducted with promising results. This functionality and the results provided valuable inputs to the trial performed in 2007 under the NUP2+ program, concerning CDTI locations and flight deck procedures.

4.3. Airborne spacing

4.3.1. Progress overview

4.3.1.1. Sequencing and merging operations (ASPA-S&M)

Key projects addressing the application: MFF, MA-AFAS, NUP I, NUP II, CoSpace, FALBALA, DAG-TM, G2G, FlySafe, UPS Merging and Spacing (FAA operational approval December 2007), EFAS (UK), SEAP, CRISTAL Paris (completed 2007).

In Europe, the work towards implementation of this application is co-ordinated by the EUROCONTROL CASCADE Programme. This includes amongst others an intensive involvement in the standardisation work (RFG).

CRISTAL Paris completed in 2007. CASCADE validation report concluded potential for this application high however important avionics changes and airspace redesign are required for significant benefits to be gained.

RFG target dates for ASPA S&M are yet to be defined, although ASPA S&M has been advanced as background task with a feasibility check in January 2008. CASCADE report does not expect EUROCAE/RTCA standard to be published before 2009.

FAA gave operational approval of merging and spacing to UPS at Louisville in Dec 2007

4.3.1.2. Enhanced crossing and passing operations (ASPA-C&P)

Key projects addressing the application: MA-AFAS, MFF, G2G. Results from controllers have not been positive. (see related application under airborne separation)

4.3.2. Maturity assessment

4.3.2.1. Operational concepts

Application	Maturity level	Notes
ASPA-S&M	3.5 (+0.5)	Consolidated OSED from several validation activities and RFG work.
ASPA-C&P	1	Operational concept to be refined/reviewed in further activities.

4.3.2.2. Benefits and constraints

Application	Maturity level	Notes
ASPA-S&M	3.5 (+1)	Results on benefits have been produced by UPS M&S Flight Operation.
ASPA-C&P	1	Negative initial results – controllers uncomfortable with responsibility for separation. Further development depends on whether the application moves to Airborne separation category.

4.3.2.3. Safety assessment

Application	Maturity level	Notes
ASPA-S&M	3.5 (+0.5)	ASOR and preliminary safety assessment performed along standardisation activities.
ASPA-C&P	1	Negative initial results from a controller perspective.

4.3.2.4. Procedures and human factors

Application	Maturity level	Notes
ASPA-S&M	3.5	Besides the need of further refinement UPS has introduced M&S application along operational flights.
ASPA-C&P	1	Re-definition of responsibilities required.

4.3.2.5. Systems, HMI and technology

Application	Maturity level	Notes
ASPA-S&M	3.5 (+1)	ACSS has developed a fully operational (i.e. certified and operationally approved) working system used by UPS during M&S operational flights.
ASPA-C&P	1	A review of systems supporting this application is required.

4.3.2.6. Transition issues

Application	Maturity level	Notes
ASPA-S&M	3 (+0.5)	Some assessment on technical and operational transition issues. Adaptation of airspace is the key issue.
ASPA-C&P	1	Further investigation required.

4.3.2.7. Summary

ASPA-S&M - A lot of activity has taken place. G2G; MITRE: Flight Deck based M&S; CRISTAL and PALOMA: S&M in Paris; Experiments on the impact of wind ASPA S&M; ASPA in TMA. Good results have been achieved.
ASPA-C&P –No further activities have taken place - research results indicate this application should be re-classified as ASEP- C&P.

4.3.3. Critical path and blocking issues

In ASAS spacing several important results have been achieved. ASAS spacing applications have been successfully demonstrated and the operational procedures designed ad-hoc for projects like MFF, Cospace, NUP and G2G have also been successfully tested. There are still some pending issues, e.g. the use of data-link for target identification, benefits identification for local implementations, and airspace re-design guidance.

4.3.4. Current implementation and plans

The example of UPS's "Merging and Spacing", while not exactly the same as ASPA S&M, is a good example of the level of benefits that can be achieved by such an application in a high equipage environment.

UPS trials are tailored for a specific environment and concept of operations;. On the other hand UPS has mentionned the intention to implement M&S application in Europe in its hub in Koln. An initial exchange of views has taken place between DFS and UPS. European Commission should sponsor the assessment of the application in its own real-life ATM local context, in order to benefit from all positive results achieved up to now in all EC sponsored projects and drawing appropriate conclusions on implementation issues as well as on operational applicability/usability

Future ASPA research should quantify the benefits in terms of capacity,efficiency and environment and should address the inter-relationships with other TMA concepts (e.g. Continuous Descent Approaches and P-RNAV). On TMA related concepts, the EP3 project is planning two cycles of ASPA validation activities which are expected to provide final results by end of 2009.Performance Based Navigation (RNAV and RNP) is an environment characteristic which needs to be accounted for.

4.4. Airborne separation

4.4.1. Progress overview

4.4.1.1. Lateral crossing and passing (ASEP-LC&P)

The ASEP-LC&P application was studied in ASSTAR. It was also investigated during the MA-AFAS and MFF programmes.

EUROCONTROL's ADAS (Advanced Data-link and Airborne Surveillance Applications) activity is integrating data-link requirements into ASEP LC&P starting from the kernel procedure designed by RFG and ASSTAR.

4.4.1.2. Vertical crossing and passing (ASEP-VC&P)

Though the ASEP-VC&P application is not subject of considerable work at present within the ASAS community, it has been identified by EUROCONTROL's ADAS, during the work on ASAS Concept of Use, as being potentially beneficial in the departure phase. As such it will form part of the ASEP C&P OSED produced by ADAS.

4.4.1.3. In-trail procedure (ASEP-ITP)

Within ASSTAR, there are six ITP climb or descent manoeuvres, as follows:

- A Following Climb.
- A Following Descent.
- A Leading Climb.
- A Leading Descent.
- A Combined Leading-Following Climb.
- A Combined Leading-Following Descent.

4.4.1.4. In-trail follow (ASEP-ITF)

The ASEP-ITF application was studied in ASSTAR which uses the MFF Operational Concept as the basis for defining the ASEP-ITF application.

Within the context of ASSTAR, the use of ASEP-ITF procedures will replace most of the controller's use of the sliding Mach technique to separate traffic in the NAT Organised Track System, or more general in NAT (or similar) airspace for traffic flying the same route.

4.4.1.5. Sequencing and merging operations (ASEP-S&M)

The ASEP-S&M application is currently studied by EUROCONTROL-ADAS.

4.4.1.6. In-trail Merge (ASEP-ITM)

The ASEP-ITM application was proposed and studied in ASSTAR to enable the re-routing of aircraft to another oceanic exit point (within the Shanwick Oceanic Control Area), after 20 West, to reduce ATM complexity, and/or improve the remaining route towards the destination.

4.4.2. Maturity assessment

4.4.2.1. Operational concepts

Application	Maturity level	Notes
ASEP-LC&P	2	Overall, the concept is now well defined following work carried out in ASSTAR. Also demonstrated in MA-AFAS and MFF.

ASEP-VC&P	1 (0)	The VC&P application has yet to be explicitly looked at, but has been recognised in the SESAR ConOps as a potential ASEP application.
ASEP-ITP	2	This application is well defined from work carried out on package 1 ATSA-ITP, and has been studied in detail in ASSTAR.
ASEP-ITF	2	Studied in ASSTAR which uses the MFF Operational Concept as the basis for defining the ASEP-ITF application. Application also very similar to ASPA-S&M.
ASEP-S&M	1.5	The concept is in advanced definition phase. The concept uses all the lessons learnt from ASPA-S&M (CoSpace, G2G, MFF, etc)
ASEP-ITM	1	Need identified following ASAS-TN2 Third Workshop in Glasgow (September 2006) and defined during the ASSTAR project.

4.4.2.2. Benefits and constraints

Application	Maturity level	Notes
ASEP-LC&P	2.5 (+0.5)	Was studied during ASSTAR. Benefits through ATCo workload reduction and more efficient aircraft routes.
ASEP-VC&P	1	Some perceived benefits, generally based on assumptions, but no definite conclusions yet.
ASEP-ITP	2.5 (+0.5)	Was studied during ASSTAR. Benefits mainly operational related to aircraft efficiency.
ASEP-ITF	2.5 (+0.5)	Was studied during ASSTAR. Benefits mainly aircraft efficiency but also benefits to ATM efficiency due to enhanced usage of available flight levels and flow management improvements. NASA Glenn Research Center prepared Benefits Assessment of Reduced Separations in North Atlantic Organized Track System which is similar to ASEP-ITF application.
ASEP-S&M	1.5	Will be studied by ADAS. Expected benefits include reduced controller workload, improved predictability, increased runway throughput and more efficient flight operations
ASEP-ITM	2 (2)	Was studied during ASSTAR. Benefits to aircraft and ATM efficiency which compensate a probably increase in ATCo workload.

4.4.2.3. Safety assessment

Application	Maturity level	Notes
ASEP-LC&P	2 (+0.5)	Was studied during ASSTAR.
ASEP-VC&P	1	No specific analysis has been carried out yet.
ASEP-ITP	2 (+0.5)	Was studied during ASSTAR.
ASEP-ITF	2 (+0.5)	Was studied during ASSTAR.
ASEP-S&M	1	Will be studied by ADAS
ASEP-ITM	1.5 (1.5)	Was studied during ASSTAR.

4.4.2.4. Procedures and human factors

Application	Maturity level	Notes
ASEP-LC&P	2 (+0.5)	Was studied during ASSTAR.
ASEP-VC&P	1	No assessment carried out yet.
ASEP-ITP	1.5	Was studied during ASSTAR.

ASEP-ITF	2 (+0.5)	The ASEP-ITF application is analogous to ASPA-ITF which is already well defined, the difference is ASEP-ITF is defined for non-radar environments. Was studied during ASSTAR.
ASEP-S&M	2 (+1)	Will be studied by ADAS
ASEP-ITM	1 (1)	Initially studied during ASSTAR.

4.4.2.5. Systems, HMI and technology

Application	Maturity level	Notes
ASEP-LC&P	2	Work on this aspect has been carried out during MA-AFAS. NLR have also done some work. System requirements were also studied during ASSTAR.
ASEP-VC&P	1	NLR have performed some initial work in this area.
ASEP-ITP	2	Work has been carried out by NLR for similar types of operation. Also investigated during ASSTAR.
ASEP-ITF	2	Based on the similarities to ASPA-S&M and work carried out in ASSTAR..
ASEP-S&M	2(+1)	Will be studied by ADAS
ASEP-ITM	1 (1)	Initially investigated during ASSTAR.

4.4.2.6. Transition issues

Application	Maturity level	Notes
ASEP-LC&P	1	Transition issues not investigated yet.
ASEP-VC&P	1	Transition issues not investigated yet.
ASEP-ITP	1	Transition issues not investigated yet.
ASEP-ITF	1	Transition issues not investigated yet.
ASEP-S&M	1	Will be studied by ADAS
ASEP-ITM	1	Transition issues not investigated yet.

4.4.3. Critical path and blocking issues

Final harmonized versions of operational concepts are maturing (from the initial work of the MFF and NUP II projects) in the ASSTAR project, and these will require validation. In this regard, ASSTAR has undertaken a number of real and fast time simulations. It has been identified that the amount of communications within the ASEP procedures needs to be reduced. It is anticipated that reducing the message exchanges will make the procedure faster. ADAS Datalink User Group will be looking at developing application OSED for ASEP S&M and ASEP C&P that will include the analysis of use of data-link and (potentially) intent information

Acceptance of the ASEP applications will also depend on the outcome of cost benefit analyses and safety cases, which have yet to be completed. The safety case in particular will drive some of the operational requirements as well as the cost.

The critical path and blocking issues of ASEP applications relate to the transfer of responsibility, criticality of equipment, airborne separation etc. The EUROCONTROL SSATS domain addresses these issues in the near-term future through ADAS.

4.4.4. Current implementation and plans

The ASSTAR project has developed ASEP operational concepts and also performed safety and cost benefit analyses.

EUROCONTROL/FAA Action Plan 23 (Advanced ASAS) activity is responsible for coordinating the identification of Package 2 applications. The work is done building on CASCADE and RFG work on Package 1 applications and standards developed for initial ADS-B applications.

ASEP applications have also been identified within the scope of the SESAR Concept of Operations.

4.5. Airborne self-separation

4.5.1. Progress overview

4.5.1.1. Self-separation in segregated free flight airspace (SSEP-FFAS)

The SSEP-FFAS concept, which is in line with the EUROCONTROL definition, was studied extensively in the following projects:

- NLR/NASA Free Flight project
- 3FMS project
- FREER project
- INTENT project
- MFF project
- Hybridge project

Fast-time simulations, human-in-the-loop simulations and flight trials were conducted, together with extensive safety case analysis.

4.5.1.2. Self-separation in managed airspace (SSEP-MAS)

This concept was studied extensively by NASA Langley in fast-time and human-in-the-loop simulations.

4.5.1.3. Self-separation in an organised track system (SSEP-FFT)

The ASSTAR project tested this concept in fast-time and human-in-the-loop simulations, as well as by means of an extensive safety analysis.

NASA has developed the expanded concept 'dynamic multi-track airways (DMA)', assessed feasibility, modelled aspects of it in fast-time simulation, and prototyped the airborne passing tools.

4.5.2. Maturity assessment

4.5.2.1. Operational concept

Application	Maturity level	Notes
SSEP-FFAS	2	flight tested, MFF
SSEP-MAS	2	human-in-the-loop simulations conducted, Langley
SSEP-FFT	2	Human-in-the-loop simulations conducted in ASSTAR& concept described in DMA

4.5.2.2. Benefits and constraints

Application	Maturity level	Notes
SSEP-FFAS	2	fast-time simulations conducted, MFF
SSEP-MAS	2	quantitative assessment of single-year benefits conducted and life-cycle benefit/costs from detailed capacity/demand and controller workload models, Langley
SSEP-FFT	2 (+1)	Was studied during ASSTAR. Benefits mainly aircraft efficiency and through ATCo workload reduction. preliminary benefits assessment, DMA

4.5.2.3. *Safety assessment*

Application	Maturity level	Notes
SSEP-FFAS	2	safety cases conducted (OSED, OHA, ASOR), MFF, NLR/NASA Free Flight. quantitative risk assessment conducted, HYBRIDGE
SSEP-MAS	1.5	hazards/risks identified, safety design established, and validation simulations underway, Langley
SSEP-FFT	2 (+1)	qualitative and quantitative safety assessment conducted, ASSTAR no safety case conducted yet, DMA

4.5.2.4. *Procedures and human factors*

Application	Maturity level	Notes
SSEP-FFAS	2	flight tested in MFF
SSEP-MAS	2	integrated air-ground human-in-the-loop simulations conducted, Ames-Langley
SSEP-FFT	2	initial procedures described, initial human-in-the-loop simulations performed by ASSTAR

4.5.2.5. *Systems, HMI and technology*

Application	Maturity level	Notes
SSEP-FFAS	2	flight tested, MFF
SSEP-MAS	2	Integrated human-in-the-loop simulations conducted, Ames-Langley
SSEP-FFT	2	Initial human-in-the-loop simulations conducted, ASSTAR. Prototype airborne system for passing developed but not formally evaluated, DMA.

4.5.2.6. *Transition issues*

Application	Maturity level	Notes
SSEP-FFAS	2	human-in-the-loop simulations conducted, MFF
SSEP-MAS	2	human-in-the-loop simulations conducted, Langley
SSEP-FFT	1.5	transition issues identified and options posed, ASSTAR, DMA

4.5.2.7. *Summary*

SSEP-FFAS - After extensive human-in-the-loop simulations, in July 2005, the MFF flight trials have been completed. These flight trials have shown that the SSEP-FFAS concept is feasible in a real-life environment. Further, the safety case of SSEP-FFAS in MFF has been completed using OSED, OHA and ASOR.

SSEP-MAS - The SSEP-MAS concept has not been tested yet flight trials, but human-in-the-loop simulations have shown that the concept is feasible
SSEP-FFT - The SSEP-FFT concept is refined based on fast-time simulations (benefits, safety) and human-in-the-loop simulations performed by the ASSTAR project

4.5.3. Critical path and blocking issues

The main near-term benefits of the SSEP concept in general are expected in procedural environment. Since SSEP-FFAS and SSEP-MAS can obviously not be introduced immediately, a transition path towards these concepts is required. The SSEP-FFT is part of this transition path, and was studied and refined by the ASSTAR project, both in simulations and in the safety case. Future work should further refine the operational concepts based on the outcome of the ASSTAR project.

The requirements for Airborne Self-Separation need to be defined in detail, particularly safety (integrity, continuity) and performance requirements, and their impact on existing standards and systems, such as the ADS-B link, need to be analysed. The standardisation and certification process is still in its infancy and significant interoperability work will need to be undertaken. The standardisation and approval of procedures and safety cases within the relevant ICAO groups and panels will also be required before SSEP activities can move out of the research domain.

Benefit analyses need to be performed in more depth, the use of SSEP applications have to deliver the needed capacity and efficiency benefits in the future ATM system. This includes analyses on exactly how SSEP applications can be integrated into 4D trajectory-based operations (ref. SESAR and NextGen Concept of Operations, reduced separation standards in NAT airspace), partial equipage, large number of traffic samples, opposite/crossing traffic in oceanic airspace, interaction between oceanic and domestic sectors, etc.

In case of positive results, the SSEP-FFT concept is ready to be flight tested over segregated Oceanic airspace. If these trials are also positive, the next step towards implementation can be made. If the SSEP-FFT is implemented, the next steps are to transition towards SSEP-FFAS. The SSEP-MAS concept is not feasible in oceanic environment, since there is no TIS-B available by which the equipped aircraft can “see” the non-equipped aircraft. SSEP-MAS is applicable in RADAR airspace, and the work to prove the safety of distributed systems should be continued

Other issues related to implementation is the lead time needed to certify the technology, and the formal acceptance of new liabilities arising from the adoption of this family of applications.

4.5.4. Current implementation and plans

Quantitative risk assessment of self-separation applications as performed in the HYBRIDGE project is further progressed within the iFLY project.

Further benefit analysis would support the introduction of SSEP. The airlines are invited to participate in this benefit analysis, as this is typically airline specific. Initial “back-of-the-envelope” calculations results are very positive and support the quick return on investment requirements by the airlines.

NASA’s research is progressing in the following areas:
(1) traffic complexity management research through development of new decision-support functions
(2) performance-based analysis of self-separation through batch simulation
(3) safety design validation through batch simulation
(4) consideration of self-separation aircraft by Tactical Flow Management
(5) further benefits analyses

SSEP applications have also been identified within the scope of the SESAR Concept of Operations.

4.6. Summary of annual changes (2007-8)

4.6.1. ADS-B equipage status

4.6.1.1. Europe:

In the period October 2006 to January 2008 the percentage of flights that are Mode-S equipped increased slightly from 95.3 % to 97.0 %. ADS-B Extended Squitter capability as percentage of Mode-S equipped flights increased from 57.3% to 78.3%.

4.6.2. ADS-B surveillance

4.6.2.1. Airport surface surveillance (ADS-B-APT)

In the Asia Pacific Region, a number of countries are implementing A-SMGCS systems with ADS-B capability:

- Australia in Sydney, Brisbane and Melbourne;
- Republic of Korea in Seoul;
- Kazakhstan in Almaty;

Note that many recent A-SMGCS installations include a multilateration system that can also receive ADS-B signals, directly providing the ADS-B ground receiver function required for ADS-B-APT.

4.6.2.2. ATC surveillance in radar airspace (ADS-B-RAD)

In particular, the CRISTAL MED (Co-opeRative ValidatIon of Surveillance Techniques and AppLications of Package I Mediterranean) project (started in late 2005) addresses the use of this application in Portugal, France, Italy, Malta, Greece, Cyprus and Turkey. Australia will begin work on implementing ADS-B-RAD during 2008.

ADS-B-RAD is one of the three first priority applications in the RFG now that work on ADS-B-NRA / ED126 has been completed.

FAA have developed a positive business case for this application in their national context.

In the context of the Australian Upper Airspace Programme,
- Australia is already using ADS-B operationally in Bundaberg Queensland in a radar environment

- Australia has purchased and now received additional ADS-B ground stations to be installed at existing civil enroute radar stations and at some Defence radar locations

- In addition, Australia has contracted a supplier to update the ATC system to process and fuse ADS-B data with radar (including ModeS DAPS) into a system track. This capability will be deployed at all enroute and all existing terminal area consoles.

- The Australian implementation may differ from the RFG RAD application because it will not require the transmission of Mode A SSR codes in ADS-B messages because the ATC automation is capable of managing without Mode A, including inter centre co-ordination.

4.6.2.3. ATC surveillance in non-radar areas (ADS-B-NRA)

Three ground stations have been installed on the island of La Reunion in the Indian Ocean by DSNA (France) and are currently used for operational validation. Operations will start in

2008, first providing a situation display in support of procedural separation, then to support separation.
ADS-B-NRA OSED, SPR and INTEROP material developed by the RFG was accepted by the EUROCAE and RTCA early 2007 and published as ED-126/D0-303. This is the basis for the relevant certification material: A Notice of Proposed Amendment-NPA was published by EASA in 2007 and the Acceptable Means of Compliance-AMC is expected in 2008.

Airbus has certified the A380 (with Do-260A) and A330/A340 families (with Do-260) for Non Radar Operations ED-126. Certification is ongoing for the A320 family (with Do-260).

The recent contract award by the FAA to implement ADS-B nationwide includes the provision of ADS-B-NRA services in some areas e.g. Gulf of Mexico.

Daily operation of ADS-B-NRA in Australia started in 2007. Eleven stations are operational and data is presented to controllers today. In the scope of this program, the Australian regulator (CASA) has approved 5NM separation between two aircraft equipped with approved ADS-B avionics. Over 500 airframes (most DO-260 equipped) have been approved for use in this program including many international carriers.

In Canada, NavCanada is implementing ADS-B to provide surveillance over the Hudson Bay. Ground Stations are installed and operations are expected to start late 2008.

4.6.2.4. Aircraft derived data for ground tools (ADS-B-ADD)

ADD Safety Now project due to start by ENAV

4.6.2.5. Changes to maturity scores:

- ADS-B-APT
  - Benefits and constraints increased from 2 to 3
- ADS-B-RAD
  - Operational concept increased from 2.5 to 3.0
  - Safety assessment increased from 2 to 3.0
  - Procedures and human factors increased from 1 to 1.5
- ADS-B-NRA
  - Safety assessment increased from 3.0 to 4.0
  - Procedures and human factors increased from 3 to 4.0
  - Systems, HMI and technology increased from 3.5 to 4.0
- ADS-B-ADD
  - No change

4.6.2.6. Critical path and blocking issues

The Eurocontrol Pioneer Airlines project involves a number of aircraft types including Boeing and Airbus airliners, business jets and regional transport aircraft, and will significantly contribute to fixing any remaining incorrect configurations for air transport aircraft.

The lack of change in score of Aircraft derived data for ground tools over the three year period implies the application needs to be revisited in the context of SESAR and NextGen.

4.6.2.7. Current implementation and plans

Significant implementation plans are now in progress in various parts of the world and related regulation steps are taking place.

In 2007, ICAO defined and published documents to support the implementation of ADS-B:

- ADS-B amendments to **PANS-ATM** effective starting 22 Nov 07;
- ADS-B based **5 NM separation criteria** published as **Circular 311**.

Australia is implementing ADS-B for Upper Airspace Surveillance with DO-260 (accepts 260A as well). To support the 5 Nm ADS-B based separation, CASA published in June 2007 an amendment to ‘Civil Aviation Order 20.18’ requiring aircraft flying in Australian airspace to comply with an approved ADS-B Out equipment configuration. The ATLAS project, which is currently the subject of consultation, would go a step further towards mandating ADS-B for enroute separation, including in airspace currently surveilled by en-route radars.

In Europe, EASA plans to publish in 2008 the ‘AMC 20-24’ document to support operational implementation of ADS-B surveillance. This document is expected to refer to DO-260A but to allow DO-260 equipment for initial operation.

A NavCanada programme to develop ADS-B based separation services over the Hudson Bay is well underway. In this context, NavCanada published AIC 18/07 which requires mandatory carriage of either DO-260 or DO-260A ADS-B out equipment over the Hudson Bay by November 2008.

A wide-scale implementation project is underway in the USA that includes ADS-B surveillance in both radar and non-radar airspace, as well as at the airport. In this context, the FAA published a Notice of Proposed Rulemaking (NPRM 29305) that will require mandatory carriage of ADS-B out equipment by all types of aircraft flying under IFR rules. For aircraft operating entirely below FL240, UAT is allowed instead of Mode S ES. For AT aircraft, DO-260A plus Changes 1 and 2 (at least) will be required. Early NRA implementation may allow DO-260.

The final rule is expected to be published in 2009 for mandatory carriage by 2020. Infrastructure expected to be in place by 2013.

4.6.3. Airborne traffic situational awareness

4.6.3.1. Enhanced traffic situational awareness on the airport surface (ATSA-SURF)

The NUP II+ project includes ADS-B operational tests at Stockholm-Arlanda airport in Sweden.
In autumn of 2007 tests on runway incursion services were performed. In these tests a SAS 737NG and various ground vehicles were involved. VDL-4 was used as the ADS-B medium. The Aircraft was equipped with a Rockwell-Collins VMMR and dual Electronic Flight Bags(EFB). Cautions and warnings were generated by algorithms internally in the EFB thus assuring their independency and were visually presented on the EFB in the trial aircraft. In the future cautions and warnings will be complemented by aural callouts. The results were very encouraging and confirmed that the service performed exactly as planned.

Mobiles equipped with ADS-B out/in and a CDTI/EFB on board will also be able to display all surrounding traffic via direct ADS-B complemented by TIS-B transmissions. One B737NG and two vehicles will initially be fully equipped during these trials. Plans are to equip additionally three SAS 737NG with VMMR and EFB.

RFG will begin work on ATSA-SURF in 2008.

4.6.3.2. In-trail procedure in procedural airspace (ATSA-ITP)

ATSA-ITP trials are conducted by EUROCONTROL CASCADE (CRISTAL ITP involves NATS, ISAVIA, Airbus and Alticode). Real time simulations have been conducted in

Shanwick, Reykjavik and Toulouse, some of them interconnecting ATC and aircraft simulators. Flight tests are expected by end of March 2008.

Air Services Australia has conducted simulations of ATC procedures associated with ITP, and is preparing ATSA-ITP operational evaluation flights and support for NASA. ICAO's Separation & Airspace Safety Panel (SASP) is currently considering ITP, including collision risk modelling by the Mathematics Sub Group (MSG).

4.6.3.3. Changes to maturity scores:

- ATSA-AIRB
  - Benefits and constraints increased from 1.0 to 2.5
  - Procedures and human factors increased from 3 to 4
  - Systems, HMI and technology increased from 3 to 4
- ATSA-SURF
  - Operational concept increased from 2 to 3
  - Benefits and constraints increased from 2 to 3
- ATSA-ITP
  - Operational concept increased from 3 to 3.5
  - Safety increased from 2.5 to 3.5
  - Systems, HMI and technology increased from 3 to 4
- ATSA-VSA
  - Systems, HMI and technology increased from 3 to 4

4.6.3.4. Summary

Certifications are on-going

4.6.3.5. Current implementation and plans

LFV conducted a live trial at Arlanda during the 4th quarter of 2006 to assess flight crew benefits of ATSA-SURF. The trial targeted one flight crew on the calibration aircraft. During these trials initial verification of a runway incursion detection algorithm where conducted with promising results. This functionality and the results provided valuable inputs to the large scale trials performed in 2007 under the NUP2+ program, concerning CDTI locations and flight deck procedures.
The 2007 trial included runway incursion services and further trials, also including taxi routing services, are planned to be completed in early 2008.
A SAS B737NG equipped with ADS-B and dual CDTI (EFB) installations is the aircraft used and, additionally, three Aircraft are planned to be equipped.

CRISTAL ATSA-ITP validation project has been launched. Validations on simulators have been performed under the umbrella of Eurocontrol CASCADE CRISTAL.

FAA granted UPS Operations Approval on December 28, 2007. The suite of ADS-B applications is marketed as SafeRoute. The suite consists of Flight Deck Merging and Spacing, CDTI Assisted Visual Separation and Surface Area Movement Management (SAMM)

The SAMM application provides a moving airport surface map with traffic in the cockpit, in late 2009 certification of an alerting feature to tell the flight crew that a runway is occupied or about to be occupied is planned.

Airbus has already taken the decision to launch ATSAW based on internal cost benefit analysis. ITP and VSA are the main drivers.

4.6.4. Airborne spacing

4.6.4.1. Sequencing and merging operations (ASPA-S&M)

CRISTAL Paris completed in 2007. CASCADE validation report concluded potential for this application high however important avionics changes and airspace redesign are required for significant benefits to be gained.

RFG target dates for ASPA S&M are yet to be defined, although ASPA S&M has been advanced as background task with a feasibility check in January 2008. CASCADE report does not expect EUROCAE/RTCA standard to be published before 2009.

FAA gave operational approval of merging and spacing to UPS at Louisville in Dec 2007

4.6.4.2. Enhanced crossing and passing operations (ASPA-C&P)

Results from controllers have not been positive – they are uncomfortable with responsibility for separation..

4.6.4.3. Changes to maturity scores

- ASPA-S&M
    - Operational concepts increased from 3 to 3.5
    - Benefits and constraints increased from 2.5 to 3.5
    - Safety assessment increased from 3 to 3.5
    - Systems, HMI & technology increased from 2.5 to 3.5
    - Transition issues increased from 2.5 to 3
- ASPA-C&P
    - No change

4.6.4.4. Summary

ASPA-S&M - A lot of activity has taken place. G2G; MITRE: Flight Deck based M&S; CRISTAL and PALOMA: S&M in Paris; Experiments on the impact of wind ASPA S&M; ASPA in TMA. Some good results have been achieved.

4.6.4.5. Current implementation and plans

UPS operations are tailored for a specific (US) environment and concept of operations; Europe needs to assess the application in its own real-life ATM context to draw the appropriate conclusions on implementation issues as well as operational applicability/usability. On the other hand UPS has mentionned the intention to implement M&S application in Europe in its hub in Koln. A first initial exchange of views has taken place between DFS and UPS. European Commission should sponsor the assessment of the application in its own real-life ATM local context, in order to benefit from all positive results achieved up to now in all EC sponsored projects and drawing appropriate conclusions on implementation issues as well as on operational applicability/usability

Future ASPA research should quantify the benefits in terms of capacity, efficiency and environment should address the inter-relationships with other TMA concepts (e.g. Continuous Descent Approaches and P-RNAV). On TMA related concepts, the EP3 project is planning two cycles of ASPA validation activities which are expected to provide final results by end of 2009.
Europe is missing an operational trial of S&M operation. Based on the UPS and MFF examples, we know it is achievable from a technical perspective.
Performance Based Navigation (RNAV RNAV and RNP) is an environment characteristic which needs to be accounted for.

4.6.5. Airborne separation

4.6.5.1. In-trail procedure (ASEP-ITP)

Studied during ASSTAR.

4.6.5.2. In-trail follow (ASEP-ITF)

. Studied during ASSTAR.

4.6.5.3. Sequencing and merging operations (ASEP-S&M)

The ASEP-S&M application is currently studied by EUROCONTROL-ADAS.

4.6.5.4. In-trail Merge (ASEP-ITM)

The ASEP-ITM application was proposed and studied in ASSTAR to enable the re-routing of aircraft to another oceanic exit point (within the Shanwick Oceanic Control Area), after 20 West, to reduce ATM complexity, and/or improve the remaining route towards the destination

4.6.5.5. Changes in maturity scores

- ASEP-LC&P
  - Benefits & constraints increased from 2 to 2.5
  - Safety increased from 1.5 to 2
  - Procedures & human factors increased from 1.5 to 2
- ASEP-VC&P
  - Operational concept increased from 0 to 1
- ASEP-ITP
  - Benefits & constraints increased from 2 to 2.5
  - Safety increased from 1.5 to 2
  - Procedures & human factors increased from 1.5 to 2
  - Systems, HMI & technology increased from 1.5 to 2
- ASEP-ITF
  - Benefits & constraints increased from 2 to 2.5
  - Safety increased from 1.5 to 2
  - Procedures & human factors increased from 1.5 to 2
- ASEP-S&M
  - Procedures & human factors increased from 1.0 to 2.0
  - Systems, HMI & technology increased from 1.0 to 2.0
- ASEP-ITM (New application)
  - Operational concept increased from 0 to 1.5
  - Benefits and constraints increased from 0 to 2
  - Safety assessment increased from 0 to 1.5
  - Procedures and human factors increased from 0 to 1

4.6.5.6. Critical path and blocking issues

ADAS Datalink User Group will be looking at developing application OSED for ASEP S&M and ASEP C&P that will include the analysis of use of data-link and (potentially) intent information

The critical path and blocking issues of ASEP applications relate to the transfer of responsibility, criticality of equipment, airborne separation etc. The EUROCONTROL SSATS domain addresses these issues in the near-term future through ADAS.

4.6.5.7. Current implementation and plans

EUROCONTROL/FAA Action Plan 23 (Advanced ASAS) activity is responsible for coordinating the identification of Package 2 applications. The work is done building on

CASCADE and RFG work on Package 1 applications and standards developed for initial ADS-B applications.

ASEP applications have also been identified within the scope of the SESAR Concept of Operations.

4.6.6. Airborne self-separation

4.6.6.1. Self-separation in segregated free flight airspace (SSEP-FFAS)

4.6.6.2. Self-separation in managed airspace (SSEP-MAS)

Quantitative assessment of single-year benefits conducted and life-cycle benefit/costs from detailed capacity/demand and controller workload models, Langley

Hazards/risks identified, safety design established, and validation simulations underway, Langley

4.6.6.3. Self-separation in an organised track system (SSEP-FFT)

The ASSTAR project tested this concept in fast-time and human-in-the-loop simulations, as well as by means of an extensive safety analysis.

4.6.6.4. Changes to maturity scores

- SSEP-FFAS
  - No change
- SSEP-MAS
  - No change
- SSEP-FFT
  - Benefits and constraints increased from 1 to 2
  - Safety increased from 1 to 2

4.6.6.5. Critical path and blocking issues

The main near-term benefits of the SSEP concept in general are expected in procedural environments. Since SSEP-FFAS and SSEP-MAS can obviously not be introduced immediately, a transition path towards these concepts is required. The SSEP-FFT is part of this transition path, and was studied and refined by the ASSTAR project needs to be studied in detail, both in simulations and in the safety case. Future work should further refine the operational concepts based on the outcome of the ASSTAR project.

The requirements for Airborne Self-Separation need to be defined in detail, particularly safety (integrity, continuity) and performance requirements, and their impact on existing standards and systems, such as the ADS-B link, need to be analysed. The standardisation and certification process is still in its infancy and significant interoperability work will need to be undertaken. The standardisation and approval of procedures and safety cases within the relevant ICAO groups and panels will also be required before SSEP activities can move out of the research domain.

Benefit analyses need to be performed in more depth, the use of SSEP applications have to deliver the needed capacity and efficiency benefits in the future ATM system. This includes analyses on exactly how SSEP applications can be integrated into 4D trajectory-based operations (ref. SESAR and NextGen Concept of Operations, reduced separation standards in NAT airspace), partial equipage, large number of traffic samples, opposite/crossing traffic in procedural airspace, interaction between procedural and radar/surveillance sectors, etc.

4.6.6.6. Current implementation and plans

Quantitative risk assessment of self-separation applications as performed in the HYBRIDGE project is further progressed within the iFLY project.

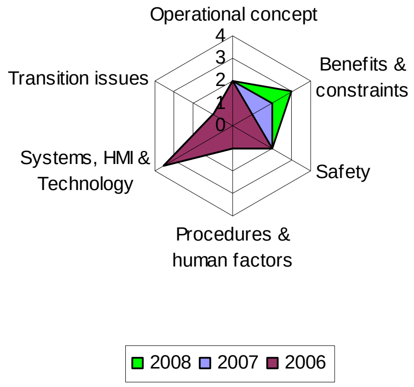
SSEP applications have also been identified within the scope of the SESAR Concept of Operations.

4.7. Graphical summary

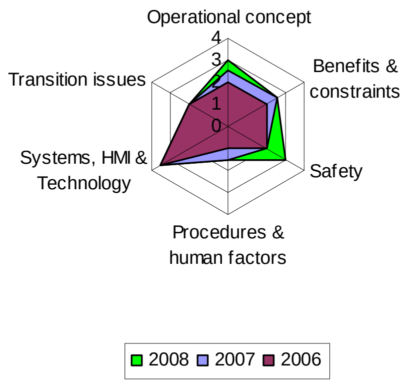
The following diagrams try to give an indication of the overall level of maturity of each application with respect to the six criteria selected for the assessment. The size of the shaded area does not necessarily reflect the readiness for deployment because all axes may not carry equal weight. The values for three consecutive years 2006-8 are shown on the same axes for comparison.

4.7.1. ADS-B surveillance

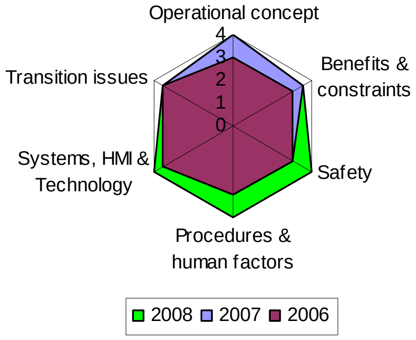
Airport surface surveillance
(ADS-B-APT)



ATC surveillance in radar airspace
(ADS-B-RAD)



ATC surveillance in non-radar areas
(ADS-B-NRA)



Aircraft derived data for ground tools
(ADS-B-ADD)

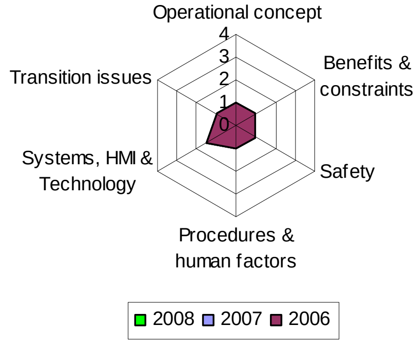


Figure 6: ADS-B surveillance applications maturity summary

4.7.2. Airborne traffic situational awareness

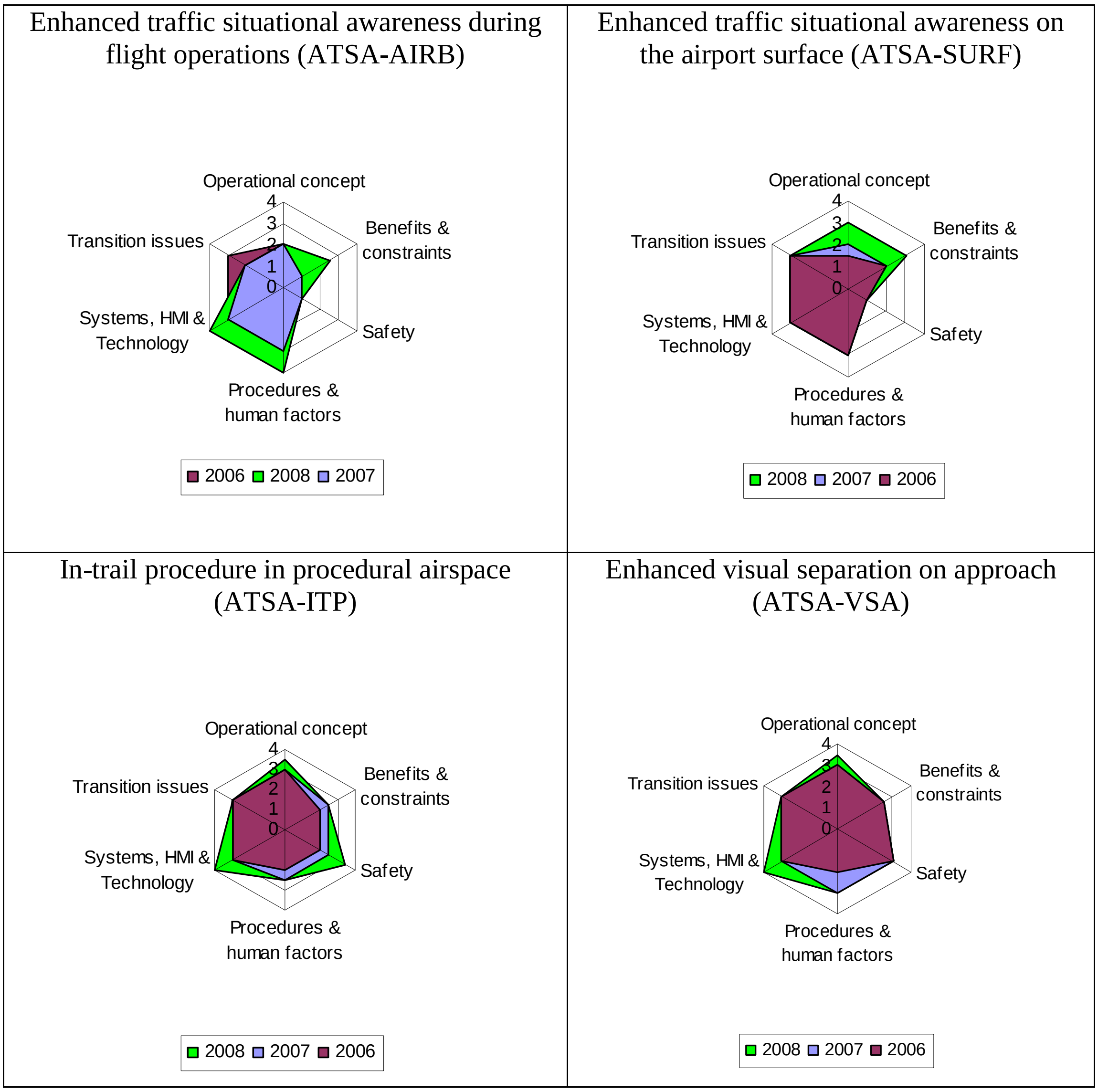


Figure 7: Airborne traffic situational awareness applications maturity summary

4.7.3. Airborne spacing

Sequencing and merging (ASPA-S&M)	Enhanced crossing and passing (ASPA-C&P)

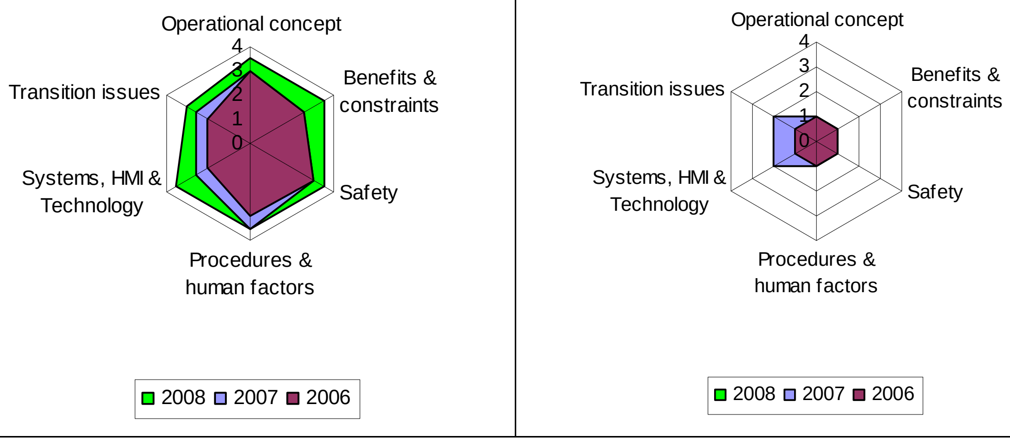
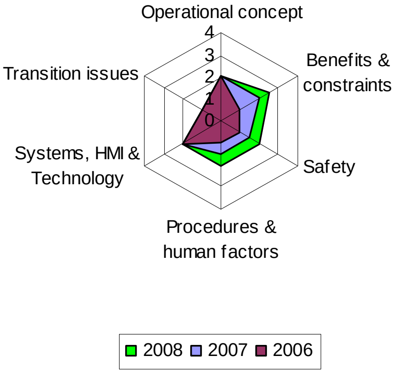


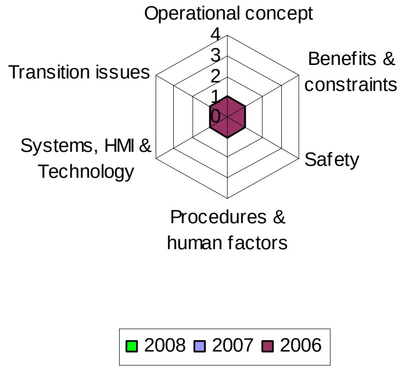
Figure 8: Airborne spacing applications maturity summary

4.7.4. Airborne separation

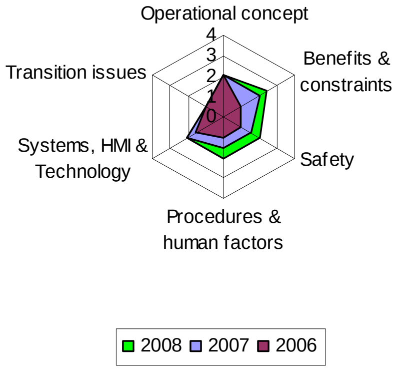
Lateral crossing and passing
(ASEP-LC&P)



Vertical crossing and passing
(ASEP-VC&P)



In-trail procedure
(ASEP-ITP)



In-trail follow
(ASEP-ITF)

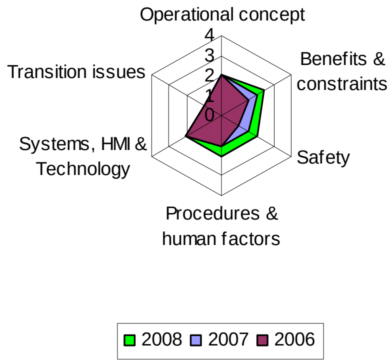


Figure 9: Airborne separation applications maturity summary

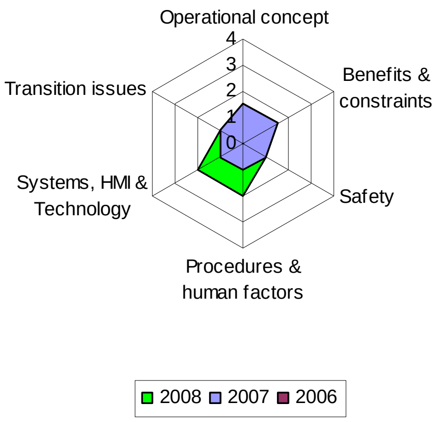
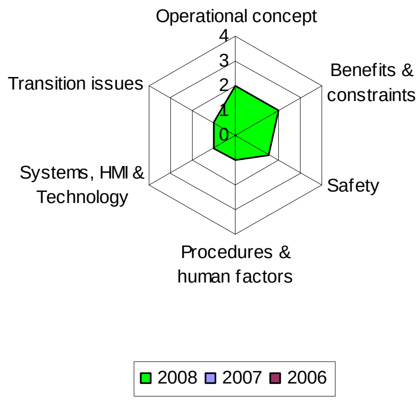
Sequencing and Merging (ASEP-S&M)	In trail Merge (ASEP-ITM)
	

Figure 10 Airborne separation applications maturity summary (2)

4.7.5. Airborne self-separation

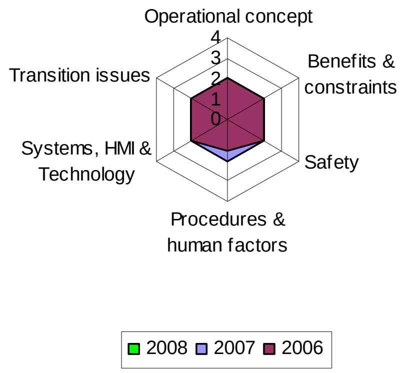
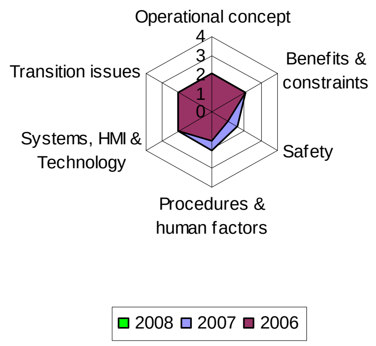
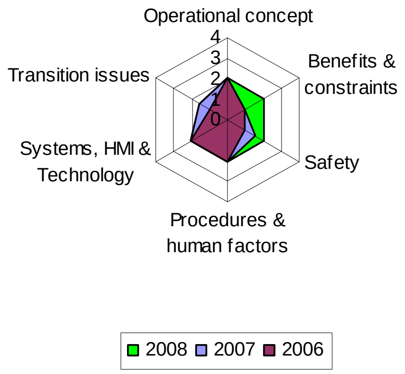
Self-separation in segregated free flight airspace (SSEP-FFAS)	Self-separation in managed airspace (SSEP-MAS)
	
Self-separation in an organised track system (SSEP-FFT)	
	

Figure 11 Airborne self-separation applications maturity summary

4.7.6. Trend over three year period 2006-8

Figure 12 gives an overview of the total maturity score of each application per year over the period from March 2006 to February 2008. The applications are grouped by surveillance and ASAS categories. The order corresponds to increasing on-board functionality with which can be seen a trend of decreasing maturity. The relatively high initial self-separation scores can perhaps be explained by the free flight research initiatives in the US and Europe during the previous decade with separation category applications catching up more recently.

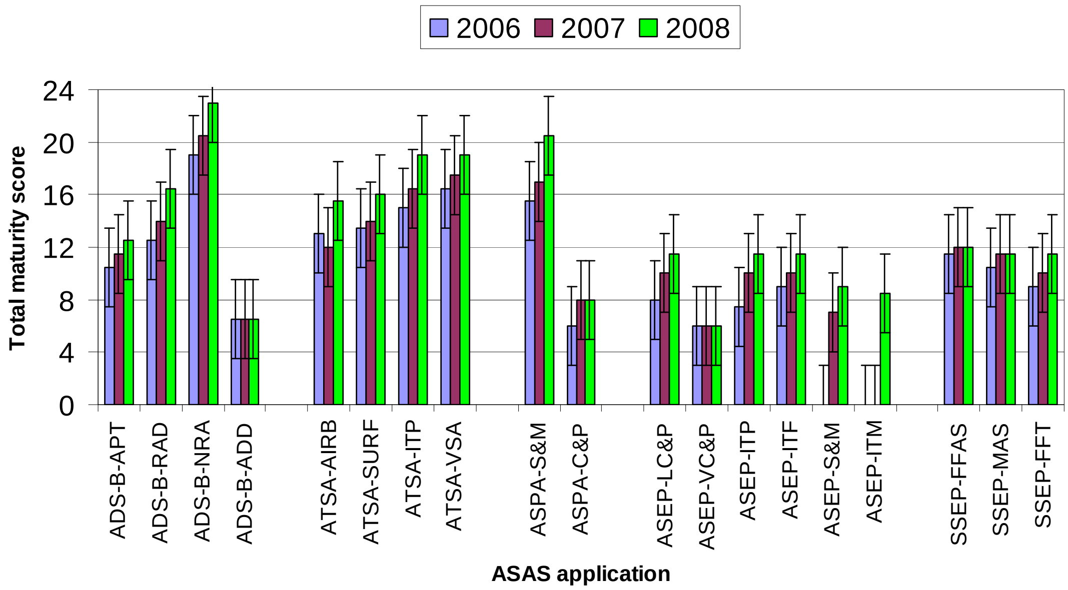


Figure 12 Total maturity score per application for each of the three years

5. Conclusion

In the period October 2006 to January 2008, the percentage of European flights sampled that are Mode-S equipped increased from 95.3 % to 97.0 %. ADS-B Extended Squitter indicated capability as percentage of Mode-S equipped flights increased from 57.3% to 78.3%.

This assessment indicates that one of the most mature applications is ‘ATC surveillance in non-radar areas’ with a total score of 23.0 out of a possible 24. The airborne traffic situational awareness applications ‘In-trail procedure in procedural airspace’ and ‘Enhanced visual separation on approach’, and the Airborne spacing application ‘Sequencing and merging’ also seem to have made progress with total scores of 19 and above. The applications judged to be relatively immature are ‘Aircraft derived data for ground tools’ (ADS-B surveillance category) and ‘Vertical crossing and passing’ (Airborne separation category) with total scores less than 7.

Over the year from March 2007 to February 2008 the maturity scores of fourteen out of nineteen applications increased (compared with fifteen the previous year) including a new application In-trail Merge (Airborne separation category). ‘Sequencing and merging’ (Airborne spacing category) showed the greatest annual change in total score from 17 to 20.5 after FAA gave UPS/ACSS operational approval in December 2007.

Over the two year period from March 2006 to February 2008 the maturity scores of seventeen out of nineteen applications increased. The total maturity score of the airborne spacing application ‘sequencing and merging’ increased the most over the two year period going from 15.5 to 20.5. The two applications’ with the lowest scores also matured at the slowest rate over the two year period: Aircraft derived data for ground tools’ (ADS-B surveillance category) and ‘Vertical crossing and passing’ (Airborne spacing category) did not change maturity score. The lack of change in score of Aircraft derived data for ground tools over the two year period implies the application needs to be revisited in the context of SESAR and NextGen.

6. References

ASAS related projects used for this review
3FMS (http://www.cordis.lu/)
AATT/DAG-TM (http://www.asc.nasa.gov/aatt/dag.html)
ADAS (website under development)
ASSTAR (www.asstar.org/index.111206.php)
Australian UAP (Upper Airspace Program)
(http://www.airservicesaustralia.com/pilotcentre/projects/adsb/adsbuap.asp)
CARE/ASAS (www.eurocontrol.int/care-asas/public/subsite_homepage/homepage.html)
CASCADE Stream 1&2/Cristals (Validation report, v1.0, 11th Jan 2008)
(http://www.eurocontrol.int/cascade/public/subsite_homepage/homepage.html)
C-ATM (http://www.c-atm.com/)
COSPACE (http://www.eurocontrol.int/eec/public/standard_page/SSP_cospace.html)
DADI II (http://icadc.cordis.lu/)
EASA regulation development (http://www.easa.eu.int/home/)
EFAS Environmentally Friendly Airport System
EMERALD (http://www.cordis.lu/transport/src/emerald.htm)
EMERTA (http://www.cordis.lu/transport/src/48320.htm)
EMMA (http://www.dlr.de/emma)
FAA Safe Flight 21 (www.faa.gov/safeflight21) including Capstone (Alaska) and Gulf of Mexico
FALBALA (http://www.eurocontrol.int/care-asas/public/subsite_homepage/homepage.html)
FlySAFE (http://www.eu-flysafe.org/)
FREER (www.eurocontrol.int/eec/public/standard_page/SSP_cospace)
http://www.g2g.isdefe.es/
HYBRIDGE (hosted.nlr.nl/public/hosted-sites/hybridge)G2G (http://www.g2g.isdefe.es/)
ICAO standards development (e.g.ASAS SG)
iFly Sefety, Complexity and Responsibility based design and validation of highly automated Air Traffic Management
INTENT (www.intentproject.org)
ISAWARE II (http://www.isaware.org/home.htm)
MA-AFAS (www.ma-afas.com)
DMA Dynamic Multi-track Airways
MEDUP (http://www.adsmedup.it/)
MFF (www.medff.it)
NASA Glenn Research Center
(http://acast.grc.nasa.gov/resources/documents/Benefits_Assessment_Red_Sep_NAtlantic_OTS_Final_Report_2005Oct3.pdf
NASA Langley/Ames (www.asc.nasa.gov/aatt/dag)
NLR/NASA Free Flight (hosted.nlr.nl/public/hosted-sites/freeflight)
NUP - OPERATIONAL ENVIRONMENT DEFINITION (OED) Pilot Delegated In-Trail Procedure (ITP) in Non- Radar Oceanic Airspace, REY_NUP_WP8_OED_1, 07/01/01
NUP - OPERATIONAL ENVIRONMENT DEFINITION (OED) Delegated Airborne Separation Approach and Climb-Out Stockholm-Arlanda, SAS_NUP_WP2_OED2DAS, 01/03/30.
NUP - OPERATIONAL ENVIRONMENT DEFINITION (OED) Delegated Airborne Separation Cluster Control (DAS-CC) En-Route Maastricht UAC, MAAS_NUP_WP2_OED5, 2000/08/30.
NUP2, NUP2+ (www.nup.nu)
RFG (http://www.eurocontrol.int/cascade/public/subsite_homepage/homepage.html)
RTCA SC 186 (www.rtca.org)
SEAP (http://www.ads-seap.com)