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Air Traffic Management (ATM) and the use of Airborne Separation Assistance Systems (ASAS) for Fuel Efficiency and Reduced Emissions

by
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1 Introduction

Airborne Separation Assistance Systems (ASAS) applications have the potential to improve the efficiency of flight operations by allowing air crew to take a more active part in the tactical aspects of Air Traffic Management (ATM). Many studies, simulations and trials indicate that fuel can be saved, with corresponding reductions in emissions and noise, while at the same time increasing the overall capacity of the system. And some 'early' ASAS applications are just beginning to be introduced into operational service.

This short outline describes the main features of the SESAR Concept of Operations (ConOps) for European ATM to show how ASAS will be integrated into the future ATM environment. It then goes on to describe ASAS, the use of some of its applications and initial results. It ends by presenting some ideas for changes to the operating methods on long oceanic routes.

The information in sections 2 to 9 on the SESAR Concept of Operations comes from the work done by EUROCONTROL and the SESAR Consortium. The information in sections 10 to 15 on ASAS comes from the various presentations made at the European Commission's ASAS Thematic Network workshops, in particular from the EUROCONTROL Experimental Centre, Airbus, Boeing, the FAA, NASA, NLR, ACSS, UPS and the EC's 6th Framework Programmes – the ASSTAR Consortium and the FLYSAFE Consortium.

2 The SESAR Concept of Operations for European ATM

The SESAR Concept of Operations is a trajectory based system, having seven major features, the first two of which are a necessary foundation for the others:-

1. A System Wide Information Management (SWIM) network to support all major processes.
2. Collaborative Decision Making (CDM) to define a rolling Network Operations Plan (NOP), and to negotiate trajectory changes.
3. Airports fully integrated into the ATM network.
4. Aircraft and ATM system "ATM Capability Levels".
5. A Trajectory Managed environment rather than one that is based on Airspace Management.
6. Extensive use of automation support to reduce controller task load, but in which controllers remain in control and manage the overall system.
7. New separation modes to take advantage of airborne surveillance and advanced aircraft navigation capabilities and to allow tasks to be delegated to pilots so as to further reduce controller task load.

The essence of the system is to use precise 4D trajectory data, combined with cockpit displays of surrounding traffic:- (a) to improve predictability throughout the whole ATM system; (b) to increase capacity, productivity and safety; (c) to save fuel and to reduce environmental noise and emissions; and (d) to share tasks and increase the situational awareness of pilots and controllers.

These features are very similar to those being developed in the USA for their NextGen system. Therefore, not only will interoperability be assured, but it may also be possible to achieve economies of scale.

Finally, the SESAR ConOps is compatible in all respects with the ICAO Global Air Traffic Management Operational Concept, as described in Doc 9854 AN/458, and represents the concrete application of this global concept, adapted and interpreted for Europe with due regard to the need to be globally interoperable.

3 System Wide Information Management (SWIM)

SWIM is fundamental to the whole SESAR ConOps. Without SWIM SESAR will not work. The SWIM network will be an IP based data transport network, using proven information communication technology. It will replace the current point to point data systems with net-centric communications connecting all ATM partners; Air Navigation Service Providers (ANSPs), airports and airspace users, including the military. Aircraft will become travelling nodes in the network, permanently connected by a new high capacity air/ground data link.

Using the SWIM network, all partners (in the air and on the ground) will become both consumers and producers of information, which they will share, tailored to their individual needs. This will allow them to make decisions based on full knowledge of accurate up-to-date information and to put back into the system the results of their decisions for others to use.

The technology itself is reasonably mature. However, all partners in the SWIM network will need to adapt their behaviour to the new environment. The focus will shift from the producer of information to the information itself, with generalised access enabling users to create their own applications which best suit their mission needs. They will need to agree on the level of interoperability required and to agree the rules, roles and responsibilities of information sharing. These are important since they determine which kind of information is shared by whom, with whom, where, when, why, how much, how often, at which quality level, in what form, for which purpose, at what cost, under what liability, under which circumstances and which security levels.

The benefits are considered to be substantial, not only in terms of improved decisions but also in unifying working methods across the whole European ATM network, with consequential improvements in efficiency.

4 Collaborative Decision Making (CDM)

CDM is already used at a number of European airports. In SESAR this method of decision making will not be confined only to airports but will be further developed and spread throughout the network. It needs to cover the sharing of information related to the progress of flights (on the ground and in the air) and the actions taken on this information. It is not a separate part of the ATM network, it is a method of working which is applicable to most decision making aspects of the ATM operational concept.

The process is iterative but can be thought of as beginning when the airspace users define and then share, with ATM partners, their business/mission intentions. These trajectories are then modified as necessary using a layered CDM planning process which takes account of identified constraints. The ATM planning process is one of continuous refinement as better data becomes available. There is no clearly defined starting point to the process; it starts many years before the day of operation, taking into account such considerations as staff recruitment, training plans and major system procurements. The goal of collaborative layered planning is to balance ATM resources and airspace user demand.

In the months leading up to the initiation of the flight the iterative planning process refines the trajectories and the available resources and expresses these as the Network Operations Plan (NOP). The NOP is a rolling plan giving a snapshot of the network at any one time. The aim of the NOP is to facilitate the processes needed to reach agreements on demand and capacity. This planning is overseen by a Network Management function which assures, at both network and regional level, the stability and efficiency of the ATM network.

The final trajectory just before flight execution is called the Reference Business Trajectory (RBT), the word 'business' being used to show that it is not only a 4D trajectory but that it also expresses the business intention of the airspace user, or mission intention in the case of the military. Depending on the ATM Capability Level (see section 6) it is expressed in up to 4 dimensions, and is the trajectory which the airspace user agrees to fly and the ANSP and airport agrees to facilitate.

The features described in sections 3 and 4 above on SWIM and CDM provide the essential system environment in which the following processes can deliver the benefits defined in the SESAR goals.

5 Airports

Airports are a complete subject in themselves and are not covered in any detail in this paper. However, in SESAR, airports are fully integrated into the ATM network as nodes in the system. CDM will be used to ensure a seamless process over the entire planning spectrum, and will be used between airspace users, ANSPs and airports (using enhanced arrival, departure and surface management tools) to assist queue management so as to make best use of all available runway capacity.

Runway throughput will be increased by reducing occupancy times, reducing arrival and departure spacing, through improved wake vortex prediction systems and improved surface movement guidance systems. Safety will be enhanced by using cockpit displays giving complete situational awareness on and in the vicinity of the airport surface and allowing warnings to be provided directly to the flight crew rather than through the intermediary of a controller.

It is expected that the combination of Trajectory Management, Airborne Spacing tools and precision navigation techniques will reduce air and ground holding and enable Continuous Descent Approaches (CDAs) thus leading to reduced noise and environmental emissions per flight as specified in the SESAR goals.

6 ATM Capability Levels

ATM Capability Levels are defined to describe the on-going deployment of progressively more advanced ATM systems for aircraft, ground systems and airports. Their purpose is to ensure the synchronisation of cost effective system enhancements in the air and on the ground and between ground systems.

The following different levels of ATM capabilities are defined:-

ATM Capability Level 0:	Legacy systems that do not meet at least the ATM-1 capabilities.
ATM Capability Level 1:	Capabilities of existing systems and those delivered up to 2012/2013, having largely "today's capabilities".

ATM Capability Level 2:	Capabilities of systems delivered and in-service from 2013, having a range of new capabilities but which do not fully meet the 2020 needs.
ATM Capability Level 3:	Main capabilities required by the key SESAR target date of 2020. These will be based upon the SESAR concept needs at the time and a realistic assessment of potential capabilities.
ATM Capability Level 4:	The very advanced capabilities that potentially offer the means to achieve the SESAR goals, in particular the very high-end capacity target. The timeframe for initial availability and progressive equipage is in the range 2025+.

It should be noted that in the later Deliverables of the SESAR Definition Phase these 4 aircraft ATM Capability Levels were expanded into 6 Capability Levels, together with 6 ATM service Levels. This was done to give more precise detail to the proposed implementation steps, but the principle remains the same.

7 Trajectory Management

The collaborative planning process described in section 3 on CDM terminates when the Reference Business Trajectory (RBT) is published. When published, the RBT does not represent a clearance but is the goal to be achieved and which will be progressively authorised, either as a clearance by the ANSP or as a function of aircraft crew/systems, depending on whether the ANSP or the flight crew is the designated separator.

The RBT is defined by the airline's Flight Operations Centre (FOC) flight planning system. Trajectories may also be defined by handing agents or pilots on behalf of smaller airlines, business aviation and general aviation flights, or by the ANSP if required (e.g. on behalf of the military). The essential point for ATM is that, instead of having several versions of the trajectory in the system, there is a unique accurate trajectory for each flight that is used throughout the entire ATM network.

Until the aircraft is airborne, available 4D trajectory data retain a level of uncertainty that limits their use for purposes other than planning. Once aircraft are airborne, trajectories attain high precision also in the time dimension, and are continuously shared and available via the NOP. Non-time critical trajectory changes are made through CDM – constraints arising for any reason (other flights, airspace reservations, etc.) are published via the NOP, with the airspace user adjusting the trajectory to comply in a way that best suits the user's operational and business needs. However, it must be emphasised that this does not prevent controllers and pilots making time critical changes as required.

Unique 4D trajectories permit a number of very significant advantages:-

1. They reduce the uncertainty which in turn reduces the number of conflicts/interactions that need to be resolved.
2. When combined with improved navigation performance (vertical, lateral and in time), they reduce the amount of 'unusable' airspace around each aircraft thus allowing more aircraft in the airspace.
3. They are a source of accurate data which can be used by automated controller support tools.
4. They redefine the need for many airspace structures which currently restrict the efficiency of flight paths, both laterally and vertically.

8 Automation Support

The main constraint to airspace capacity is controller task load. Therefore in order to increase capacity there must be a substantial reduction of controller task load per flight, while also meeting the SESAR safety, environmental and economic goals. Controller task load is generated from two different sources:- (i) the routine task load associated with managing a flight through a sector (such as coordination in and out, routine communications, data management), and (ii) the tactical task load associated with separation provision (situation monitoring, conflict/interaction detection, and conflict resolution). As the traffic throughput increases the routine task load increases proportionally (three times the flights equals three times the task load). The separation provision task load, however, increases relative to the number of conflicts/interactions, approximately according to the square of the increase in traffic (three times the flights equals nine times the task load).

To address the controller task load issue, without incurring a significant increase in ANSP costs, three lines of action are included in the concept:-

1. Automation for the routine controller task load supported by better methods of data input and data management.
2. Automation support to situation monitoring, conflict/interaction detection, and conflict resolution.
3. A significant reduction in the need for controller tactical intervention, by (a) reducing the number of potential conflicts using a range of de-confliction methods, and (b) redistributing the tactical interventions to the pilots.

This will require an intense enhancement of integrated automation support while human operators are expected to remain at the core of the system. Humans will need to remain in command as overall system managers, but using automated systems possessing the required degree of integrity and redundancy.

9 New Separation Modes

As a further means of reducing controller task load new separation modes are introduced within the SESAR concept. Separation modes fall into three broad categories:-

1. Conventional Modes:- those that are essentially unchanged by SESAR.
2. New ANSP Separation Modes:- new modes that are applied purely by ATC that involve Precision Trajectory Clearances (PTC).
3. New Airborne Separation Modes:- new modes that involve the aircraft and in which the pilot is the separator either by delegation or as the standard case.

Precision Trajectory Clearances (PTC) can either be (i) on 2D routes (with lateral containment), (ii) on 3D routes (with lateral and vertical containment), (iii) through trajectory control by ground based speed adjustments, or (iv) through 4D contracts which prescribe the containment of the trajectory in all 4 dimensions for the period of the contract. The purpose of each of these is to reduce substantially the uncertainty of the predicted aircraft position and thus reduce the number of potential conflicts/interactions that need to be resolved by the controller.

New Airborne Separation Modes use airborne systems to allow spacing and separation tasks to be delegated to the pilots. Three basic stages are envisaged; (i) pilots are required to identify a specified aircraft and maintain the designated spacing from it, (ii) pilots are required to identify a specified aircraft and to separate themselves from it, and (iii) pilots accept responsibility to self separate from all other aircraft in the vicinity. The periods and circumstances of such delegations will need to be clearly defined, together with clear unambiguous procedures for their use.

10 ASAS Applications

There are four broad categories of ASAS applications:-

1. Situational Awareness:- where traffic information is displayed on a Cockpit Display of Traffic Information (CDTI) to supplement verbal traffic information and out of the window visual scans.
2. Spacing:- where the controller can instruct flight crews to establish and maintain a given time or distance in trail from a designated aircraft.
3. Separation:- where responsibility for separation is delegated to the flight crew to remain clear of a designated aircraft (limited in time and scope). ATC retains responsibility for the separation of all other aircraft.
4. Self Separation:- where flight crews are allowed to select the trajectory freely in real-time and are responsible for conflict management. This is likely to be applied for particular portions of the flight only.

Several 'early' applications, becoming available in 2013, are envisaged in the SESAR ConOps. Among them are Sequencing and Merging (ASPA-S&M), Situational Awareness on the airport surface (ATSA-SURF), and In Trail Procedures in non-radar oceanic airspace (ATSA-ITP). These are discussed below in sections 11, 12 and 13 respectively. More details of these and the other more advanced applications can be found on the ASAS Thematic Network website (www.asas-tn.org).

It should be noted that in the USA ASPA-S&M uses the same algorithms as in Europe but is called Flight Deck Merging and Spacing (FDMS), an ATSA-SURF application is available but is called Surface Area Movement Management (SAMM) and visual separation is enhanced by CDTI Assisted Visual Separation (CAVS).

The more advanced applications such as Self-Separation (SSEP) will require systems having high levels of accuracy, integrity and reliability. However, oceanic airspace with its relatively low density of traffic, might offer an ideal opportunity for introducing SSEP above certain flight levels (see section 14). This could then enable the use of cruise climb procedures which, so far, have been confined to those aircraft operating at very high altitude, e.g. Concorde and some military operations.

11 ASAS Sequencing and Merging

The Sequencing and Merging application (ASPA-S&M) is designed to be used in the Terminal Area (TMA) during the descent and final approach to the runway. The objective is to redistribute tasks related to sequencing (e.g. in-trail following) and merging of traffic between controllers and the flight crews. The controllers instruct the flight crews to establish and maintain a given time or distance in trail from a designated aircraft. The flight crews perform these new tasks using a suitable human-machine interface.

The aircraft equipment consists of Automatic Dependent Surveillance-Broadcast (ADS-B) to broadcast identification, position, velocity and intent information and to receive this same information from other aircraft. This information is then processed and displayed on a Cockpit Display of Traffic Information (CDTI). The applications can either be integrated into the aircraft's avionics and the display combined with the pilot's Primary Navigation Display or they can be kept completely separate and housed and displayed in Electronic Flight Bags (EFBs), a cheaper and easier way to retrofit aircraft.

Real and fast time simulation results completed by the EUROCONTROL Experimental Centre (EEC), based on the Paris TMA, and using active controllers and line pilots, indicate several potential benefits:-

1. ASAS resulted in more consistent spacing on final approach leading to approximately 2 more movements per hour.
2. The underlying new route construct enabling airborne spacing also reduced fuel consumption by enabling Continuous Descent Approaches (CDAs) without loss of capacity.
3. The number of R/T instructions was reduced which translates into a reduction of workload for both pilots and controllers

The freight and parcel airline, UPS, has been pioneering a similar system at Louisville, Kentucky, using EFBs developed by Aviation Communications & Surveillance Systems (ACSS). UPS has the advantage of dominating operations at Louisville thus making it relatively straightforward for them to conduct operational trials. They started by performing CDA flight trials in 2004 using B757s equipped with ADS-B and a first generation CDTI. The results obtained showed a reduction of fuel burn of between 250 and 465 lbs per flight, a 30% reduction of noise (up to 6 dB), and a 34% reduction of nitrous oxide emissions. They now have five B757s (and one in Europe) certificated and fitted with the ACSS SafeRoute system (CDTI, FDMS, SAMM and CAVs), and five B767s fitted but awaiting certification (expected end of November). They have conducted 84 CDA/M&S operations (with one lead aircraft and one or two in-trail aircraft) since January 2008. They are also targeting early 2009 for similar trials in Cologne.

For UPS to obtain full benefits, the aircraft systems have to be used in conjunction with an Airline Based En-Route Sequencing and Spacing (ABESS) system to set up the arrival sequence and initial spacing. In Europe, SESAR envisages the use of enhanced Arrival Management (AMAN) systems to do the same which will need to work seamlessly across multiple ANSPs. In each case Controlled Times of Arrival (CTAs) would be issued requiring aircraft to arrive over a suitable inbound fix at the required times, before using the ASAS equipment to merge behind and then maintain relative spacing to touch down.

12 Situational Awareness on the airport surface

Enhanced traffic situational awareness on the airport surface (ATSA-SURF) provides the flight crew with information on the surface traffic that supplements normal out of 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.

As with ASPA-S&M in section 11 above, it requires ADS-B (in and out) and a CDTI display, either integrated into the aircraft's avionics or separate in EFBs. Own position, other aircraft and ground vehicles can all be displayed on an airport moving map. However, with such small distances involved (e.g. between aircraft on adjacent taxiways and/or runways) position accuracy, integrity and system latency must all be of a very high order. The FLYSAFE Consortium consider that, as the system is developed, it will provide a natural interface on which to build advanced functions such as active runway labels, taxiway and runway closures, alerts of conflicting traffic, visualisation of taxi instructions, and runway incursion alerting. However, these will not be easy to certificate and it will be necessary to devise clear and unambiguous procedures for flight crews and controllers to follow.

Runway incursions are a real hazard. In the 21 EUROCONTROL reporting states (and it is important to note that not all EUROCONTROL states report incidents properly) high risk runway incursions are running at a rate of over 1 per week. The rate is similar in the USA, where the Commercial Aviation Safety Team (CAST) has stated that 95% of all runway incursions could be prevented by having a cockpit moving map display showing other traffic and vehicles, automatic runway occupancy alerting and digital data-linked clearances that are then displayed on the moving map.

UPS, in the ACSS SafeRoute system installed in EFBs, already has in operational service a Surface Area Movement Management (SAMM) system which shows own aircraft position in relation to the terminal area, the airport surface, ground traffic and airborne traffic. In the near future they intend also to have visual and aural alerts and clearances with automatic runway occupancy alerting and positive runway selection and identification. The FAA is funding a project at Philadelphia in which 20 Airbus A330s belonging to US Airways will be fitted with the ACSS system so that they can develop Operational Performance Assessments and Operational Safety Assessments for Conflict Alerting and Indication. Philadelphia is also used by UPS therefore there will be a 'target rich' environment, ideal for these tests.

The efficiency and capacity of airport surface operations are closely linked with safety. If, as is expected, the runway becomes the ultimate bottleneck limiting the overall capacity of the ATM system, and if runway throughput is increased using the various enhancements listed in the SESAR ConOps, additional safety systems will be required. ATSA-SURF would appear to be an ideal candidate since there is good reason to believe that it could increase safety as stated above, it is relatively easy to add it to the suite of ASAS applications already being developed, and it is likely that it will also ease congestion (and possibly reduce fuel burn) by facilitating ground manoeuvring.

13 In Trail Procedures in non-radar oceanic airspace

In Trail Procedures (ITP) have been developed to allow aircraft to climb through the altitude of a 'blocking' aircraft using a distance based longitudinal separation minimum with the blocking aircraft during the manoeuvre. 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.

The operational procedures have been developed on both sides of the Atlantic. In the USA NASA and the FAA have been developing these procedures for use in the Pacific, while in Europe they have been worked on using Airbus facilities in Toulouse, NATS in Prestwick, and ISAVIA in Reykjavik. All these activities have been coordinated and standardised through ICAO. On 26 March 2008 they were successfully tested in the Reykjavik FIR by Airbus using an A340 test aircraft to 'climb through' the altitude of a blocking SAS aircraft which was on a normal trans-Atlantic revenue flight. The benefits have been assessed by the UK National Air Traffic Service (NATS) using the North Atlantic Simulation Model (NATSIM) assuming varying levels of equipage and traffic growth. Actual traffic samples for representative periods in 2007 were grown, in accordance with NATS traffic projections, for the years 2010, 2015 and 2020.

They first established a base line, modelled on today's operation in which aircraft enter N. Atlantic airspace at a compromise level and maintain this, with only around 6% achieving step-climbs. Fast time simulations were then used to generate two sets of results for each year mentioned above. The first set was based on aircraft entering at the compromise level, requesting step-climbs more frequently through the use of the CDTI, and being able to use the ITP climb-through procedure. The second set was based on aircraft entering the oceanic airspace at the optimum level and being able to step-climb so as to follow the optimum step-climb profile. Allowance was also made for the fact that this would benefit operations before and after the portion of the flight in N. Atlantic airspace. Then, for each of the chosen years, a comparison was made.

Using the traffic sample for the final year 2020, the simulations showed that the maximum benefit for those aircraft requesting optimum step-climbs was:-

1. With 95% of aircraft ADS-B Out equipped, 70% of these ITP enabled, and 75% of these requesting step-climbs, the number of step-climbs achieved in N. Atlantic airspace increased by 607% with a reduction in fuel burn of 0.62%.
2. With 100% of aircraft ADS-B Out and assuming the ideal situation of 100% ITP enabled and 100% requesting step-climbs, the number of step-climbs achieved increased by 1,107% with a reduction of fuel burn of 0.99%, and a corresponding reduction of CO_2 emissions.

14 Self Separation, User Preferred Routes and Cruise Climb in all oceanic airspace

The ultimate fuel optimised flight requires (i) the aircraft to fly at the optimum economy cruise speed, (ii) to be planned on an optimum trajectory both laterally and vertically to take best advantage of the prevailing winds and temperatures, and (iii) to combine this with a cruise climb as the fuel is burnt and the aircraft's weight reduces. Currently, most flights can only approximate to this as (a) the route is often constrained by airspace structures, fixed routes and organised track structures, (b) conflicts with other aircraft may require tactical adjustments to ensure separation, and (c) to simplify and make possible the separation task for ATC it is necessary to do a series of step-climbs which 'bracket' the optimum cruise climb profile.

The trajectory based ATM systems proposed by SESAR in Europe and by NextGen in the USA will overcome many of these problems; however, there still remain two main obstacles to achieving the most fuel efficient cruising flight. These are the lack of a true cruise climb mode in the aircraft's FMS, and the inability of ATC to facilitate cruise climb without blocking off large bands of airspace. Although most FMS have what is called a 'cruise climb' mode it is in fact a climb between two cruise levels performed at ECON speed using climb thrust and VNAV speed, achieved through a combined use of the autopilot mode control panel and FMS. The manufacturers do not offer a true cruise climb mode because airlines do not ask for it for the simple reason that ATC cannot handle it in normal operations.

As has been said, cruise climb, using current ATM methods, requires bands of altitude to be blocked off in which the aircraft can drift slowly upwards as fuel is burnt and weight reduced. But this is an inefficient use of airspace when a number of aircraft are involved and would cause a large reduction of precious airspace capacity. Concorde was able to use a cruise climb mode because there were hardly any other aircraft operating above 50,000ft. The basic parameters were to use maximum continuous power and the autopilot Mach Hold mode giving a constant Mach No. (except when limited by skin temperature), with the aircraft gradually drifting up, but also sometimes down depending on ambient temperature.

Boeing proposed a cruise climb regime when they were doing the initial development work on the Sonic Cruiser because it was intended to cruise above FL 410. Dassault Aviation and the business jet community would like to do the same because most business jets can climb from take-off straight to FL 410.

At these altitudes there are very few aircraft and ATC can easily block off altitudes above and below the flight path along the route. But as traffic levels rise this would be impossible. However, with ASAS Self Separation conflicts could be resolved laterally, with negligible deviation from optimum regardless of whether or not the aircraft was drifting up or down, thus enabling large numbers of aircraft to be accommodated in the airspace while cruise climbing.

NLR in Amsterdam, and NASA in the USA, have both been working on Self Separation techniques. NLR developed their system in order to break through the 'capacity barrier' that limits the capacity of the current ATM system in dense airspace. Currently the tactical controller is the 'single channel' separator. In this situation, the number of conflicts/interactions that the controller has to identify and resolve increases according to the square of the increase of traffic (three times the flights equals nine times the task load). However, in a distributed system, where separation responsibility is delegated to the pilots, the relationship is linear (three times the flights equals three times the task load). Clearly to certificate such a system will be difficult as it will require high levels of accuracy, integrity and reliability.

Equally, there are many who doubt that such a system would be operationally acceptable. NLR have tested this by running a number of simulations in the Maastricht area with three times the current traffic, using line pilots to test the human/machine interface, to develop procedures and to test workload and acceptability. The results have been very satisfactory, with the system and procedures being easy to use, and the overall workload acceptable. The slight increase in workload from the separation task is offset by the reduction in R/T messages.

The author has flown these simulations several times flying at altitude towards Frankfurt and, again, while descending into Amsterdam. It is easy to learn how to use the system, the flight displays are intuitive and the procedures straightforward.

Depending on the mix of routes, NASA estimates that around 30% of a US domestic airline's total annual fuel consumption occurs on oceanic flights. It is probable that the proportion is similar for other airlines having a mixed route structure. US (and Asia/Pacific) airlines are particularly interested in the long routes across the Pacific, many of which are payload/range limited. For example, on the South Pacific SOPAC routes between Australia and the US West Coast aircraft are usually operating at maximum gross take-off weight, therefore any increase in the fuel requirement has to be offset by reducing payload. Equally, if the airline knows that it can rely on always obtaining efficient cruising levels, contingency fuel can be reduced and a higher payload sold to customers. The necessity reliably to obtain and operate at the most efficient series of cruise levels is the driver for the current work to introduce the ITP climb procedures described in section 13.

But there is a further step that could be taken with advantage on all oceanic routes. This paper proposes that the aim should be to introduce Self Separation in low density airspace, initially in oceanic areas at all levels, and then in continental airspace above certain defined altitudes (say FL 410), so that all aircraft could be operated in cruise climb. When combined with user preferred trajectories, this would allow all aircraft to operate with the maximum possible efficiency. In low density airspace the certification of Self Separation would probably be less difficult and could prove to be an ideal method of first proving the system. It could then gradually be introduced into denser continental airspace, maybe at night and at progressively lower altitudes.

The UK National Air Traffic Service (NATS), using their NATSIM model, has not only done benefit studies on the use of ITP in N. Atlantic airspace (see results in section 13 above), they have also modelled the benefits to be gained from using lower separation minima and using 'free flight'. This was done when RVSM was introduced. The results are shown in the table below taken from the CRISTAL ITP Project Benefits Analysis.

Year	Scenario				
	RVSM	RVLSM	RVHSM-4	RVHSM-100	FF
1996	0.55%	0.65%	0.77%	0.91%	1.58%
2000	0.68%	0.79%	0.93%	1.06%	1.76%
2005	0.78%	0.93%	1.06%	1.19%	1.93%
2010	0.90%	1.08%	1.19%	1.33%	2.11%

Reduction in Fuel Burn for Reduced Separations (NICE Study)

The NAT Implementation Cost Effectiveness (NICE) Task Force used traffic samples grown for the years shown in the table above. The columns show the fuel burn reductions for:-

1. RVSM:- reduced vertical separation from 2000ft to 1000ft.
2. RVLSM:- as for RVSM, but with longitudinal separation reduced from 10mins to 7mins.
3. RVHSM-4:- as for RVLSM, but with lateral separation reduced from 60Nms to 30Nms and with only 4% of step-climb being achieved (the actual figure at the time of the study).
4. RVHSM-1000:- as for RVHSM-4, but with the request rate for step-climbs being raised to 100% (similar to maximum in the ITP analysis referred to in section 13 above).
5. FF:- this being the theoretical optimum using 'dynamic flight planning' (optimum user preferred routeing, cruise climb and zero separation).

Self-Separation would allow all aircraft to use very low separation minima, maybe as low as 5Nms if certification can be achieved. It is clear from the study that, in each of the traffic levels simulated, there was an advantage when using Self Separation and cruise climb, and that this increased with increasing traffic levels. The maximum reduction in fuel burn in the table was 0.78% when compared with the best reduced separation scenario (FF minus RVHSM-100).

When compared with current operations the fuel burn reduction (FF minus RVSM) was 1.21%. When compared with the maximum benefit shown in the ITP Benefit Analysis (0.99% in sub-para 2, section 13) the reduction was 1.12%. However, caution is advised with these comparisons since the NICE study and the ITP study figures are not exactly comparable. But, since neither could take into account the all additional benefits to be derived from flying SESAR user preferred trajectories throughout the flight in the continental areas (and not using fixed entry/exit points into and out of oceanic airspace) it is not unreasonable to assume that the overall benefit could be in the order of 1.5% compared to current operations.

15 Conclusions

Conclusion 1:- Europe with SESAR, and the USA with NextGen, are working towards very similar ATM operating concepts, both being based on a 4D trajectory environment and including ASAS. There is a high degree of commonality and considerable interchange between them, extending also to work in Canada, Ausralia and the Asia/Pacific region.

Conclusion 2:- By 2013 both Airbus and Boeing will be including in their avionics fit a number of the 'early ASAS applications' utilising ADS-B in and out, these being Situational Awareness applications such as ATSA-SURF and ATSA-ITP, and Spacing applications such as ASPA-S&M. All have been shown to offer benefits in terms of reduced fuel burn, reduced emissions, improved safety and improved capacity. The more demanding Separation applications will come later, definitely by 2020.

Conclusion 3:- There is unlikely to be a business case for each individual application by itself, but as a package there probably is. And by using Electronic Flight Bags it is relatively easy to retrofit these to existing aircraft.

Conclusion 4:- A significant proportion of a longhaul airline's fuel burn is on oceanic routes, for US airlines this is around 30%. It would be interesting to know what the proportion is worldwide.

Self Separation was developed to provide a solution to the ATM capacity limitations in dense airspace, but this may take time to certificate in such a demanding environment. The less dense oceanic routes could offer a simpler environment in which to start. It could also be extended to continental airspace above certain defined altitudes, starting at FL 410 for business jets.

By extrapolating from the evidence from the studies carried out by the UK NATS it is probable that by using Self Separation, User Preferred Routes and Cruise Climb a total fuel burn reduction of 1.5% could be achieved on North Atlantic routes when compared to today's operation. It would be interesting to know if similar benefits could be achieved on Pacific routes.

The author proposes that:-

1. An initial study needs to be made to show the benefits of such an operating regime.
2. Manufacturers should consider developing Cruise Climb modes so as to be ready to take advantage of ASAS Self Separation.
3. And member of this audience might be able to help promote these ideas.

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