Chapter 3

OPERATIONAL OPPORTUNITIES

ICAO
ENVIRONMENTAL
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Operational Opportunities
Overview

By ***ICAO Secretariat***

The term "operations" in the context of aviation can be used to describe a broad range of activities including: the flying of the airplane, the control and/or monitoring of the aircraft by the air traffic management system, and the conduct of various airport activities. Operations begin with planning activities even before the passengers and cargo are loaded, through the entire flight, until after the passengers have disembarked and the cargo has been unloaded. One constant that applies whenever it comes to defining operational procedures, is that safety must always come first.

Reducing aircraft emissions, whether for an individual flight or globally, can be achieved through various means, including aircraft technologies (see Chapter 2 of this report), the use of sustainable alternative fuels (see Chapter 5 of this report), economic instruments (see Chapter 4 of this report), and by means of operational improvements, which are discussed later in this chapter of the report. While aircraft technologies alone can determine the theoretical environmental performance of the aircraft, the actual performance will be the result of how the aircraft is operated subject to the constraints imposed by air traffic services and the supporting infrastructure.

The operational opportunities to reduce emissions that are described in this chapter of the report are delivered through optimized ground and in-flight procedures that do not compromise safety. In reality, they represent a double win-win solution. First, based on the premise that the most effective way to minimize aviation emissions is to minimize the amount of fuel used in servicing and operating each flight, environmental benefits that are achieved through reduced fuel consumption also result in reduced fuel costs. Second, operational measures do not necessarily require the introduction of new equipment or the deployment of expensive technologies. Instead, they are based on different ways of operating aircraft that are already in service. For instance, some States have implemented training courses in environmentally friendly piloting techniques. This chapter of the report describes numerous examples of aircraft operating in an environmentally optimized fashion; all of which showcase the potential for improvement with existing technology.

ICAO is working to deliver an interoperable global air traffic management (ATM) system, for all users during all phases of flight (see *ICAO's Global Air Traffic Management (ATM) Operational Concept and Global Air Navigation Plan Both Support Fuel and Emissions Reductions*, later in this chapter of the report). An important step toward realizing this vision was the endorsement of the ICAO Global ATM Operational Concept in 2003, which is an integral part of all major ATM development programmes including NextGen of the United States (see *NextGen and the Environment – The U.S. Perspective*, later in this chapter of the report), and the European SESAR (see *SESAR and the Environment*, also later in this chapter of the report).

The importance of the interoperability of the Global ATM System has been highlighted through a number of cooperative demonstrations, such as the Atlantic Interoperability Initiative to Reduce Emissions (AIRE) and the Asia and Pacific Initiative to Reduce Emissions (ASPIRE), both of which are described later in this chapter of the report. Domestic initiatives such as those in New Zealand (see *Operational Measures to Reduce Carbon Dioxide Emissions from Aviation: Initiatives from New Zealand*, later in this chapter of this report), and Brazil (see *Environmental Benefits of New Operational Measures - A Case Study: Brasília Terminal Area*, also later in this chapter of the report) both highlight, not only the benefits that can be delivered quickly through improved operations, but also the interrelationships among noise, local air quality, and emissions.

Looking to the future, ICAO's panel of independent experts developed operational efficiency goals for the global ATM system (see *Opportunities for Air Traffic Operations to Reduce Emissions – Mid-Term and Long-Term Operational Goals*, Chapter 3 of this report). The realization of the targets set by the independent experts will depend on the successful delivery of the Global Air Navigation Plan.

In 2003, ICAO first published Circular 303 – Operational Opportunities to Minimize Fuel Use and Reduce Emissions. That document identifies and reviews various operational opportunities and techniques for minimizing fuel consumption in civil aviation operations and is aimed at: airlines, airports, air traffic management and air traffic service providers, airworthiness authorities, environmental agencies, and various government bodies. The Committee on Aviation Environmental Protection (CAEP) developed rules of thumb to assist States with estimating the potential environmental benefits from the implementation of new operational procedures (see *Aviation's Contribution to Climate Change – Overview*, Chapter 1 of this report).

As the articles in this chapter of the report illustrate, aircraft operations are being optimized today to improve environmental performance while maintaining safety. With the realization of a global, interoperable, ATM system, in combination with technological advances, the eventual achievement of future goals for aviation environmental performance will become possible. ■

ICAO's Global Air Traffic Management (ATM) Operational Concept and Global Air Navigation Plan

By ***ICAO Secretariat***

ICAO is the driving force for the ongoing development of a global air traffic management system that meets agreed levels of safety, provides for optimum economic operations, is environmentally sustainable, and meets national security requirements. Achieving such a worldwide ATM system will be accomplished through the implementation of many initiatives over several years on an incremental basis. With the increased focus on aviation environmental concerns in recent years, it is recognized that the Global ATM Operational Concept is a key component of the mitigation measures to address noise, gaseous emissions and other environmental issues. This article explains the background of the Global ATM Operational Concept and illustrates how it takes into account aviation environmental concerns and priorities.

Global ATM Operational Concept

ICAO effort's to continually improve the ATM system are focused on the Global ATM Operational Concept. The vision of the operational concept is to achieve an interoperable global air traffic management system, for all users during all phases of flight that meets agreed levels of safety, provides for optimum economic operations, is environmentally sustainable, and meets national security requirements. The Concept was endorsed by the Eleventh Air Navigation Conference in 2003 and is now an important part of all major ATM development programmes including NextGen of the United States and the European SESAR.

The global ATM system envisaged in the operational concept, is one in which aircraft would operate as closely as possible to their preferred 4-dimensional trajectories. This requires a continued effort toward removal of any and all ATM impediments.

Global Performance of the Air Navigation System

The operational concept recognizes that reaching the desired "end-state" cannot be achieved by revolution; rather, it will be an evolutionary process, with an ultimate goal of global harmonization. This will allow ICAO States, regions and homogeneous areas to plan the significant investments that will be needed, and the timeframe for those investments, in a collaborative decision-making process.

Rather than emphasizing improvements solely in the areas of efficiency or safety as the sought after outcome, the operational concept recognizes that competing interests for the use of airspace will make airspace management a highly complex exercise, necessitating a process that equitably balances those interests. Each of those interests must be considered on the basis of a weighted "desired outcome contribution". The environment is certainly one of the key outcomes that must be considered.

In an effort to assist planners in weighing outcomes and making appropriate decisions, the *Manual on Global Performance of the Air Navigation System* was developed. The guidance contained in that document supports an approach to planning, implementation, and monitoring that is based on performance needs, expected benefits, and achievement timelines. Such explicit planning and management of ATM performance will be needed to ensure that throughout the transition process towards the Global Air Navigation System, as envisaged by the Global ATM Operational Concept, the expectations of the entire community will be met.

The Global Air Navigation Plan and the Planning Process

The Global Air Navigation Plan will be revised to assist States and regional planning groups in identifying the most appropriate operational improvements and to make sure it considers regional programmes that are already in place such as NextGen and SESAR. To support the implementation process, the revised Plan will clearly describe a strategy aimed at achieving near- and medium-term ATM benefits on the basis of available and foreseen aircraft capabilities and ATM infrastructure. The Global Plan will therefore pave the way for the achievement of the vision established in the Global Concept.

The set of initiatives contained in the Global Plan are meant to facilitate and harmonize the programmes and work that are already underway within the regions, and to bring needed benefits to all the aviation community over the near and medium term. ICAO will continue to develop new initiatives on the basis of the operational concept which will be placed in the Global Plan. In all cases, initiatives must meet global objectives. On this basis, planning and implementation activities will begin with application of available procedures, processes and capabilities. The evolution progresses through the application of emerging procedures, processes and capabilities, and ultimately, migrates to the ATM system, based on the operational concept. All regions have well established implementation plans and are progressing with their individual work programmes.

Performance and the Environment

A key tenet of the operational concept is its performance orientation. The concept contains 11 expectations of the international ATM Community which can also be described as key performance areas. The ATM system performance requirements should always be based on the key understanding that the ATM system is the collective integration of services, humans, information and technology.

Members of the ATM community have differing performance demands of the system. All have either an explicit or implicit expectation of safety. Some have explicit economic expectations, others want efficiency and predictability, and of course others have the environment as their main concern. For optimal system performance, each of these sometimes competing expectations needs to be balanced. Interests must be considered on the basis of a weighted "desired outcome contribution". As stated previously, the environment is one of the key issues to be considered. The operational concept outlines a total system performance framework to assist in the process and recognizes that the ATM system needs to contribute to the protection of the environment by considering noise, gaseous emissions and other environmental issues in the implementation and operation of the global ATM system.

Since 2006, when the ICAO Council approved the Global Plan Initiatives as part of the Global Plan, Planing Implementation Regional Group (PIRG)s initiated the adoption of a performance framework, performance objectives, and implementation timelines, along with the development of a comprehensive schedule and programme of work planning activities to guide their work.

A series of workshops for ICAO regions were held with the objective of providing detailed guidance to States on the development of national performance frameworks for air navigation systems. The workshops, that covered almost all ICAO Regions, were held in 2009/2010. Similar workshops will be conducted in the remaining regions during the following years to increase their knowledge and assist them with timely implementation of the measures that will, among others benefits, support the reduction of the impact of aviation on climate change.

The means and tools to establish performance targets and measure performance are being used by several groups both within and outside of ICAO.

Reduced Vertical Separation Minimum

Reduced Vertical Separation Minimum (RVSM) facilitates more efficient use of airspace and provides for more economical aircraft operations because it allows aircraft to operate closer to their preferred levels, thereby reducing fuel burn and consequently emissions. RVSM was first implemented in 1997 in the airspace of the North Atlantic and is forecast to be completed at a Global level by 2011 when the Eurasia region will implement it with guidance provided by ICAO.

Following the implementation of RVSM in various ICAO Regions, environmental studies have concluded that RVSM implementation led to significant environmental benefits. All the reports state that total fuel burn, NO_x emissions, CO_2 emissions, and H_2O emissions were reduced, which also translates into reduced costs for airlines operating in the RVSM airspace. The study reports go on to state that the environmental benefits were even more positive for the high altitude band along and above the Tropopause, at an altitude between 8 and 10 kilometres.

ICAO's role in supporting the realization of RVSM was and continues to be significant. From the detailed safety related work, the development of Standards and supporting guidance material, to the extensive planning and safety assessments conducted by the regional planning groups; RVSM could not have been implemented globally without ICAO leadership.

An important lesson learned from the success of RVSM is that improving efficiency leads to environmental benefits. We should therefore continue working toward the establishment of a common performance framework, establishing environmental and efficiency targets and developing the methods to measure outcomes.

Performance Based Navigation

Performance Based Navigation (PBN) allows aircraft to fly even closer to their preferred 4D trajectory. Developed, after the improvement of the air navigation system in the vertical plane, PBN improves the efficiency in the horizontal plane. The PBN concept is being used to implement more flexible use of the airspace and optimize the operations to meet the expectations of the aviation community in terms of safety, efficiency, predictability, among others. These can be directly translated into environmental benefits through reduced aircraft flying distances and/or times when compared with the legacy systems that are based solely on ground based navigation aids.

Continuous Descent Operations

Continuous Descent Operations (CDO) allow the arrival, approach and landing of the aircraft with a more efficient profile, thus reducing the need for energy use. The increased use of these types of operations is anticipated because they meet the expectations of the aviation community in terms of reduced fuel burn and emissions.

Through different operational improvements and initiatives the ATM system is being updated to allow more use of continuous descent operations taking into consideration that it also impacts other areas related to air navigation.

Conclusions

The aviation community has been working on ATM operational improvements steadily since the 1920s. The work accelerated with the onset of CNS/ATM systems. Technology development has been more rapid in recent years and improvements are now occurring even more quickly.

A major operational improvement was the implementation of the RVSM , which yielded significant operational benefits to the aviation community in terms of reduced fuel burn, availability of optimal flight levels, increased capacity, as well as significant spin-off environmental benefits.

ICAO plays a central role in planning for the implementation of operational improvements. In addition to developing the necessary standards and guidance material, ICAO has developed a Global ATM Operational Concept that has been widely endorsed and adopted as the basis for planning. ICAO also provides the planning framework through the Global Air Navigation Plan and several other documents and tools that support planning and implementation efforts. Computer models are under development to assess the environmental benefits accrued through implementation of the various initiatives.

Every ICAO Region has a list of identified performance objectives and has developed work programmes to yield near- and medium-term benefits, while integrating those programmes with the extensive work that has already been accomplished.

Opportunities for Air Traffic Operations to Reduce Emissions

Mid-Term and Long-Term Operational Goals

*By **Alan Melrose**, Chair of Independent Expert Operational Goals Group-IEOGG*

***Alan Melrose** has 38 years experience in environmental management in a wide range of private and public sector organisations. Establishing Manchester Airport's Environmental Control Department in 1988, he was actively involved in delivering Manchester's Second Runway and helped to secure several 'world firsts' in environmental management.*

Alan joined EUROCONTROL 9 years ago and leads projects including the Continuous Descent implementation initiative, Collaborative Environmental Management roll-out and environmental training. Alan supports various ICAO activities including the development of CDO guidance and is a task leader in CAEP Working Group 2 including chairing the Independent Expert Operational Goals Group.

Introduction

In support of the Committee on Aviation Environmental Protection (CAEP) work programme, a panel of Independent Experts (IEs) was tasked to undertake a review of NO_x technologies that would culminate in recommendations for medium (10 year) and long term (20 year) goals for NO_x control (see article *ICAO Technology goals for NO_x*, Chapter 2 of this report). In 2007, CAEP/7 agreed that this NO_x review was to be treated as a reference point for similar efforts in other areas such as noise, fuel burn, and operational goals, where reviews had been requested. During the CAEP/8 cycle, reviews for NO_x, noise, and operational goals were held, and their respective IE Groups presented reports to CAEP/8 in February 2010

The Independent Expert Operational Goals Group (IEOGG) was tasked, based on the independent expert (IE) process, to examine and make recommendations for noise, NO_x and fuel burn with respect to air transport operational goals in the medium term (2016) and the long term (2026), based on a 2006 base-year. The work was further focused on ATM operations.

IEOGG produced a detailed report that summarizes future environmental goals for air traffic management (ATM) operations. That report provides an initial range estimate of operational efficiency and noise mitigation goals, assuming that the maximum ATM improvements possible by 2026 are fully implemented. Achieving this will require delivery of the ICAO Global Air Navigation Plan including the SESAR and NextGen programmes as a minimum.

Independent Expert Operational Goals Group Composition

To conduct this work, IEOGG members were selected as individual experts, and not as representatives of their home organizations. IEOGG comprised 10 individual experts from three national authorities and four different industry groups, so there was a broad range of operational, institutional, academic and technology skills available. Because IEs came from a variety of different expertise domains, their consensus can be taken as being fairly representative of the overall expert community perspective.

Process and Challenges

IEOGG used a top-down approach to identify the total potential operational benefit pool available within which to set ambitious goals. The experts agreed that there will always be some operational inefficiency that is very difficult or impossible to address such as that caused by: noise routes, airspace constraints, unplanned military events, safe separation, requirement, severe weather events, etc.

This top-down approach was considered to be more robust than to simply aggregate the total expected benefits for all planned operational improvements, since that would merely be an accounting exercise for existing plans and therefore would not necessarily be challenging. Also, the experts felt that aggregating the benefits from known technologies, techniques, enablers and institutional arrangements was not possible in the timeframe available for the IEOGG since such a summation would be very complex. Nevertheless, it became clear that at some stage in the future this additional work will be required in order to validate any aspirational goal and to allow progress to be tracked, and gaps or variances addressed.

In terms of challenges, IEOGG determined operational efficiency by comparing the actual horizontal trajectory of a flight with the Great Circle route between terminal areas. While this method is reasonably robust, the experts identified that it does not account for other operational performance parameters such as: auxiliary power unit (APU), vertical inefficiency, speed control, wind assistance and additional contingency fuel uplift due to lack of predictability, etc.

They identified that information on total operational performance simply does not exist at a global level. However, it was recognized that if such information does become available it will either affect the assessment of base-case efficiency, or it will increase the total impact of operations, rather than require an adjustment to any aspirational goal. Because of lack of data on the base-case (i.e., future do-nothing scenario) known, it was decided to set an aggressive **aspirational** total operational efficiency target of 95% operational efficiency by 2026. To ensure clarity for the scope of this target, 100% operational efficiency was defined as being the achievement of the perfectly fuel efficient profile for each flight in the entire gate-to-gate and enroute-to-enroute concepts.

Key Inputs

The main sources of input used by the IEOGG in its work included: ICAO Global Air Navigation Plan, SESAR deliverables, NextGen documentation, an IATA review of operational opportunities and the CANSO report "ATM Global Environment Efficiency Goals for 2050". The CANSO report was used as the starting point because it had also used a top-down approach to estimate how much inefficiency existed within the existing system. Before agreeing to use that report as the basis for its deliberations, the IEOGG had a vigorous debate to ensure that the CANSO assumptions and assessments were valid and acceptable as the foundation for the IEOGG collective approach.

Operational Efficiency Goals and Findings

The key influencing elements that contribute to the total "flight fuel efficiency" were identified in order to establish the context for the 'operational efficiency' analysis paradigm, as shown in Figure 1.

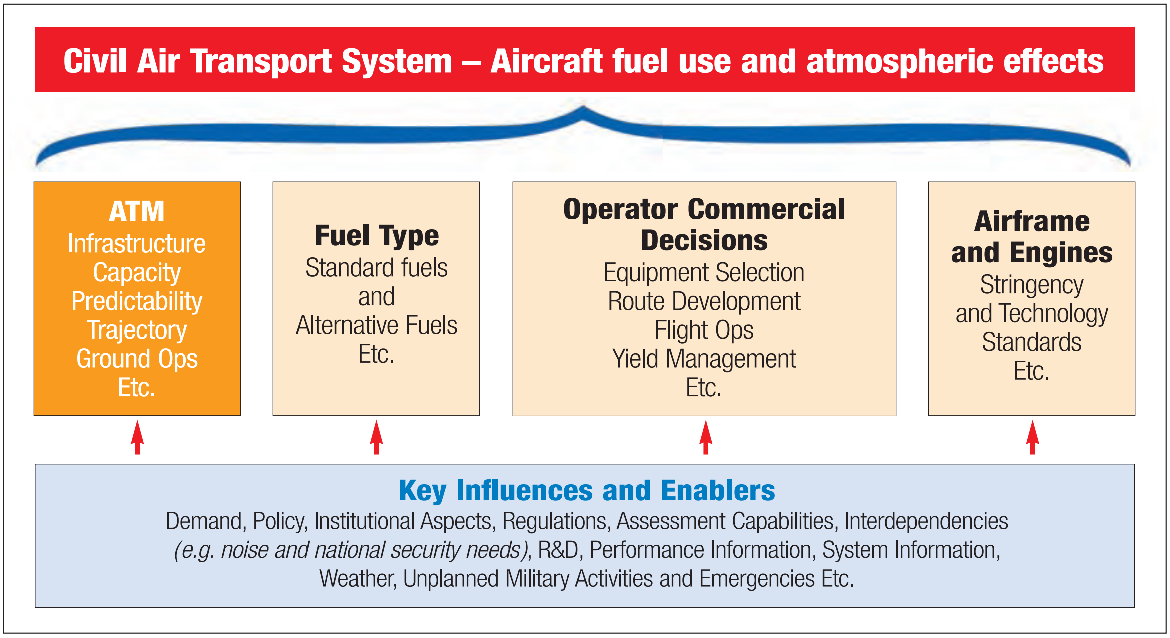

Figure 1: *Civil Air Transport System – fuel use and atmospheric effects; key influencers and enablers.*

The two components shown at either end of that list, ATM operations, and airframe and engine technology, are two of the main areas which are already covered by CAEP IE Groups. However, IEOGG also identified areas that CAEP was not covering (e.g. fuel-type), and other areas that would be outside of the scope of ICAO (e.g. operator commercial decisions). No globally-accepted goals for these elements have yet been set. While the IEOGG tried to be consistent with the technology goals activities, there is at least one critical difference. That is, growth that stimulates additional demand for new aircraft also accelerates the adoption of new technology. Hence, growth actually improves efficiency per flight due to new technologies. On the other hand, growth in operations puts ever-increasing pressure on airspace, and it works against efficiency. Thus, goals for technologies may never be fully consistent with goals for operations.

The conceptual diagram in Figure 2 shows the limited degree to which operational efficiency can be improved over the present case by ATM improvements. It also illustrates that the value of maintaining operational efficiency increases over time, as ever more growth is accommodated. In other words, merely maintaining operational efficiency is an immense challenge. Trying to accommodate growth without aggressive performance improvements would ultimately result in degraded efficiency. There could eventually be a situation of '*un-accommodated demand*' which would result in much higher costs (e.g. from delays or adverse economic impacts), than the additional fuel costs incurred due to loss of efficiency alone.

Defining the base-case against which to measure the goal represented a significant challenge for the IEOGG. In the end, it was thought that it would be misleading to quote a percentage change figure over the current performance level, considering the potential for efficiency to degrade over time with the do-nothing scenario. This decision was reinforced when it became clear that adequate global information on the non-great circle inefficiencies was not available. It is common practice when comparing future proposal assessments, to compare the future case with the proposal against the future case without the proposal. However, for operations, the global future do-nothing scenario is not yet defined. This was another key knowledge-gap that the IEOGG had to deal with and something that IEOGG would need to be addressed in the future.

The other key difference that was encountered when comparing with the technology goals, relates to the fact that the IEOGG was expected to produce two technology scenarios; a less aggressive option, and a more aggressive option. However, the group decided that the most aggressive operational

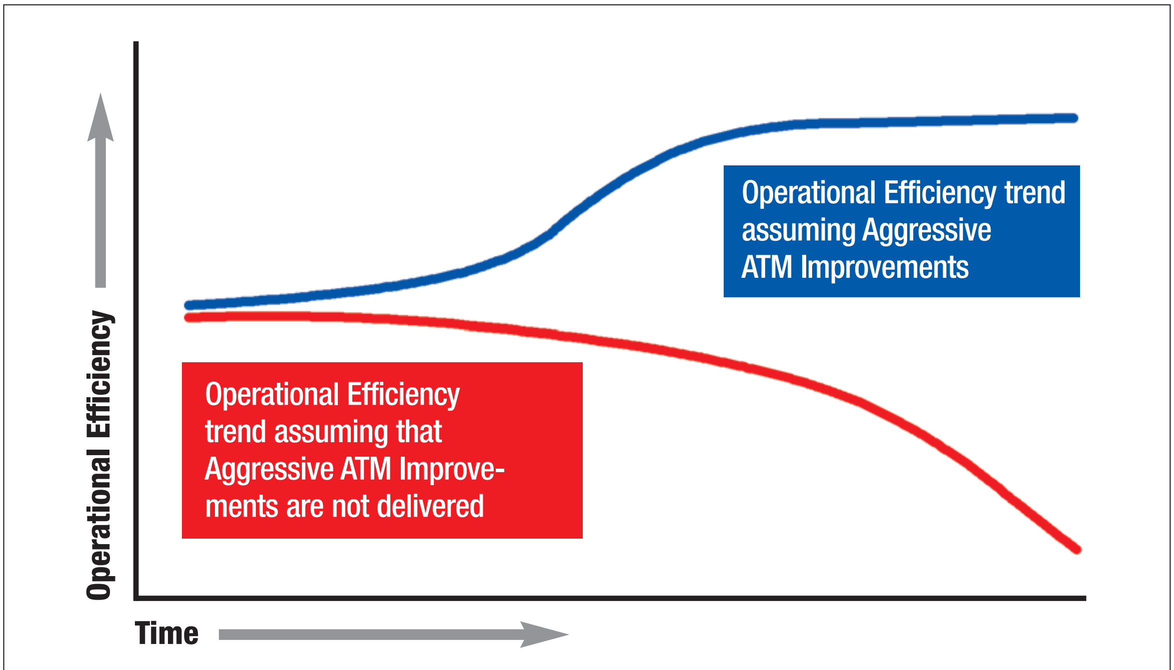

Figure 2: *Operational efficiency over time - with and without ATM improvements.*

Canso Region	ICAO Region	% of global aircraft movement in 2006	Basis of Goal Setting (Sources of inefficiency covered)						Estimated Base Level Efficiency	Operational Efficiency Goals	
			Great Circle Route	Delays and Flow	Vertical Flight	Airport & Terminal Area	Wind Assisted Routes	Contingency Fuel Predictability	2006	2016	2026
World		100%	assessed	assessed	assessed	assessed	not assessed	not assessed	92-94 %	92-95 %	93-96 %
US		35%	assessed	assessed	assessed	assessed	not assessed	not assessed	92-93 %	92-94 %	93-96 %
	North America		assessed	assessed	assessed	assessed	not assessed	not assessed	92-93 %[1]	92-94 %	93-96 %
ECAC		28%	assessed	assessed	assessed	assessed	not assessed	not assessed	89-93 %[2]	91-95 %	92-96 %[3]
	Europe		assessed	assessed	assessed	assessed	not assessed	not assessed	89-93 %	91-95 %	92-96 %
Other Regions		37%	estimated	estimated	estimated	estimated	not estimated	not estimated	**91-94 %**	94-97 %	95-98 %
	Central America / Caribbean		estimated	estimated	estimated	estimated	not estimated	not estimated	**93-96 %**	94-97 %	95-98 %
	South America		estimated	estimated	estimated	estimated	not estimated	not estimated	**93-96 %**	94-97 %	95-98 %
	Middle East		estimated	estimated	estimated	estimated	not estimated	not estimated	**92-94 %**	94-97 %	95-98 %
	Africa		estimated	estimated	estimated	estimated	not estimated	not estimated	**90-93 %**	94-97 %	95-98 %
	Asia/Pacific		estimated	estimated	estimated	estimated	not estimated	not estimated	**91-94? %**	94-97? %	95-98? %

Figure 3: *Operational efficiency goals (great circle), 2016-2026.*

[1] This is a direct copy of the US figures and, as a general principle, regional goals should not be applied to individual states.
[2] This IPCC based estimations of the base-case matches the EUROCONTROL PRR07 report.
[3] This figure extrapolated from the CANSO report is used for consistency, but may be conservative when compared to work by SESAR on 'Gate-to Gate fuel efficiency'.

performance improvement is the **only** option for ATM if threefold demand is to be accommodated while improving all 11 ATM Key Performance Areas. It is believed that the ICAO Global Air Navigation Plan, SESAR, NextGen, and all of the other ATM initiatives, are the most aggressive operational programmes possible, and a goal necessarily has to be in-line with these aggressive initiatives.

With reference to Figure 3, the first thing that was done was to rationalize the CANSO report regions to match the ICAO regions to suit CAEP needs. This included a series of assumptions, such as the CANSO US ATM efficiency estimate which was used as a proxy for North America. It is interesting to note that there is a massive variance in different parts of the world in terms of current ATM system efficiency. For example, because of the lack of fragmentation in Australian airspace, that country is probably already operating at about 98% efficiency; so in this case a target of 95% is not applicable. This raises a very important caveat that a global goal should not be applied equally to each region or state, as their base levels could be different.

For flight efficiency (i.e. fuel burn and CO_2) it was agreed that a global goal of 95% operational efficiency by 2026 would be a very challenging but realistic goal, and its simplicity would help to ensure its consistent use. A detailed definition of what that level of efficiency means in operational terms is contained in the report.

IEOGG could not define a global base-case efficiency level or an expected percentage increase in operational efficiency due to the paradigm that is shown in Figure 2 which indicates that efficiency will drop off. In addition, global data for many of the operational inefficiencies that affect the base-case is not yet available. So, the goal had been based on a required percentage performance improvement over the present day, and if new knowledge about the base case was uncovered later, then the expected benefits pool would change and the goal itself would also shift. This would make such a percentage performance improvement based goal very difficult to follow from a policy perspective. For that reason, the single simple absolute efficiency based objective was chosen by IEOGG.

ATM system Global Operational Efficiency Goal 'That the global civil ATM system shall achieve an average of 95% operational efficiency by 2026 subject to the following notes':	
Note 1	This goal should not be applied uniformly to Regions or States;
Note 2	This is to be achieved subject to first maintaining high levels of safety and accommodating anticipated levels of growth in movement numbers in the same period;
Note 3	This ATM relevant goal does not cover air transport system efficiency factors that depend on airspace user commercial decisions (e.g. aircraft selection and yield management parameters etc.);
Note 4	This operational efficiency goal can be used to indicate fuel and carbon dioxide reductions provided fuel type and standards remain the same as in 2008. The goal does not indicate changes in emissions that do not have a linear relationship to Fuel use (such as NO_x); and
Note 5	This assumes the timely achievement of planned air and ground infrastructure and operational improvements, together with the supporting funding, institutional and political enablers.

Figure 4: *Operational efficiency goal of 95% by 2026; with caveats.*

The 95% operational efficiency goal stated in Figure 4 includes a series of caveats, and the IEOGG report goes to great lengths to specify that this target should never be considered without these caveats being included. That is because it would be very easy to take this goal out of context. Also, if the goal-setting process is repeated in the future the caveats may well change. The requirement to periodically update this goal was subsequently ratified by CAEP/8.

Conclusions and Challenges for Future Work

Given the limited time available, coupled with some of the data availability constraints, the IEOGG reached consensus that the 95% global operational efficiency goal by 2026 is a reasonably robust target.

It is important to note that the proposed relatively modest gain in efficiency over current levels is actually an important incremental gain relative to the current high level of operational efficiency. The value and challenge of this improvement is actually very ambitious and aggressive when considering that at the same time a threefold growth in aircraft movement numbers will be accommodated.

The lack of required information needs to be addressed. Also, measuring progress towards the target will be difficult because the information for some parts of the world is not yet available. The future do-nothing base-case, as well as the bottom-up evaluation of operational improvements which were not available, need to be developed, as do the assessment methods and performance metrics. This data requirement includes information on inefficiencies in the system, which are not great circle inefficiencies such as: vertical inefficiencies, ground operational inefficiencies, unnecessary fuel uplift and transportation due to lack of predictability, etc.

NextGen and the Environment
The U.S. Perspective

*By **Victoria Cox** and **Nancy LoBue***

*As the Air Traffic Organization's Senior Vice President for NextGen and Operations Planning, **Vicki Cox** provides increased focus on the transformation of the nation's air traffic control system by providing systems engineering, research and technology development, and test and evaluation expertise. She is also responsible for the NextGen portfolio and its integration and implementation.*

Within the FAA, Cox has served as the Director of the ATO's Operations Planning International Office, the Director of Flight Services Finance and Planning and the Program Director of the Aviation Research Division.

She has a certificate in U.S. National Security Policy from Georgetown University and is a DOD Level III Certified Acquisition Professional in Systems Planning, Research, Development and Engineering. She also earned her private pilot's license in 1985.

***Nancy D. LoBue** joined FAA's Office of Aviation Policy, Planning & Environment in 2003 as Deputy Assistant Administrator. The office leads the agency's strategic policy and planning efforts, which includes the agency's performance metrics known as the "Flight Plan", develops the agency's reauthorization legislative proposals, oversees the aviation insurance program, and is responsible for national aviation policies and strategies relating to environment and energy.*

Prior to that, Ms. LoBue spent almost 20 years in FAA's Office of the Chief Counsel in various positions while managing attorneys involved in environmental review and litigation, airport financing and government contracts.

The world has arrived at a consensus on the need to arrest climate change and global warming. Aviation technology, advancing on its own separate track, promises to enable the world's aircraft operators to do their part to limit the aviation industry's environmental footprint.

NextGen Overview

In the United States, these advanced technologies, and the operational innovations associated with them, are known collectively as NextGen — the Next Generation Air Transportation System. NextGen will transform aircraft surveillance from radar to global positioning system (GPS) satellites which will change navigation from zigzagging segments into more direct trajectories. Under NextGen, much of the air-ground communications will move from voice to data. It will create a data system that provides all stakeholders with the same information at the same time. These new technologies will also help develop more fuel efficient airframes and engines and will help in the development and deployment of sustainable alternative fuels — all aimed to reduce greenhouse-gas (GHG) emissions.

Environmental benefits from the many NextGen operational initiatives are part of a scenario that offers several co-benefits. For example, most of what the FAA does to increase efficiency and curb delays will also reduce fuel consumption. This in turn will shrink the operating costs of airlines and other airspace users. More important from an environmental perspective, reduced fuel consumption will mean reduced emissions of carbon dioxide and other greenhouse gases.

NextGen systems and procedures will enable simpler, more direct trajectories throughout all phases of flight, including surface operations before takeoff and after landing. Collaboration between air traffic controllers, aircraft operators, airline flight operations centers and airport operations managers will move departing aircraft to their takeoff positions and arriving aircraft to their gates or parking assignments faster and more efficiently. System-wide management and sharing of information will make improved surveillance, communications and weather reporting and forecasting available to all these parties in a common format, enabling everyone to see and act on the same data at the same time.

Performance Based Navigation

On departures and approaches, more accurate surveillance and Performance Based Navigation (PBN) procedures will give controllers and operators options to vary flight paths for increased system efficiency and reduced distance, time in flight, and fuel consumption. On aircraft approaches, PBN will enable operators to throttle their engines down during their descent, offering the co-benefit of reducing noise exposure on the ground as well as emissions.

From the standpoint of the environment, some of the most beneficial of these PBN procedures require flight-path changes that trigger extensive environmental reviews. For example, diverging approaches and ascents create new, fuel-efficient trajectory options for controllers and operators, and in some cases they eliminate delays due to conflicts in routes to and from closely spaced airports. Because these types of flight paths differ from the current ones, the FAA must analyze its environmental impact to satisfy exacting standards. The agency's environmental management system is a key part of the strategy in such cases.

The FAA has begun implementing PBN and some of NextGen's other advanced capabilities, notably the Automatic Dependent Surveillance-Broadcast (ADS-B) system, which provides more accurate surveillance than radar and increases the situational awareness of pilots of properly equipped aircraft. ADS-B is operational in Louisville, Kentucky; Philadelphia, Pennsylvania; and Juneau, Alaska. Last December, ADS-B began operations over the Gulf of Mexico, off the U.S. southern coast, an area that was never served by radar.

NextGen Demonstrations

The FAA and its aviation community partners are demonstrating capabilities now that will begin delivering many of NextGen's most significant operational benefits during the next several years. Among these are collaboration in airport surface operations, PBN approaches and departures, reduction of in-trail separation requirements, fuel-saving en-route operations, and the beginnings of data communications. The FAA plans to reach operational status this winter for tailored arrivals at suitable locations. The agency has been demonstrating these capabilities for years at Miami, Florida, and San Francisco and Los Angeles, California.

Demonstrations are valuable in many ways. They help refine plans for developing and implementing systems and procedures. They open the door for operations personnel from the FAA and prospective user organizations to participate in planning, provide insights into development requirements, and understand innovations that they will encounter in the field. They also provide evidence of the benefits that users can expect following deployment, which in turn helps them develop a business case for investing in the aircraft equipment needed to take advantage of NextGen capabilities. The benefits of these will be substantial.

For example, demonstrations have established that collaboration among operators and controllers can reduce taxi-out times at busy airports substantially - by as much as 15 percent in one exercise. As part of the NextGen-SESAR Atlantic Interoperability Initiative to Reduce Emissions (AIRE) program - in 52 flights during 2009, Lufthansa and Air Europa avoided an average of more than 1.5 tons of CO_2 per flight. These and other demonstrations help refine the FAA's model-based overall estimate of NextGen benefits.

Environmental Benefits

The FAA expects environmental benefits from NextGen systems and procedures to help offset the expected growth of flight operations. Although aviation growth in the United States has been held down during the past decade, the FAA's Aerospace Forecast for Fiscal Years 2010-2030 (March 2010), envisions annual growth of 1.3 percent in total aircraft operations at airports with traffic control services (2.0 percent counting airline operations alone), and 2.3 percent in the number of aircraft operating with instrument flight rules handled at en route centers (3.2 percent in airline aircraft).

Airline takeoffs and landings in the United States are forecast to approach 19.5 million in 2030 vs. 15.2 million in 2000. The 30-year increase is expected to be more than 28.5 percent. Additional operational measures are needed to counter the offset from NextGen's environmental gains that this growth will cause, and the FAA is pursuing them aggressively.

Measuring and Managing Performance

With respect to environmental performance, the FAA currently uses an aviation fuel efficiency metric to measure progress in energy efficiency and emissions. The agency has an ongoing project to review which metrics to use for future measurements of NextGen environmental performance in the areas of climate, energy, air quality and noise.

To give environmental and efficiency performance a high priority, the FAA will use an environmental management system (EMS) approach to integrate environmental performance objectives into NextGen programs and systems. An EMS is intended to ensure that the agency does everything possible to integrate environmental considerations into day-to-day decisions and long-term planning.

Looking Forward

Looking beyond improved flight operations, we believe that advances in engine and airframe technologies and renewable alternative fuels will provide important environmental benefits. Historically, the greatest reductions in aviation's environmental impact have come from new technologies, and we expect aviation's proven aptitude for technological innovation to be a continuing strength.

Our principal effort to develop new technologies to reduce aviation's environmental impacts is the Continuous Lower Energy, Emissions and Noise (CLEEN) program, launched in 2009. The FAA and the aviation industry are partnering and sharing costs on work to develop and mature promising subsonic jet aircraft and engine technologies that industry can commercialize. Options for development work include composite structures, ultra-high-bypass-ratio and open rotor engines, advanced aerodynamics and flight management systems technologies. Our objective is to demonstrate a high level of technology readiness for selected initiatives within five years, so that industry can apply them commercially within five to eight years.

Jet fuels made from renewable sources are the most promising for reducing aviation's CO_2 footprint. Sustainable jet fuels also offer the co-benefits of advancing energy security and economic development. CLEEN is also pursuing development and maturation of sustainable alternative jet fuels. Since 2006, the FAA has worked with airlines, manufacturers, energy producers, researchers and U.S. and other government agencies in the Commercial Aviation Alternative Fuels Initiative (CAAFI) on sustainable alternative aviation fuels development and deployment. In September 2009, the first alternative jet fuel specification won approval, enabling the use of a 50 percent blend of synthesized hydrocarbon fuel from biomass, gas or coal mixed with Jet A. CAAFI is working with ASTM International to secure approval of a second alternative fuel blend of hydrotreated renewable jet biofuels and Jet A by 2011. Other fuels will follow.

The timing of the CLEEN and CAAFI research programs complements that of our NextGen operational improvements. As we continue deploying systems and procedures, we will reach in 2018 what we consider the mid-term, a point at which we envision cumulative fuel savings of 1.4 billion gallons, equivalent to avoiding 14 million tons of CO_2. More environmentally friendly aircraft technologies and sustainable aviation jet fuels will further allow us to make progress toward meeting ICAO's aspirational goal of enhancing aviation fuel efficiency by 2% per year and the U.S. goal to achieve aviation carbon neutral growth by 2020 using 2005 as a baseline and net reductions by 2050.

Benefits

NextGen and efforts like it promise to be substantial contributors to mitigating aviation's environmental impacts. As the FAA continues to deploy NextGen systems and procedures, cumulative fuel savings will reach 1.4 billion gallons by 2018, equivalent to avoiding 14 million tons of CO_2. More environmentally-friendly aircraft technologies and sustainable aviation jet fuels will further enable the aviation community to make progress toward meeting ICAO's aspirational goal of enhancing aviation fuel efficiency by 2 percent per year and to achieve the U.S. goal of aviation carbon neutral growth by 2020 and net reductions by 2050 (using 2005 as a baseline).

The FAA's multi-layered approach to greening aviation, and comparable initiatives being pursued throughout the world, are critically important to our collective efforts to make aviation a constructive partner in the global effort to reduce greenhouse-gas emissions and reverse global warming.

SESAR and the Environment

By ***Alain Siebert*** and ***Célia Alves Rodrigues***

__Alain Siebert__ is the Chief, Economics & Environment at the SESAR Joint Undertaking based in Brussels, Belgium. He is responsible for all economic and environmental aspects for this new, ambitious European program recently launched by the European Commission, Eurocontrol and the industry.

Alain started his career as a Management Trainee at Air France and later joined SAS Group as Executive Assistant to the Chief Financial Officer. He was later assigned Head of Strategic Development & Fuel Conservation under the responsibility of the Chief Operating Officer. There he supported the senior operations management team in strategic business planning and execution with main responsibility for Fuel Conservation.

See AIRE article for __Célia Alves Rodrigues__ biography.

Introduction

Air Traffic Management (ATM) determines when, how far, how high, how fast and how efficiently aircraft fly. These parameters in turn influence how much fuel a given aircraft burns, the release of greenhouse and other gases from the engines, and of course, how much noise the aircraft makes.

An Oxford University study has found[1] that the quickest way to reduce aircraft emissions is better flight management. According to that study, ATM enhancements through the optimization of horizontal and vertical flight profiles have the potential to trim down the in-flight CO_2 emissions accumulated over the 2008 to 2020 period by about 50 Million tons.

This article presents the European Union's Single European Sky initiative and its technical pillar, the Single European Sky ATM Research programme (SESAR). It provides an update on its implementation status (by mid-2010), focusing on its environmental perspective, without providing an exhaustive summary of the entire SESAR work programme. For more detailed information please visit **www.sesarju.eu**.

Single European Sky and SESAR

The Single European Sky is an ambitious initiative launched by the European Commission in 2004 to reform the European ATM system. It sets a legislative framework to meet future capacity and safety needs at a pan-European level. The Single European Sky is the political transformation of the European ATM system.

SESAR on the other hand, is the operational and technological dimension of the Single European Sky. It will help create a "paradigm shift", supported by state-of-the-art and innovative technologies designed to eliminate fragmentation in the future European ATM system. SESAR is composed of three phases and will be implemented in steps as shown in Figure 1.

Figure 1: *SESAR implementation phases, 2004 to 2020 and beyond.*

The European ATM Master Plan defines the "path" towards the achievement of performance goals as agreed at EU ministerial level (horizon 2020, baseline 2005) as follows:

- Enable a 10% reduction in CO_2 emissions per flight;
- Reduce ATM costs by 50%;
- Enable a threefold increase in capacity;
- Improve safety by a factor of 10.

The European ATM Master Plan also defines which operational, technological and regulatory changes are needed, where and when they are needed (including links to ICAO regulation to ensure consistency), together with a risk management plan and a cost/benefit assessment.

The SESAR Joint Undertaking (SJU) was established in 2007 as a new EU organization. It was founded by the European Commission and Eurocontrol, with the main responsibility to:

- Execute the European ATM Master Plan;
- Concentrate and integrate R&D in Europe (budget of 2,1 EUR Billion broken down as below).

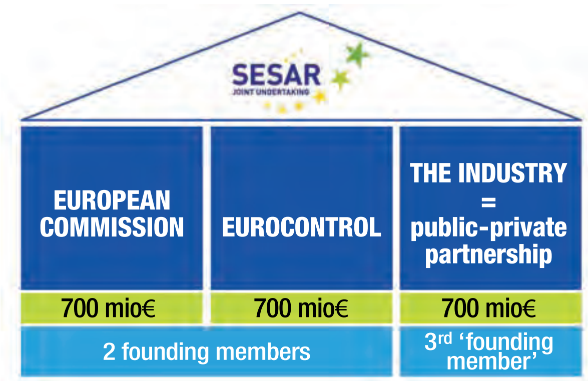

Figure 2: *Single European Sky ATM Research programme (SESAR), R & D budget breakdown.*

Environment - A SESAR Priority

Before the end of 2011, the SESAR programme will implement an advanced validation methodology that will ensure end-to-end consideration of environmental issues in all SESAR research and development (R&D) activities conducted within that timeframe. At the same time, SESAR operates in close cooperation with other European and international initiatives regarding the integration of new, environmentally friendly solutions for the aviation sector. One such project is the European Union's Clean Sky Joint Technology Initiative that will develop breakthrough technologies to significantly improve the environmental performance of aircraft. Besides enabling the ambitious environmental objectives outlined in the European ATM Master Plan, SESAR's objectives beyond 2011, are to:

- Improve the management of noise emissions and their impacts through better flight paths, or optimized climb and descent solutions.
- Improve the role of ATM in enforcing local environmental rules by ensuring that flight operations fully comply with aircraft type restrictions, night movement bans, noise routes, noise quotas, etc.
- Improve the role of ATM in developing environmental rules by assessing the ecological impact of ATM constraints, and, following this assessment, adopting the best alternative solutions from a European sustainability perspective.

The SESAR R&D Capability Is In Place

SESAR is all about partnership in practice. For the first time, all aviation players (i.e. airport operators, air navigation service providers, and the manufacturing industry) are involved in the definition, development and deployment of a pan-European modernization project right from the start. Fifteen members have joined the SJU to date: AENA, Airbus, Alenia Aeronautica, DFS, DSNA, ENAV, Frequentis, Honeywell, Indra, NATMIG[2], NATS, NORACON[3], SEAC[4], SELEX Sistemi Integrati and Thales. Several of those members represent consortia, which brings the total number of organizations directly and indirectly bound to SESAR to 35. These companies also have affiliates and sub-contractors. As a result, a total of 70 companies from 18 countries are participating in SESAR, demonstrating the impact of the programme on ATM R&D activities in Europe. In addition, the SJU programme actively involves key stakeholders such as airspace users, staff and professional associations, as well as regulatory authorities and the military through ad hoc working arrangements.

The negotiation process with SJU members was completed in June 2009 and already 80% of the 300 projects comprising the SESAR Work Programme have been launched. As a result, more than 1,500 engineers and experts from all the partner organizations, located in 17 countries, are already participating in SESAR.

Partnership In Practice - Delivering Green Results Today

The SESAR programme aims to define and validate a first set of solutions that should be delivered and ready for implementation by 2013. In the meantime, the focus is on capitalizing on current aircraft capabilities through industry leadership and partnership in order to achieve quick gains. In this respect, the activities performed under the umbrella of the Atlantic Interoperability Initiative to Reduce Emissions (AIRE) have shown very encouraging results and that programme will be further expanded (see *AIRE article*, Chapter 3 of this report).

Importance of International Cooperation and Interoperability Through Standards

SESAR is fully committed to working together on the implementation of a single strategy to effectively address the global impact of aviation. Harmonization is essential to ensure that the same aircraft can safely fly throughout the world with airborne equipment that is interoperable with any ground ATM system. This is also one of the key requirements for new ATM systems from airspace users. Interoperability requires internationally agreed standards, and SESAR works in the context of the ICAO's Global ATM Operational Concept to deliver the technical basis for defining standards through ICAO SARPs (Standards and Recommended Practices) and coordinated industry standards. The existence of such common standards will also lower costs for the manufacturing industry which will be able to design equipment for a global market. This requires collaboration with other parts of the world that are implementing change initiatives, such as NextGen in the US. The role of ICAO is pivotal towards facilitating this collaboration.

The work being done by SESAR and its environmental targets are both fully aligned with ICAO's strategic objective to minimize the adverse effects of civil aviation on the environment. Its new concepts and procedures will, to the greatest extent possible, be developed in coordination with CAEP and other technical panels to ensure global harmonization and acceptability from the outset.

New concepts and procedures will, to the greatest extent possible, be developed in coordination with CAEP and other technical panels to ensure global harmonization and acceptability from the outset.

Conclusions

Ambitious environmental targets are set for the European ATM system by 2020, making environment a priority for SESAR. The European ATM Master Plan defines the roadmap for the step-by-step evolution of the ATM System in Europe and the achievement of the environmental targets. Effective funding and governance arrangements to concentrate R&D activities and execute the European ATM Master Plan have been implemented in Europe with the establishment of the SESAR Joint Undertaking. First technological solutions will be validated by 2012. In the meantime, AIRE has demonstrated that green results can be achieved today. Public-private partnerships and international cooperation are key success factors for the programme.

The SESAR Joint Undertaking is committed to support ICAO in effectively responding to the environmental challenges that global aviation is facing today.

The Environmentally Responsible Air Transport (ERAT) Project

The Environmentally Responsible Air Transport (ERAT) project is a research project, co-funded by the European Commission under the Sixth Framework Programme which addresses the ATM community's need to reduce the environmental impact per flight to allow for sustainable growth. The project is carried out by a consortium of 11 project partners: Airbus, DLR, ENVISA, EUROCONTROL Experimental Centre, LFV, Lufthansa, National Company Bucharest Airports, NATS, NLR, Snecma, To70. The objective of ERAT is to improve the environmental performance of air transport by developing and validating Concept of Operations (CONOPS) for two airports, London Heathrow and Stockholm Arlanda. Both CONOPSs aim for environmental benefits from the top of descent, to touchdown, by focusing on more efficient operations (i.e. less radar vectoring and holding), and enabling Continuous Descent Approaches and Continuous Climb Departures.

The initial results for the London Heathrow concepts showed that the small environmental benefits in terms of less fuel burn, emissions and noise, are at the expense of runway capacity. The London Heathrow concept is planned to be refined and assessed in the fourth quarter of 2010. Two sets of real-time simulations concepts are planned in the second half of 2010 to assess the concept of operations for Stockholm Arlanda, and the results are expected to be available at the end of 2010.

Project ERAT website: ***http://www.erat.aero***

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Airtel ATN of Ireland, Northrop Grumman Park Air Systems of Norway, Saab of Sweden and SINTEF of Norway.

3 **NORACON, the NORth European and Austrian CONsortium, consists of eight European ANS providers:**
Austro Control (Austria) and the North European ANS Providers (NEAP) including AVINOR (Norway), EANS (Estonia), Finavia (Finland), IAA (Ireland), ISAVIA (Iceland), LFV (Sweden) and Naviair (Denmark).

4 **Six major European airport operators form the SEAC consortium**
SEAC includes BAA Airports Ltd, Flughafen München GmbH, Fraport AG Frankfurt Airport Services Worldwide, Schiphol Nederland B.V., Aéroports de Paris S.A. and Unique (Flughafen Zürich AG).

The Atlantic Interoperability Initiative to Reduce Emissions - AIRE

*By **Célia Alves Rodrigues,** SESAR JU*

***Célia Alves Rodrigues** has been the Environment Officer at the SESAR Joint Undertaking based in Brussels, Belgium since March 2010. SESAR's mission is to develop a modernized air traffic management system for Europe for the next thirty years. Célia is SESAR's focal point for environmental issues. As a member of the Economics and Environment Unit she provides guidance on the various projects to ensure that the environmental objectives of the programme are achieved. She is also responsible for the programme management of the Atlantic Interoperability Initiative to Reduce Emissions (AIRE). Célia served at ICAO as an Associate Environmental Officer in 2007, and prior to that she worked with the noise and health unit at the World Health Organization from 2002 to 2006.*

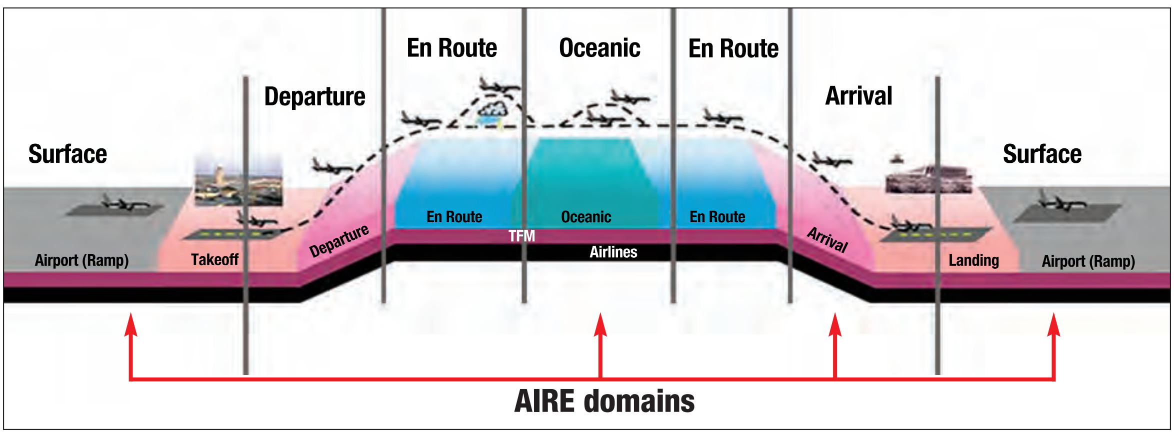
Introduction

The growth of aviation calls for global efforts to efficiently address and mitigate the sector's contribution to climate change and also to reduce local impacts on noise and air quality. In the spirit of partnership and in an effort to undertake concrete action towards the sustainable growth of aviation, the European Commission (EC) and the Federal Aviation Administration (FAA) signed a cooperative agreement establishing the Atlantic Interoperability Initiative to Reduce Emissions (AIRE) in June 2007. AIRE is part of SESAR and NextGen joint efforts to hasten environmental improvements.

AIRE aims to improve energy efficiency, lower aircraft noise, enhance ATM interoperability through the acceleration of the development and implementation of environmentally friendly procedures for all phases of flight (gate-to-gate), and validate continuous improvements with trials and demonstrations. This article presents the AIRE trials conducted during 2009, on the European side, managed by the SESAR Joint Undertaking (SJU). More details can be found on the AIRE executive summary available at **www.sesarju.eu/environment**.

2009 Flight trials

Under the framework of the AIRE programme, approximately 1,150 demonstration trials for 'green' surface, terminal and oceanic procedures took place in five locations, involving 18 partners. Additionally, two full 'green' gate-to-gate flights, from Paris Charles de Gaulle (CDG) to Miami, took place in April 2010.



These trials represented not only substantial improvements for the greening of air transport, but the motivation and commitment of the teams involved, and created momentum to continue to make progress on reducing aviation emissions.

Domain	Location	Number of trials performed	CO_2 benefit flight
Surface	Paris, France	353	190 –1,200 kg
Terminal	Paris, France	82	100 – 1,250 kg
	Stockholm, Sweden	11	450 – 950 kg
	Madrid, Spain	620	250 – 800 kg
Oceanic	Santa Maria, Portugal	48	90 – 650 kg
	Reykjavik, Iceland	38	250 – 1,050 kg
Total		**1152**	**390 tons**

Table 1: *Summary of AIRE trials for 2009.*

Ground movements

The AIRE ground movements' project was conducted by a consortium involving Aéroports de Paris, the French Direction des Services de la Navigation Aérienne (DSNA) and Air France. The positive results of the trials demonstrated that the necessary steps toward deploying and routinely using the tested procedures (planned for the summer of 2010) have already been taken .

Three types of innovative ground movement measures were evaluated: "Departure taxiing with one or two engines off," with the objective of measuring fuel savings; "Minimising arrival taxi time," with the objective of reducing arrival taxi time, when possible; and "Minimising departure taxi time," with the objective of optimising the sequence of departures to reduce the waiting time at the departure threshold.

Regarding "Departure taxiing with one or two engines off," for the four engine aircraft (B747), the observed fuel consumption reduction was about 20 kg/minute with two engines off and 10 kg/minute with one engine off. For the "Minimising arrival taxi time," benefits came from a mean reduction of taxi-in time of about 1min. 45s per aircraft parking in specific areas and also on a positive in-flight impact of 30 seconds (two miles) on the assigned aircraft approach trajectory. For the A320 family, benefits were estimated at about 50 kg fuel savings per arrival flight taxiing to parking area, equivalent to 160 kg CO_2 savings. For "Minimising departure taxi time," the departure taxi time was reduced by an average of 45 seconds per flight in nominal conditions, and by about one minute per flight in non-nominal conditions. The estimated total fuel savings for these limited trials were approximately six tons, equivalent to 19 tons of CO_2 savings. According to ATC, such benefits could be reproduced for the four most important departure peak periods.

Terminal

Three consortiums in three different locations carried out projects for the terminal area. In **Stockholm, Sweden**, AVTECH, the LFV Group, Novair, Egis Avia, Thales, and Airbus, with the contribution of an Expert Advisory Group, carried out the Minimum CO_2 in the TMA (MINT) project. Optimised (addressing both lateral as well as vertical parts of the approach) aircraft operations during descent into Stockholm Arlanda airport were performed by combining benefits from using the aircraft Required Navigation Performance (RNP) capability with benefits from flying efficient Continuous Descent Approaches (CDAs). The project identified 165 kg of potential fuel savings for the 01R runway when arriving from the south and 140 kg potential savings if also including other directions and other runways to the baseline performance. The observed lateral navigation precision of flight of the aircraft was excellent. The RNP procedure also proved itself to be a strong tool for addressing noise distribution problems by enabling circumnavigation of the areas. From an operational perspective, no problem was identified in implementing the new procedure which is planned to enter into normal operation very soon, during low traffic periods.

The **Paris** project was conducted by a consortium composed of the French DSNA and Air France. The demonstrations included: Continuous Climb Departure (CCD) from Charles de Gaulle (CDG) and from Orly (ORY) to North West; Tailored Arrivals to CDG and to ORY from North West; and CDA to ORY from South West.

The "CCD to North West" showed about 30 kg of fuel savings per flight at CDG and about 100 kg of fuel savings at ORY (about 100 kg and 300 kg of CO_2 savings, respectively). For "Tailored Arrivals from the North West", the procedures included an enhancement of the vertical profile from cruise to an Initial Approach Fix. In addition, for ORY it involved an optimisation of the downwind leg by raising a flight level constraint. The results varied from 100 kg to 400 kg of fuel savings per aircraft at CDG, depending on the West or East configuration, and about 200 kg of fuel at ORY (on average about one ton and 600 kg of CO_2 savings respectively). The demonstrations of the "CDA to ORY from South West" showed about 175 kg of fuel savings per flight (i.e. about 530 kg of CO_2 savings).

In **Madrid, Spain**, Air Navigation Service Provider and Airports Operator of Spain (AENA), Iberia and INECO conducted the RETACDA project. The objective was to perform integrated flight trials and demonstrations in the Terminal Area (TMA) using a CDA, with the aim of reducing CO_2 emissions and of optimising the fuel consumption in the TMA around Madrid-Barajas airport. CDA procedures were performed at night using A320 and A340 Iberia fleet in a North configuration. Data from other flights in the same fleet, not performing CDAs, was used as a baseline to compare the CDA fuel savings benefit, estimated at approximately 80kg. For the four engine aircraft (A340), the fuel consumption reduction was about 260kg. For both types of aircraft, around 25% less fuel during descent was consumed performing "CDA" rather than "non-CDA". Translated to emissions reductions, the results show that the potential savings per flight are about 250 kg and 800 kg of CO_2 respectively.

Oceanic

Two projects in two different locations tested the optimisation of flight profiles. In **Santa Maria, Portugal** the NATCLM Project was conducted by a consortium composed of Adacel (ATM system supplier), Air France, NAV Portugal and TAP Portugal. Several demonstration flights with Air France B777 and TAP Portugal A330 provided data and derived results for the project. Flights were from Paris to the Caribbean West Indies and also between Portugal and North, Central and South America. The demonstrations were carried out inside the Santa Maria Oceanic Flight Information Region (FIR) (ICAO NAT region) managed by NAV Portugal. The FAA supported some of the flights, allowing the extension of the flight profile optimisation from Santa Maria FIR to inside the New York Oceanic FIR.

The vertical (cruise climb) optimisation demonstration was performed with a manual cruise climb like function with a sequence of 100 ft climbs. Overall, an estimation of savings relative to cruise climb showed potential savings of 29 kg of fuel (i.e. savings of approx. 90 kg of CO_2) compared to a 2,000 ft step climb or 12 kg (i.e. savings of approx. 40 kg of CO_2) or two 1,000 ft step climbs (i.e. six kg of fuel per each 1,000 ft climb performed in 100 ft steps). For lateral optimisation (horizontal), the pilot was allowed to optimise the route with the most up-to-date meteorological information. With the updated met data, a new flight plan could be calculated in-flight. In some cases, the route could be optimised and thus a different route was flown. The fuel savings using this technique varied, with values of up to 90 kg (i.e. savings of approx. 300 kg of CO_2) saved for an Airbus A330 flying from Lisbon to Caracas. For the longitudinal optimisation (time, cost index – Mach number), the study used the comparison of the flight plans computed with derived constant Mach number and the actual cost index (CI). By definition, flying at economic speed (i.e. at the given cost index) minimises total costs and therefore determines the cost savings obtained by flying at that given cost index when compared to flying at a constant Mach number. Significant savings have been computed in the range of 130 kg to 210 kg of fuel per flight.

Since the end of the demonstrations, several airlines are being cleared by Santa Maria FIR on a daily basis to perform profile optimisations. The enhancements identified are expected to bring a valuable contribution by allowing aircraft to fly as close as possible to their business trajectory and consequently, maximise fuel efficiency and minimise CO_2 emissions.

The Oceanic-Nat ADSB Project in **Reykjavik, Iceland** was conducted by a consortium composed by the Service Provider ISAVIA, Icelandair and TERN Systems. The project aimed at demonstrating, through simulations and flight trials, the environmental benefits that can be achieved by pursuing more optimal flight profiles using cruise climb, direct routing, and variable speed in ISAVIA's proposed ADS-B oceanic corridor within the Reykjavik Control Area (CTA).

Icelandair ran 38 flight trials on the Keflavik – Seattle route between October 2009 and January 2010. Icelandair's flight control evaluated each flight and executed step climbs, with a reduced rate of climb (approximation of optimised cruise climb), direct routing, and/or variable speed when desirable. Fuel data was logged and compared to baseline fuel consumption using a statistical approach. For the variable speed, flight trial savings results are inconclusive, as the comparison to aircraft supposed to fly at a constant Mach did not actually fly at a fixed Mach number. This led to unreliable data on consumption even though earlier results from Icelandair flying cost/index showed considerable fuel savings. In the current environment and with some adaptation of the Flight Data Processing System, it may be possible to use the procedure insofar as its use is limited to the Reykjavik CTA low density area of the airspace and within the surveillance corridor.

The vertical (limited cruise climb) optimisation demonstration was performed with vertical speed of 100 ft per minute and 1000 ft step climbs. Overall, an estimation of savings relative to cruise climb showed potential savings of 330 kg of fuel (i.e. saving approx. 1040 kg of CO_2). For direct routings, flight trial savings are reported at approximately 80 kg fuel reductions or 252 kg of CO_2. Medium savings were obtained mainly because the Reykjavik CTA already offers maximum flexibility within the NAT structure.

Full gate-to-gate flights

The two first complete (gate-to-gate) green transatlantic flights were operated in April 2010 from CDG to Miami airport. The flights were carried out by Air France (6 April) and American Airlines (7 April). During the approximately nine hours of flight, enhanced procedures were used to improve the aircraft's energy efficiency. These procedures, applied at each flight stage and coordinated among all project participants, reduced fuel consumption (and hence CO_2 emissions) throughout the flight, from taxiing at CDG to arrival on the parking stand in Miami. During the departure and arrival phases, the procedures helped minimise noise levels. Air France estimates that applying these optimisations to all Air France long-haul flights to and from North America, would result in a reduction of CO_2 emissions by 135,000 tons per year, with fuel savings of 43,000 tons.

Conclusions

In 2009, having performed 1,152 trials, the AIRE programme was successful in demonstrating that significant savings can be achieved using existing technology. CO_2 savings per flight ranged from 90 to 1,250 kg and the accumulated savings during trials were equivalent to 400 tons of CO_2. Another positive aspect was the human dimension - the projects boosted crew and controller motivation to pioneer new ways of working together focusing on environmental aspects and enabled cooperative decision making towards a common goal.

Lessons learned and best practices from the AIRE trials are also going to be implemented in the SESAR work programme, thus, allowing the broad deployment and standardisation of these procedures. In January 2010, a new call for tender was launched by the SJU for AIRE allowing the performance of more green operations and significant fuel savings to take place in 2010 and 2011. The new AIRE projects cover all of the North Atlantic, are closely linked to deployment and place a greater focus on gate-to-gate solutions.

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The ASPIRE Project

By ***Japan Civil Aviation Bureau***

Hideki Sugai *is Director of the Air Traffic International Affairs Office, JCAB. He has extensive experience in Air Traffic Control of terminal, en-route, and oceanic airspace. From 1998 to 1999 he worked in Nepal to assist the implementation of Kathmandu airport's terminal radar control. He was also a member of the ICAO Obstacle Clearance Panel (OCP) from 2001 to 2003. Just before his current post, he was an administrator of Matsuyama airport. He studied Russian and politics at the Kobe City University of Foreign Studies. He is also a semi-professional jazz bassist.*

Introduction

The air transportation industry is essential for global future economic growth and development. In 2007, more travellers than ever before, nearly 2.2 billion people, flew on the world's scheduled air carriers, with predictions of 9 billion passengers by 2025. In the Asia Pacific region, the rapid movement of people and materials provided by aviation will be crucial to continued economic growth over the next few decades.

In 2008, Airservices Australia, Airways New Zealand and the Federal Aviation Administration (US-FAA) joined forces to create the Asia and South Pacific Initiative to Reduce Emissions. Since the group inception the ANSP membership has expanded with the inclusion of Japan Civil Aviation Bureau (JCAB) in 2009 and the Civil Aviation Authority of Singapore (CAAS) in 2010. The project is now known as the ASia Pacific Initiative to Reduce Emissions (ASPIRE).

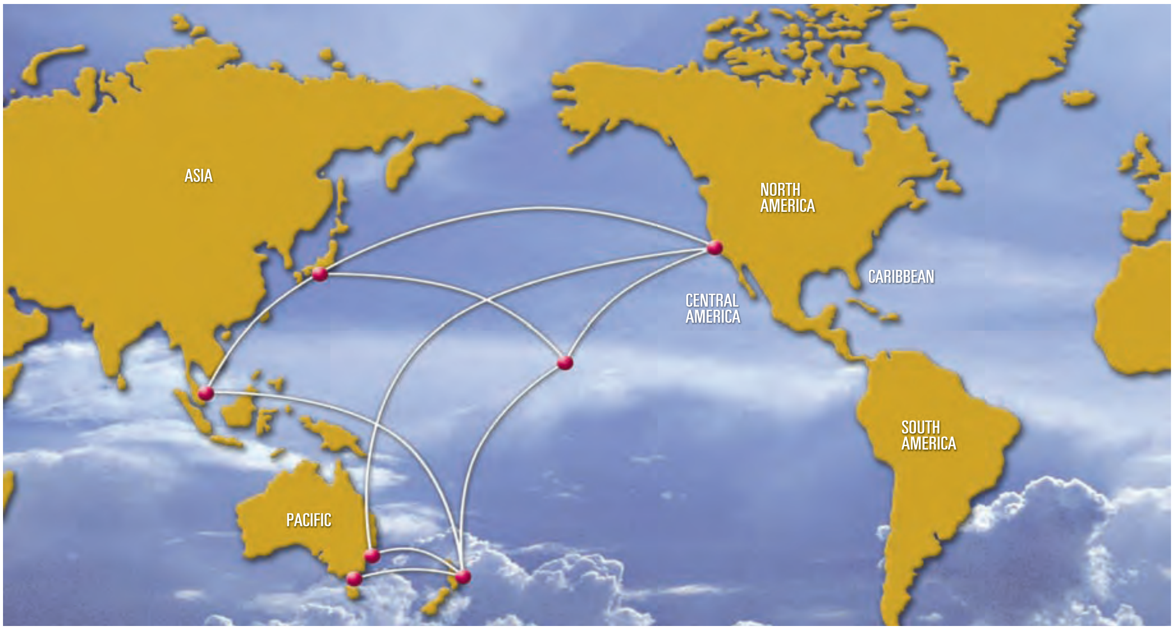
The ASPIRE project

ASPIRE is a collaborative approach to the environmental stewardship of Asia and South Pacific aviation. The joint venture is designed to lessen the environmental impact of aviation across Asia and the South Pacific with each partner to focus on developing ideas that contribute to improved environmental standards and operational procedures in aviation. Working closely with airline partners, Air New Zealand, Qantas, United Airlines, Japan Airlines and Singapore Airlines, ASPIRE will measure the efficiency of every aspect of the flight from gate-to-gate. ASPIRE is committed to working closely with airlines and other stakeholders in the region in order to:

- Accelerate the development and implementation of operational procedures to reduce the environmental footprint for all phases of flight, from gate-to-gate;
- Facilitate the use of environmentally friendly procedures and standards world-wide;
- Capitalise on existing technology and best practices;
- Develop shared performance metrics to measure improvements in the environmental performance of the air transport system;
- Provide a systematic approach to ensure appropriate mitigation actions with short, medium and long-term results; and
- Communicate and publicise ASPIRE environmental initiatives, goals, progress and performance to the global aviation community and the general public.

Operational measures

ASPIRE promotes recommended procedures, practices and services that have demonstrated or shown the potential to provide efficiencies in fuel and emissions reductions. These encompass all phases of flight from gate-to-gate, and are designed to reflect the unique nature of the Asia and Pacific region, where international flights often exceed 12 hours in duration.



Pre-flight operations are enhanced with:

- *the use of more accurate estimations of loaded fuel;*
- *the weight reduction of cargo containers and of onboard loaded material;*
- *the extended use of ground electricity; and*
- *the engine washing.*

Ground operations are also improved by:

- *tailoring water uplift;*
- *just in time fuel loading; and*
- *optimizing ground traffic control mangement.*

After shortening the distance to reach the optimum cruising altitude after take-off, *air navigation* improvements fall into two categories: the oceanic flight and the arrivals management. User Preferred Routes, Dynamic Airborne Reroute Procedures, Performance Based Navigation (PBN) Separation Reductions, Reduced Vertical Separation Minima (RVSM) and flexible track systems are implemented during oceanic flight phases. Continuous Descent Arrivals, Tailored Arrivals, PBN Separation and Required Time of Arrival management are part of the operational measures used in the arrival flight phase.

Demonstration flights

As part of establishing a baseline for air traffic management performance and carbon emissions, the initial ASPIRE partners undertook a series of 3 trans-Pacific flights operating a B777, an A380 and a B747-400 aircraft to demonstrate and measure gate to gate emissions and fuel savings using existing efficiency procedures. Each flight was managed by an ASPIRE founding member air navigation service provider and involved close collaboration with the airline partners. These three flights resulted in a total fuel saving of 17,200 kg representing a CO_2 emissions reduction of 54,200 kg. Two additional demonstration flights, conducted by JCAB and CAAS in sequence, both operating a B747-400 aircraft, showed fuel savings of about 15,600 kg representing a CO_2 emissions reduction of about 47,000 kg.

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Operational Measures to Reduce Carbon Dioxide Emissions from Aviation: Initiatives from New Zealand

*By **Shannon Scott**, Civil Aviation Authority of New Zealand*

***Shannon Scott** joined the Civil Aviation Authority of New Zealand (CAA) in 2009 as Senior Policy Adviser for Aviation Environment. He joined the CAA from the Ministry of Research, Science and Technology, where he was responsible for developing international science cooperation programmes with partners in North Asia. Prior to joining the public service, Shannon managed an International Programmes team at the University of Canterbury, New Zealand, providing customised education and training programmes for international clients in areas such as environmental management and public sector management.*

Shannon has degrees in Geography (with a focus on Climatology) and Chinese language, and has also completed an FAA-approved aircraft dispatcher certificate course.

Aviation is extremely important to New Zealand, both economically and socially. Because the country is geographically remote from major world centres, international aviation helps it stay connected, carrying more than two million visitors each year. Domestic air transport helps overcome New Zealand's mountainous island terrain with speed and efficiency. General aviation is also a significant component of aviation in New Zealand. Altogether, there are more than 4,400 aircraft on the New Zealand register, one for every 1,000 residents.

At the same time, the country's environmental assets are of enormous value to it. Tourism relies heavily on the quality of the environment, and is New Zealand's second largest export earner. There is therefore a strong interest in ensuring the sustainability of aviation in New Zealand.

This article presents an overview of operational measures that the New Zealand aviation industry has introduced to reduce emissions. It concludes with a brief look at some of the advantages of Performance Based Navigation (PBN), which will be an important factor in future efficiency gains, and New Zealand's development of an Airspace and Air Navigation Plan.

Air Traffic Management

Airways New Zealand (Airways) is the body that provides air navigation services for aircraft flying in most of the airspace administered by New Zealand, which covers an area of 30 million square kilometres. Airways's Vision 2015 document, *A Strategic Vision of Air Traffic Management in New Zealand to 2015 and Beyond*[1], has been prepared to guide its long-term development. Vision 2015 envisages an operating environment where an aircraft's profile is managed from departure gate to arrival gate, with a shift in the primary role of air traffic management from tactical control towards strategic control and exception management – *or air traffic enabling*. Emissions management is one of the core elements of this new system, which may incorporate systems and tools that minimize intervention, minimize flight time, and facilitate best-economy power setting wherever possible.

Collaborative Flow Manager

One of the initiatives supporting Vision 2015 is Collaborative Flow Manager (CFM). This system, previously known as Collaborative Arrivals Manager (CAM), helps airlines and controllers avoid unnecessary airborne delays and holding during bad weather and at peak times, by sharing real-time flight information through a web-based interface. It allows decisions to be made to hold flights on the ground rather than incur in-flight holding and delay vectoring.

CFM has been implemented at Auckland and Wellington airports, but the benefits of reduced disruptions have spread across the entire network. Before CFM was introduced in September 2007, monthly airborne delays at Auckland and Wellington added up to an average of about 28,000 minutes; this figure fell to less than 5,000 minutes in 2009. Airways estimates that CFM saved emissions of 25,000 tonnes of CO_2 during 2009 for domestic flights into Auckland and Wellington, and 32,000 tonnes of CO_2 across the network, including international flights into Auckland (Figure 1).

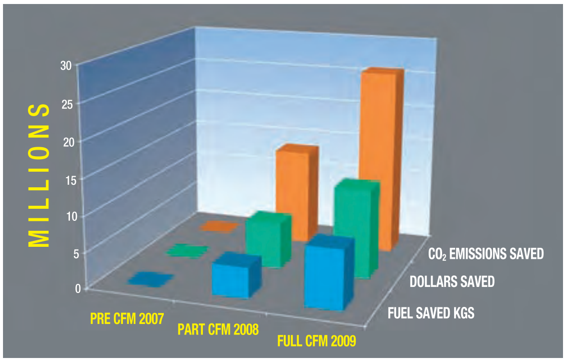

Figure 1: *Fuel and CO_2 savings from Collaborative Flow Manager (CFM).* Courtesy of Airways New Zealand.

Airlines have seen measurable benefits from CFM. Pacific Blue recorded a decrease in airborne delays of almost 15,000 minutes between 2008 and 2009 on their fleet of 737-800s, as the use of CFM became fully embedded in their operations (Figure 2).

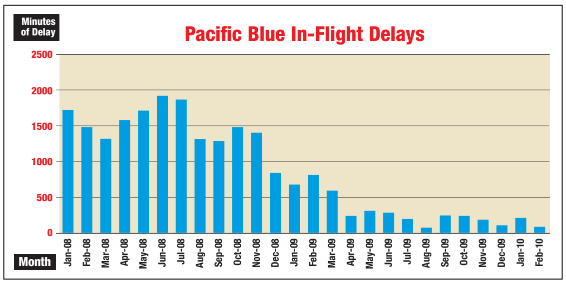

Figure 2: *In-flight delays incurred by the Pacific Blue fleet.* Courtesy of Airways New Zealand and Pacific Blue.

With CFM, international arrivals are visible to controllers two hours away, so controllers can make better flow assessments to manage these flights. As a result, airborne delays incurred by international arrivals into Auckland have been reduced from an average of 1,600 minutes per month, to 400 minutes under CFM (Figure 3).

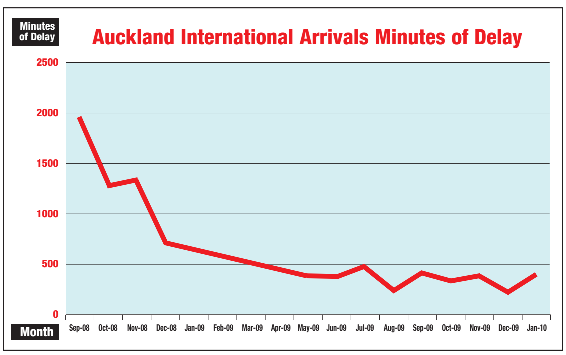

Figure 3: *Minutes of in-flight delay incurred by international arrivals at Auckland International Airport.* Courtesy of Airways New Zealand.

Oceanic

Airways New Zealand's Oceanic Control System (OCS) manages aircraft flying through the Auckland Oceanic Flight Information Region (FIR). The OCS incorporates a range of measures to enable safe and efficient flight profiles, facilitated by an automated conflict detection system. These measures include reduced horizontal air traffic separation to 30 nautical miles longitudinal and lateral (30/30 separation, first implemented in New Zealand Oceanic airspace), flexible track systems, dynamic airborne reroute procedures (DARPs) and user-preferred routes (UPRs).

UPRs are available for all flights in the Auckland FIR. In 2008, Air New Zealand reported that UPRs were saving them an average of 616 kg of fuel per flight to Japan and Shanghai, a total of over 1 million kg of fuel per year[2].

ASPIRE

Airways is a founding member of the Asia and Pacific Initiative to Reduce Emissions (ASPIRE) partnership, which now includes the US Federal Aviation Administratio (FAA), Airservices Australia, the Japan Civil Aviation Bureau, and the Civil Aviation Authority of Singapore[3]. The partnership aims to demonstrate and implement operational procedures that reduce aviation's environmental footprint and also increase its efficiency.

Air New Zealand operated the first ASPIRE demonstration flight, on a Boeing 777 from Auckland to San Francisco, on 12 September 2008. This first flight saved an estimated 3,500 kg or 4% of fuel, equivalent to a reduction in emissions of 11,000 kg of CO_2. The results of these "ideal flights" are forming the basis of benchmark metrics for fuel and emissions, which will be presented in the 2010 ASPIRE Annual Report. One of the next challenges for ASPIRE is to insert the benefits of the "ideal flights" fully into daily operations, something which is planned to begin in 2010 with daily ASPIRE flights on selected routes.

Airline Operations

Air New Zealand has either implemented or has under way 40 to 50 projects to reduce fuel use and associated greenhouse gas emissions. Since 2005, excluding new aircraft purchases, their operational fuel savings initiatives have reduced total fuel burn by 4.5% across the fleet, equivalent to 130,000 tonnes of CO_2. The savings for the domestic Boeing 737-300 fleet have been even greater, reaching 6%.

The airline has introduced a range of techniques to optimize operations, including:

- Continuous descents and tailored arrivals (where available), with the ultimate aim of implementing 4-dimensional trajectory (4DT) approaches using required navigation performance – authorisation required (RNP AR) to minimise track distances.
- Flying aircraft slower, and using delayed flap approaches.
- Reverse idle thrust on longer runways, and single engine taxi-in.
- Reducing the use of auxiliary power units (APUs).
- Just-in-time fuelling.

Air New Zealand recently installed blended winglets on its fleet of five B767-300s. These 3.4 metre high extensions, developed by Aviation Partners Boeing, are helping the airline save an average of 5.5% in fuel burn, equivalent to over 18,000 tonnes of CO_2 emissions a year.

The airline is a launch customer of the B777-200 performance improvement package, which is expected to save 1% of fuel. The package includes three technical modifications that reduce airplane drag: drooped ailerons, lower-profile vortex generators, and an improved ram air system for the environmental control system. They have also installed zonal driers on their B767s and A320s to remove the weight of excess moisture from fuselage insulation. Installation of zonal driers on the B777-200s is currently under development.

Upgrades to the airline's fleet are expected to deliver a significant change in efficiency beginning with the first delivery of new aircraft at the end of 2010. In November 2010, B777-300s will begin taking the place of B747-400s. The new aircraft are up to 15% more fuel efficient per passenger. The airline is the launch customer for the new "sharklet"-equipped A320, which will be delivered starting in 2012. Airbus expects that the "sharklets", a type of winglet, will reduce fuel burn by up to 3.5% over longer sectors. In addition, the airline is the launch customer of the Boeing 787-9. It has eight aircraft on order to replace its fleet of B767s, with an associated estimated fuel efficiency gain of around 20%.

Airport Operations

Although airport operators make a small overall contribution to aviation's total emissions, their significance as gateways to communities, cities and nations can give them a visible leadership role when they undertake emissions reduction measures.

Christchurch International Airport, the largest airport in the South Island, was the first airport in the Southern Hemisphere to gain carbon-neutral certification. This was achieved in 2008 through CarboNZero[4], a leading programme set up by one of New Zealand's government-owned research institutes, Landcare Research.

As well as measuring emissions, the CarboNZero programme also requires the airport to reduce its emissions. The airport operator has undertaken a range of projects to achieve this, including:

- Identifying and addressing energy inefficiencies in the terminal building.
- Using groundwater as a heat sink for air conditioning systems.
- Using a lower-temperature paving system and recycling asphalt during runway maintenance.
- Establishing a comprehensive recycling system for public areas.

Auckland International Airport, the country's main international gateway, participates in the Carbon Disclosure Project's annual survey of companies. The company has also been listed on the FTSE4Good index in the UK on the strength of their sustainability reporting and carbon disclosure. Their emissions reduction projects include:

- Introducing low-emission vehicles, which reduced greenhouse gas emissions by 67 tonnes over two years.
- Establishing an airport-wide staff travel and car pooling programme, now involving over 800 staff from more than 20 companies. This programme is potentially reducing CO_2 emissions from staff travel to and from work by up to 70 tonnes per annum.
- Installing a 300m^2 solar photovoltaic array, one of New Zealand's largest, on the roof of the international arrivals area. The array is saving up to 49,500 kWh of electricity supply a year.

- Installing solar hot water panels to supply passenger facilities, generating electricity savings of up to 15,000 kWh per year.
- Undertaking a detailed energy audit of the international terminal, which identified potential energy savings of 22%, equating to a potential reduction in total carbon footprint of 13%.

Next Steps

Performance Based Navigation

PBN , with its reduced reliance on ground-based navigation aids, will be a major component of future efficiency gains. Procedures under the two sets of PBN standards – area navigation (RNAV) and required navigation performance (RNP) – have been implemented in New Zealand airspace at selected airports and on selected routes, including in Oceanic airspace.

RNAV standard terminal arrivals (STARs) have been introduced at the three main international airports of Auckland, Wellington and Christchurch. The Wellington RNAV STAR saved an estimated 1,170 tonnes of CO_2 over the first nine months of 2009, due to the shorter distances flown by arriving aircraft.

Queenstown Airport, located in a mountainous region, was the first New Zealand destination to have required navigation performance – authorization required (RNP AR) approach procedures defined. These procedures are helping Qantas and Air New Zealand avoid costly flight diversions when visibility at Queenstown is low. During the first 12 months of Air New Zealand's B737 operations into Queenstown using the new procedures, the airline avoided 46 diversions and 40 cancellations of inbound flights. In nearly seven years of RNP AR operations into the airport, Qantas has recorded only four diversions, none of which were directly related to visibility.

A second RNP AR approach was published in April 2010 for Rotorua Airport, which is also terrain-constrained. New Zealand will be working to roll out additional PBN procedures over the coming years, as detailed in the New Zealand PBN Implementation Plan[5].

Airspace and Air Navigation Plan

The Civil Aviation Authority of New Zealand (CAA) is now in the process of developing a national airspace and air navigation plan. This will set a framework for airspace and air navigation in New Zealand in alignment with the ICAO Global Air Navigation Plan. The plan will be aimed at maintaining an accessible, integrated, safe, responsive and sustainable system, with high levels of efficiency, safety, security and environmental protection. This will help ensure that the New Zealand industry can make the best use of new technologies such as PBN, and ensure full interoperability with the rest of the world.

Conclusion

Given New Zealand's reliance on efficient air transportation, the aviation industry is very active in a broad range of measures to reduce emissions from operations. These initiatives will all help maintain the industry's performance and resilience in the years ahead.

While individual organizations can and do make a difference, a whole-of-system approach will increasingly be needed to achieve the greatest possible efficiencies. The New Zealand Airspace and Air Navigation Plan, with environmental performance as one of its cornerstone elements, is one measure that will assist in achieving this in New Zealand.

The author wishes to acknowledge the assistance of the following organisations in the preparation of this paper

Airways Corporation of New Zealand, Air New Zealand, Pacific Blue, Qantas Airways, Christchurch International Airport, Auckland International Airport.

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Environmental Benefits Of New Operational Measures

A Case Study: Brasília Terminal Area

*By **Jorge Silveira, Rafael Matera, Daniel Nicolato, Luiz Brettas, Wilton Vilanova Filho and Cesar Rosito** from ANAC and **Júlio Cesar Pereira, McWillian de Oliveira and Ronaldo da Silva** from DECEA*

National Civil Aviation Agency *(ANAC – Brazil)*
ANAC is the Brazilian civil aviation authority. The Agency is responsible for the regulation and the safety oversight of civil aviation. Established in March 2006, ANAC incorporated the staff, the structure and the functions of the Air Force's Civil Aviation Department (DAC), the former civil aviation authority.

Department of Airspace Control *(DECEA – Brazil)*
DECEA is a governmental organization, subordinate to the Ministry of Defense and to the Brazilian Air Force, that gather human resources, equipment, accessories and media infrastructure aimed to establish security and fluidity of the air traffic in Brazilian airspace and, at the same time, ensure its defense.

This article briefly describes some of the recent changes in air navigation and airport operations at President Juscelino Kubitschek International Airport, in Brasília, the Brazilian capital. These changes include the implementation of Performance-Based Navigation System, and changes in runway and taxiway management. The improvements achieved also contribute to the mitigation of environmental impacts in the area.

Background

The Brazilian Civil Aviation sector has recently been experiencing a period of significant growth. The volume of domestic and international aviation traffic increased approximately 25% during the years 2000-2008. With 2.1 million annual movements, the aircraft traffic in 2008 was the most since 2001. Brasília's international airport ranks third in Brazil in terms of aircraft movements and passengers. Due to its strategic location, the site is now becoming one of the main hubs of the country.

The Brasília Terminal Area (TMA) is located right in the middle of Brazilian territory. It acts as a hub for much of the national air traffic and connects the North and Northeast cities to the South and Southeast regions, playing a crucial connecting role in the territory. In addition, all of the international flights originating in Central and North America that are destined for the main airports in the southern region of the continent are controlled by this area. In this broad context, the consideration of environmental issues is important because the massive amount of operations that take place in this area have the potential to generate a significant environmental impact, both locally and globally.

This article presents a case study of the environmental impacts of operational changes made at Brasília airport and the surrounding terminal area. This includes a description of the recent and planned improvements, both in the airspace concept and airport airside operations, as well as the effects of these changes related to emissions and noise impacts. Specifically, it presents a brief assessment of the effects on carbon dioxide emissions derived from those changes.

Operational Improvements

The growth of air traffic and the volume of operations at the Brasília Airport have been accompanied by an increase in environmental problems. The initial concern was about noise complaints, but more recently, concerns have also been raised about engine emissions. In order to address these impacts, technical and operational measures have been implemented at the airport and in the general terminal area.

Two specific examples of recent operational improvements in the airport and TMA are presented in this article and their environmental implications are described. The first one refers to the recent redesign of the airspace at the Brasília Terminal Area, from sensor-based to performance-based navigation (PBN), aimed at producing more efficient, streamlined and safe use of airspace. The second one refers to some ongoing modifications in runway and taxiway management, introduced to optimize the taxiing operations, thus reducing taxiing time and the concomitant fuel burn.

Terminal Area Airspace Concept Improvements

Air navigation in Brazil is currently undergoing significant technology-related changes. This revolution has been made possible by a number of factors including: technological advances in aircraft, improved air navigation hardware and software, and development of more precise satellite positioning systems. These changes have been facilitated by increased investments that resulted from new political decision-making frameworks. As a result, Brazil is in the middle of a transition from sensor-based navigation to PBN. *(This is fully explained in ICAO Doc. 9613, Performance-based Navigation Manual: a Component of CNS ATM).*

The PBN concept is based on the use of area navigation capabilities and monitoring/alerting systems that are installed in modern aircraft. These elements allow improvements in airspace design by reducing the constraints on flight paths that were previously imposed by land-based navigational aids. This framework allows airspace planners to pursue specific goals, not only in terms of operational capacity and safety levels, but also with respect to environmental targets like fuel efficiency and fuel savings.

The implementation of these new airspace concepts in Brazil, including PBN, started in 2010. A multi-phase program is being implemented, the first stage of which involves the Brasília and Recife Terminal Areas. The new routes in these areas were implemented in April 2010.

The design of the Brasília airspace concept takes into account the central location of the airport in the country and other significant features. The model used is called a "four corners scheme", with entry points concentrated approximately in ordinal directions[1] and exit points in cardinal directions[2]. The design process for this system involved extensive use of both real and fast-time simulations, as well as ongoing input from airlines and other stakeholders.

With respect to air navigation, the adoption of this concept involved a very subtle change in the length of actual flight paths. The main reason this was relatively minor was because the airspace of the area was already well designed prior to the implementation of PBN. Nevertheless, important gains were obtained in fuel savings and reductions of greenhouse gas emissions. Other important benefits were also obtained such as improved traffic control and safety, as well as reductions of the workload of pilots and air traffic controllers.

The next step on the implementation of the PBN program will be the design of new airspace concepts for the São Paulo and Rio de Janeiro terminal areas, the busiest TMAs in Brazil.

Runway and Taxiway Management Improvements

In 2005, the second runway of the Brasília Airport (11R/29L) was opened, significantly increasing the overall capacity of the runway system. This also caused changes in the take-off operations that were transferred to the new threshold 11R. A special noise abatement procedure was created which required all aircraft to make a right turn after take-off, avoiding the overflight of populated areas. This measure represented a very effective way to meet a strategic objective set by ICAO, namely "*to limit or reduce the number of people affected by aircraft noise.*"

The change, however, involved trade-offs between noise and emissions. Indeed, the new configuration resulted in increased taxiing distances, and consequently, increased fuel burn and engine emissions.

In view of this fact, ATC recently adopted new procedures for the use of runways. A new schedule was adopted between 06:00h and 22:00h (local time). During this period the take-offs will occur on the runway 11L. The aircraft will take-off with a steeper climb until reaching 6,000 feet (about 1,800 meters) above sea level. The main objective of this procedure is to leave the residential area as quickly as possible. Only after reaching the recommended altitude, is the pilot allowed to manoeuvre toward the planned route of the flight. Advantages of using this procedure are shorter taxiing distance and reduced noise disturbance in the neighbourhood.

Between 22:01h and 05:59h (local time), the airport will operate with all take-offs on Runway 11R and the landings on 11L, in order to avoid night-time noise impacts. In this case, even with the higher fuel consumption generated by the greater taxiing distance, it is believed that the environmental trade-off is positive. The benefits are related to the avoidance

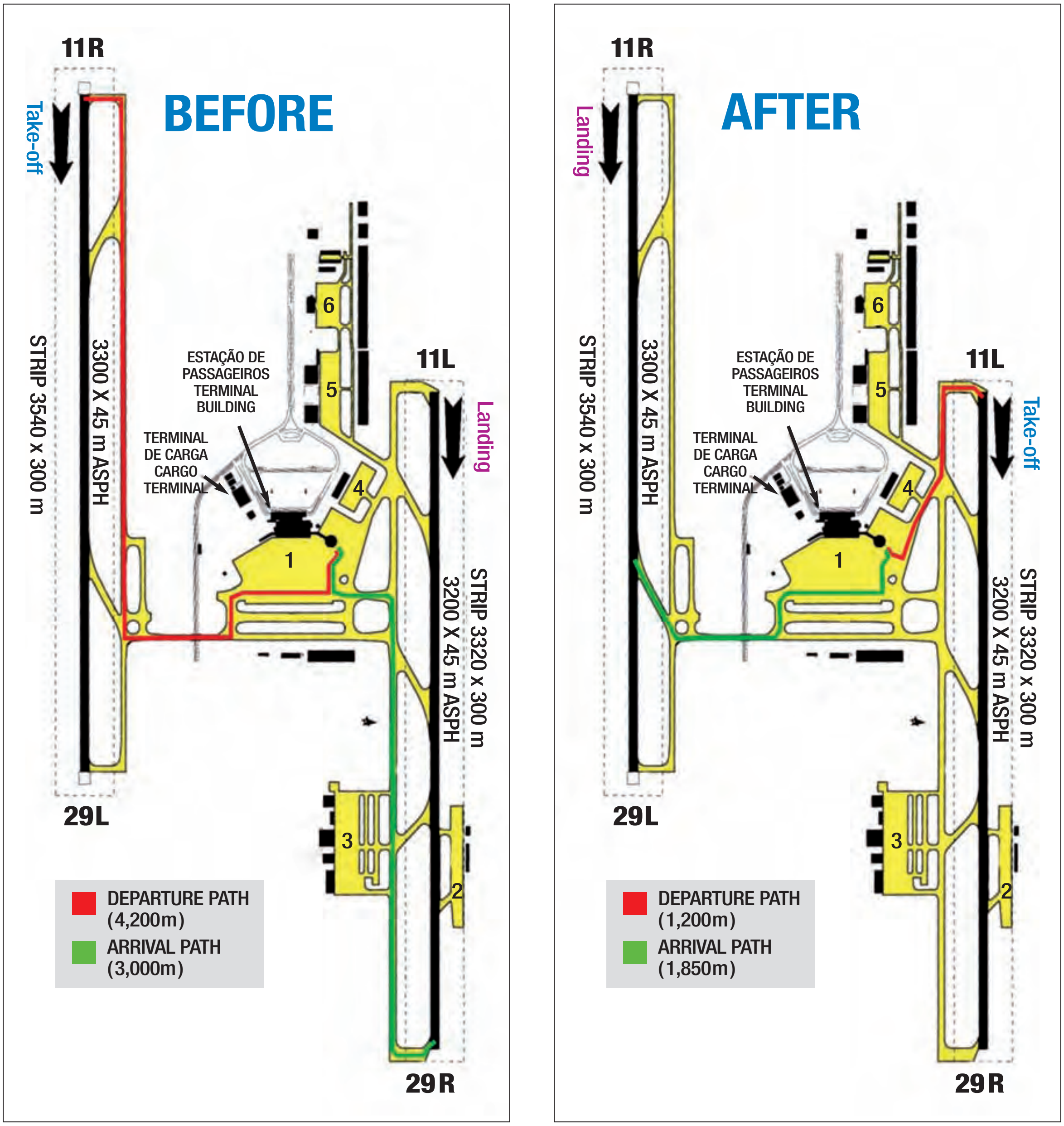

Figure 1: *Brasilia International Airport – Runway operations changes. Adapted from AIP (DECEA).*

of populated areas during the departure procedures and the reduced number of operations during the night period.

These procedure modifications were based on the fact that, the aircraft fleet operating nowadays in Brazil is one of the most modern in the world. As a result, the aircraft are quieter than the old ones operated at the time when the original procedures were established for noise mitigation.

Assessment of Impacts On Emissions

The assessment of the environmental impacts of these changes is in its preliminary stages, as the implementation of the new Brasília TMA PBN concept is quite recent. Nevertheless, first simulations indicate important potential savings in fuel consumption and reduction in emissions.

The simulations to evaluate the impacts of the implementation of PBN were performed using fast-time simulation techniques with the Total Airspace & Airport Modeler (TAAM). For the baseline simulation, March 18, 2008 was used as the representative day, with 270 movements including landings and take-offs. Runway 11L was used for landings and Runway 11R for take-offs, corresponding to the "usual" operation. The fuel savings were estimated and then converted into carbon dioxide reductions.

The simulation showed a small reduction of about 75,500 kg of CO_2 per day in the emissions from aircraft operating in the terminal area, or approximately 0.11% of all daily carbon dioxide emissions. This reduction, although small, is equivalent to the fuel use and emissions, of about 10 flights of a Boeing 737 from São Paulo to Brasília.

TAAM was also used to evaluate the changes in runway and taxi areas. Moving the landings to Runway 11R and take-offs to Runway 11L resulted in an average shortening of 2.5 km in taxiing distances, resulting in matching fuel savings.

In terms of emissions, this represents a daily saving of about 63,000 kg of jet fuel, due to reduced taxi times. This works out to an equivalent reduction of 198,000 kg of CO_2 emissions, or about 72,000 tons/year of CO_2 emissions around the airport. This is a substantial result that may be even more important in terms of its impact on overall local air quality.

Summary and Conclusions

Brazilian aviation is experiencing significant growth, which reflects the recent boom in economic development but can also generate environmental negative impacts. The increase in the number of aircraft and operations has generated a rise in the emissions of greenhouse gases and aircraft noise rates.

In order to establish a process that makes this growth compatible with the environmental demands, it is necessary to improve the management of airspace and the ground operations.

The coordinated management of these two elements enhance the efficiency and the sustainability of air transport. As described above, preliminary assessments of such operational changes at Brasília Airport Terminal have shown that reductions in greenhouse gases and noise can be achieved. Even if the individual savings are relatively small, each one of these elements contributes to a net reduction in GHG emissions and noise.

Finally, it should be noted that environmental impacts are not the only concern motivating operational changes. Furthermore, as the design of the airspace is shifting to a performance-based paradigm, it is possible to obtain further improvements in operations by aiming at higher environmental standards in the future. ■

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