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# Accelerating Air Traffic Management Efficiency: A Call to Industry

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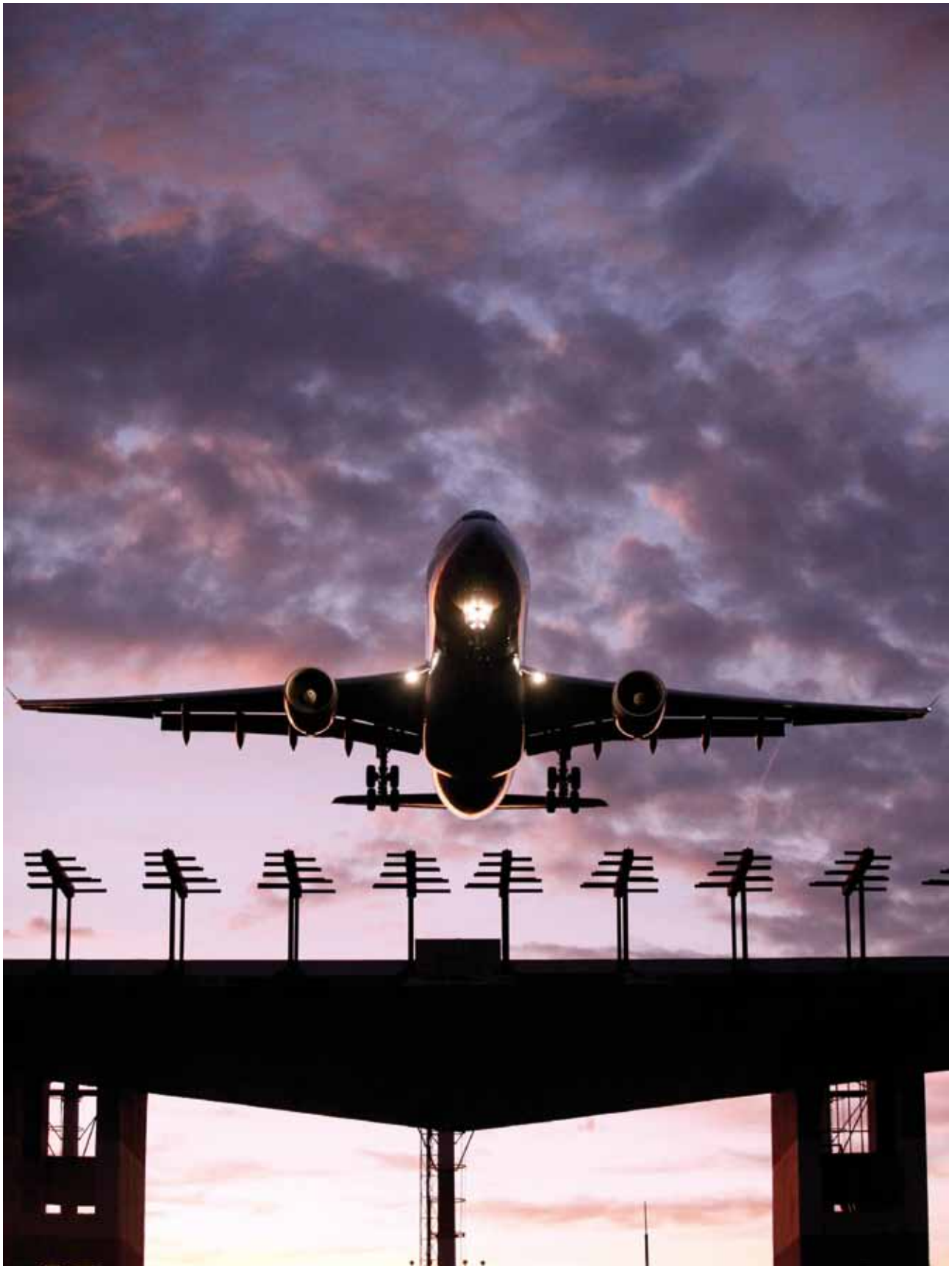

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# Accelerating Air Traffic Management Efficiency:
A Call to Industry

## 1
## Foreword

Despite interdependencies with safety, capacity, weather constraints, and individual stakeholder goals, today's Air Traffic Management (ATM) system is already highly optimised. There is, however, room for improvement – especially related to ATM initiatives that take advantage of current aircraft equipage.

In the spirit of continuous improvement, in June 2010, the Civil Air Navigation Services Organisation (CANSO) and The Boeing Company embarked on an ambitious plan to improve stakeholders' understanding of the complex near to mid-term challenges associated with operational improvements.

Parts of the ATM system are approaching maximum capacity. Current policy and procedures will not sustain future growth and local communities must be part of the future of airport growth. It is vitally important that the industry collaborate on the measures used to identify where capacity and efficiency can still be improved. As demand continues to outstrip capacity in the near- to mid-term, we need specific focus on how to take advantage of existing aircraft capabilities to manage traffic in congested environments in a more fuel efficient manner.

ATM performance is complex. Interdependencies drive up fuel burn and competing business objectives place stress on the ATM system. Airlines and ANSPs need to agree on common goals that reward airline investment but support ANSP goals to improve system-wide fuel efficiency at a lower cost. CANSO and Boeing believe that it is the responsibility of all stakeholders to bring their business objectives to the table and work with ANSPs and other stakeholders to build true future sustainability. The International aviation industry must increase collaboration to correctly diagnose the problems, set common operational goals, and prioritise focus areas that will drive real ATM fuel efficiency.

Sharing best practices, while simultaneously developing new operational procedures and conducting collaborative trials are the behavioural activities needed to leverage technical achievements. This "white paper" highlights where these progressive activities are currently happening, where collaboration is delivering change, and where agreement around the metrics and measures has led to greater understanding of the complexity of fuel burn and system wide efficiency.

The current worldwide ATM system fuel efficiency is estimated by CANSO to be between 92 and 94 percent. CANSO has also set an Aspirational Goal for 2050 for ATM system efficiency of between 95 to 98 percent. We believe there are best practices in place and key trials underway around the world that can be the basis for accelerated improvements. This paper is complementary to the Next Generation Air Transportation System (NextGen) and Single European Sky ATM Research (SESAR) programme lead by the SESAR Joint Undertaking, ATM improvement plans. This paper is also complementary to the ICAO Aviation System Block Upgrades (ASBU) initiative as a framework for global ATM harmonisation.

CANSO and The Boeing Company are committed to challenging the status quo by promoting examples of where positive change has taken place. This "Call to Industry" promotes collaboration as the core of true aviation sustainability and challenges all stakeholders to come to the table, ready to learn, to share, and to create change.

## 2
## Overview

This paper is a joint Boeing/CANSO "Call to Industry" for stronger collaboration to improve worldwide Air Traffic Management (ATM) efficiency. With the increased demand for environmental stewardship, the entire aviation industry is looking at every opportunity to reduce its net carbon footprint through new aircraft designs and alternative fuels in conjunction with more efficient operations that minimise fuel use and reduce delays. This paper only examines the collaboration required by all stakeholders to accelerate air traffic operations efficiency improvements. The pace of change and implementation must be stepped up to meet a medium-range aspirational goal of 94- 95%[1] ATM efficiency by 2025, consistent with the original CANSO aspirational goal of 95-98% ATM efficiency by 2050.

We fully support the air traffic efficiency transformational objectives of the United States' Federal Aviation Administration's (FAA) NextGen Programme, Eurocontrol's SESAR programme, and the leadership shown by the International Civil Aviation Organization (ICAO) in coordinating international efficiency improvements by highlighting the need for Aviation System Block Upgrades (ASBU). This report supports the success of these complex activities relative to ATM fuel efficiency and provides information and guidance on how to globally accelerate progress to deliver further ATM efficiency improvements.

The Air Navigation Service Provider (ANSP) community has had its share of challenges delivering capability to the ATM community. There are opportunities for enhanced collaboration between the system-wide efficiency goals of ANSPs and the airline industry's desire to benefit directly from equipping their fleets. With the collective experience of Boeing and CANSO, this paper provides a unique opportunity to identify what is working across the worldwide ATM spectrum, identify gaps and changes needed to realise efficiency improvements, and describe collaborative strategies for future success.

This paper is structured as follows:

- Section 3 presents critical actions that would help accelerate improvements,
- Section 4 provides the background behind the environmental commitments driving the need for continuous operational fuel efficiency improvements,
- Section 5 reviews the system operational interdependencies leading to inefficiencies in each phase of flight and defines "opportunity pools" for efficiency improvement,
- Section 6 further describes areas for stakeholder collaboration for efficiency improvements across the various phases of flight.
- Section 7 highlights operational improvement projects and successes throughout the world,
- Section 8 suggests ways key stakeholders can enhance collaboration to accelerate changes,
- Finally, Section 9 concludes with a call for industry stakeholders to work together to make these efficiency improvements a reality.

[1] New extrapolated CANSO/Boeing Aspirational mid-term goal for 2025

## 3
## Critical Actions

Today's aircraft have the technology to significantly improve ATM fuel efficiency. The challenge facing ANSPs is developing operational policies and procedures that compliment aircraft technology and leverage this technology to achieve new levels of ATM system efficiency. This report attempts to restructure the way the ATM community views the problems associated with fuel efficiency and focuses on worldwide best practices in place today for capturing fuel savings.

We believe the following actions are required to accelerate ATM efficiency:

- Ensure a clear understanding of the issues and interdependent constraints driving ATM fuel efficiency today and quantify opportunity pools for efficiency improvement by phase of flight;
- Examine the competing operational goals of airlines, airports, and ANSPs to identify the collaborative roles that policy makers, regulators, aircraft manufacturers and avionics/ground system suppliers can play in improving air traffic efficiency;
- ANSPs take a leadership role – becoming the connectors to facilitate and increase stakeholder collaboration and accelerate change;
- Accelerate "real-time" decision making through enhanced information sharing;
- Minimise airspace use restrictions that lead to inefficient operations;
- Ensure the air traffic control officer (ATCO) community is involved as a key stakeholder.
- Highlight and share today's best practices and successes, including new policies and procedures that improve ATM related efficiency. Emphasise a focus that takes advantage of current capabilities and promote these as a means to improve global harmonisation.

Through programmes such as "Collaborative Decision Making" the needs of most stakeholders are addressed, including the development of cooperative policy and essential business rules, which result in improved fuel efficiency, not only for the individual stakeholders, but for the system as a whole. Other key efficiency improvement opportunities can be captured in the climb, cruise, and descent phases of flight and are described in later sections. Around the world today trials are taking place and best practices are being established for ATM fuel efficiency procedures that take advantage of capability already on today's aircraft. Much can be learned from aggregating this information. ATM success is as more a function of Regulators, ANSPs, Airports, Airlines, Aircraft Manufacturers, and Avionics/Ground System Suppliers collaboratively implementing and executing new policies and procedures than it is implementing new technology.

## 4
## Background

In December 2008, CANSO, in coordination with the aviation industry, described a set of aspirational goals for improving ATM efficiency by 2050[2]. The challenge, defined by CANSO's Environment Working Group, was to reduce the impact of aviation $CO_2$ emissions on the environment by improving worldwide operational fuel efficiency. CANSO consolidated several regional studies and concluded that the global ATM system could be made between 95-98% efficient by 2050. Figure 1 below represents the carbon emissions challenge set forth by the Air Transport Action Group (ATAG)[3]. Aviation today represents 2% of global man-made $CO_2$ emissions. Key leaders in the aviation industry made a commitment in 2009 to work together towards the aspirational goal of reducing the net aviation emissions by 50% by 2050 compared to 2005 levels[4].

The portion of aviation carbon footprint being addressed in this report is part of the two middle wedges: Operations (airline focus) and Infrastructure (ATM focus). The Airlines Operations wedge includes improvements beyond ATM control like fleet mix choices and load factors. All airframe manufacturers are fully invested in the top and bottom wedges, Technology and Biofuels, making each generation of new airplanes significantly more fuel efficient than the previous generation as well as ensuring that engines can operate safely on renewable fuels. In fact, it was the aviation industry that sparked accelerated development of alternative airplane fuels and supported the development and approval of alternative fuel standards such as ASTM D7566-11 for 50% bio-fuel use. For further reference on aviation biofuels refer to the ATAG website[5].

This paper highlights available ATM "pools of efficiency opportunity" for improvements, identifies means to measure technical progress, and proposes a challenge to all industry stakeholders: Regulators, ANSPs, Airlines, Airports, Airplane Manufacturers, Avionics and Ground System Suppliers, and Communities to collaborate on a set of steps to reach 94-95% operational efficiency in the global ATM system by 2025. The efficiency benefits would flow to all, while the environmental emissions reductions will benefit the global community. The Intergovernmental Panel on Climate Change (IPCC) estimated that improvements in air traffic management and other operational procedures could reduce fuel burn by 8 to 18%, with the majority of that, 6 to 12%, coming from ATM improvements[6]. In 2005, CANSO engaged stakeholders to update the 1999 IPCC estimate of the total ATM inefficiency on a worldwide basis to be about 6 to 8% with large variances by region and by airport. Of this identified inefficiency, CANSO believes that half (3 to 4%) is related to the operational interdependencies. Some of these interdependency constraints include: safety, capacity, weather, and military airspace. Our goal now is to recover this remaining inefficiency to achieve 94-95% efficiency by 2025 and 95-98% efficiency by 2050. These goals require more efforts to improve operational efficiency than just status quo; for if nothing is done, fuel efficiencies will actually decrease due to increased global traffic density and airport constraints, as presented in Figure 2.

The aspirational goals expressed here are for a worldwide average. There will be specific regions and airports where the opportunities for improvement are much larger than indicated here, and likewise, some regions where the opportunities are much less.

[2] ATM Global Environment Efficiency Goals for 2050, CANSO Environment Working Group, December 2008, available on the web at: http://www.canso.org/environment.

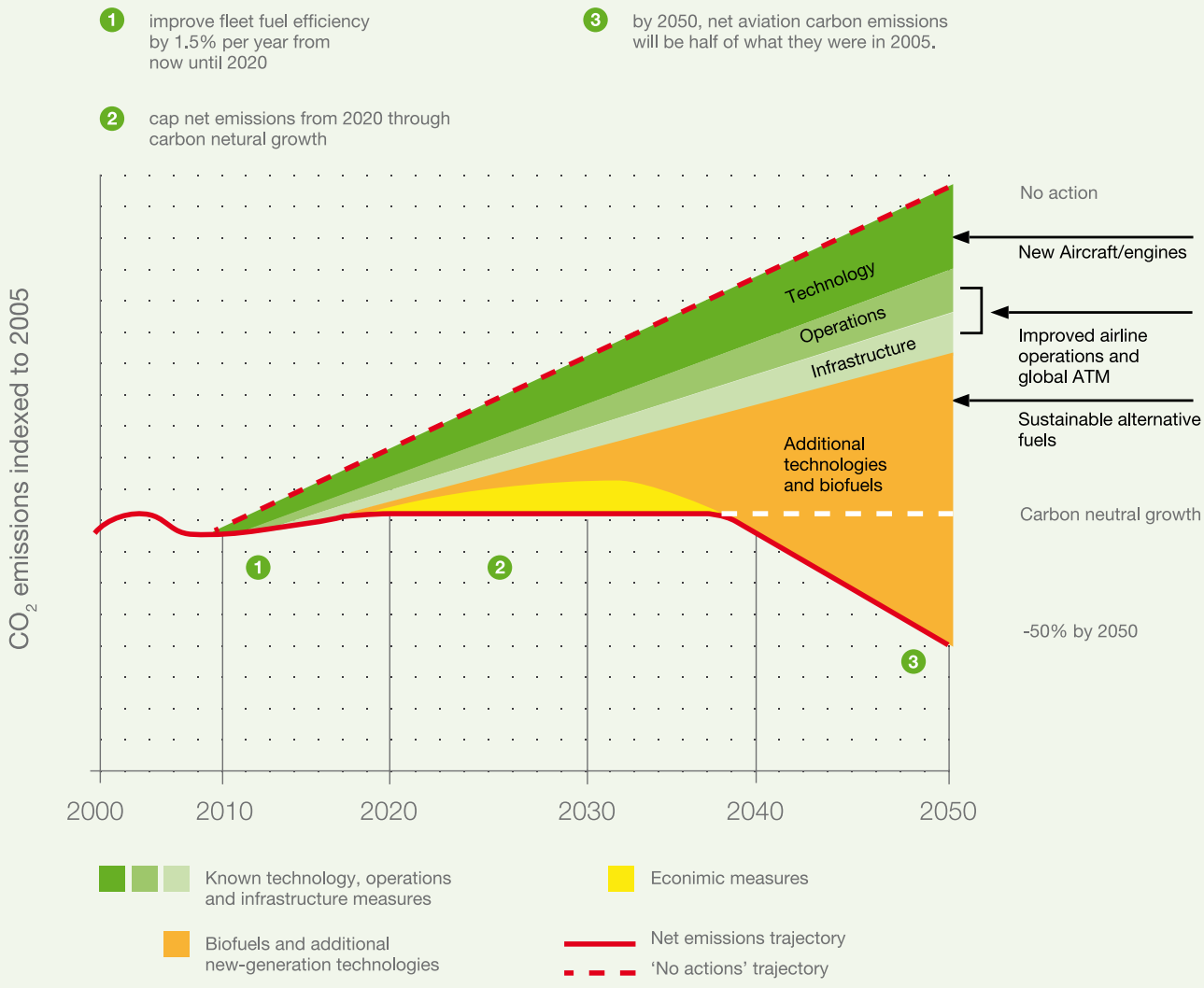
[3] The Right Flightpath to Reduce Aviation Emissions, ATAG, Nov 2011, UNFCCC Climate Talks, Durban SA.

[4] http://www.atag.org/our-activities/climate-change.html

[5] Powering the Future of Flight: The six easy steps to growing a viable aviation biofuels industry" at www.atag.org/component/downloads/downloads/58.html

[6] Aviation and the Global Atmosphere, IPCC, 1999.

## Mapping out the industry commitments




(Schematic, indicative diagram only)

Figure 1 — Carbon emissions challenge set forth Air Transport Action Group

To accomplish this increase in overall efficiency requires stakeholder collaboration to plan a phased approach to implement:

— ANSP enhancements that safely increase ATM efficiency and global interoperability.
— A change in philosophy and policy encouraging ANSPs to provide enhanced services for the "better equipped" aircraft as a means of capacity and efficiency improvement. This requires a renewed connection between the system-wide efficiency goals of ANSPs and the airline industry's desire to benefit directly from equipping their fleets. Market forces for efficiency and return on investment will offer sufficient incentives to equip if the ANSPs provide the services that deliver the benefits based on that equipage.
— Better management of fuel efficient delay absorption into congested terminal areas.
— New fuel-efficient flight tracks while managing noise consequences near airports.
— Regional solutions across major city-pair traffic flows and;
— Sharing lessons learned to bring the right procedures and technology to regions of the world based on their unique demands.

The remainder of this paper focuses on the interdependencies between ANSPs and other stakeholders that must be considered when working together to maximise ATM efficiency.

## 5
## Interdependencies and ATM Efficiency

### 5.1_Recognising the Interdependencies

Efficiency on an individual flight basis can be theoretically calculated by comparing the actual trajectory to an optimal trajectory, where each flight is assumed to be the only flight in the system. This theoretical construct is constrained as interdependencies and inefficiencies are introduced due to operations involving many aircraft, or when physical, safety, and cost factors impact operational decisions forcing less than optimal routes to be flown. These inefficiencies derive from the way the ATM system itself has evolved and can be referred to as interdependencies with "improvement opportunity pools" defined in the following section. These interdependencies include:

a. Safety – aircraft will still deviate from the optimum route in order to ensure safe separation or to safely manage airspace complexity. Future en route operations will focus more on ATM flow management and shift responsibility for tactical deviations to the airplane as technology permits.
b. Weather – to ensure a safe and smooth flight, aircraft will still need to deviate from an optimum route due to adverse weather or turbulence.
c. Capacity – to accommodate capacity limitations at the airport or through the airspace, aircraft may wait (hold) on the ground prior to departure, deviate en route, or even do an airborne hold procedure prior to arrival. When traffic demand approaches available capacity, there is some necessary increase in congestion and fuel inefficient delays to maximise use of available capacity. This congestion will reduce efficiency and increase $CO_2$ emissions.
d. Noise – to reduce noise impact on the ground, aircraft operations around the airfield can be subjected to noise abatement procedures that may reduce noise to some, yet cause the aircraft

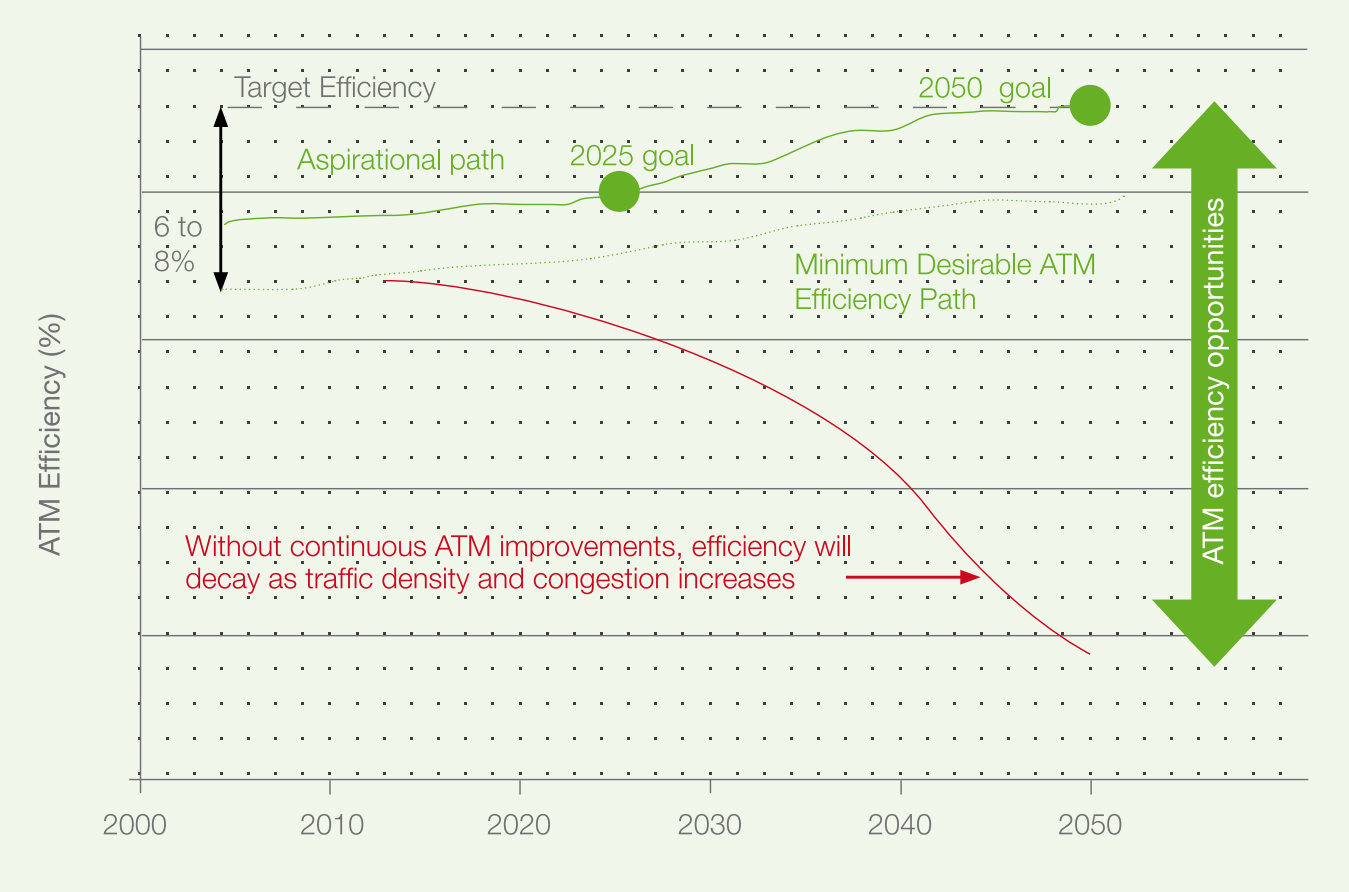
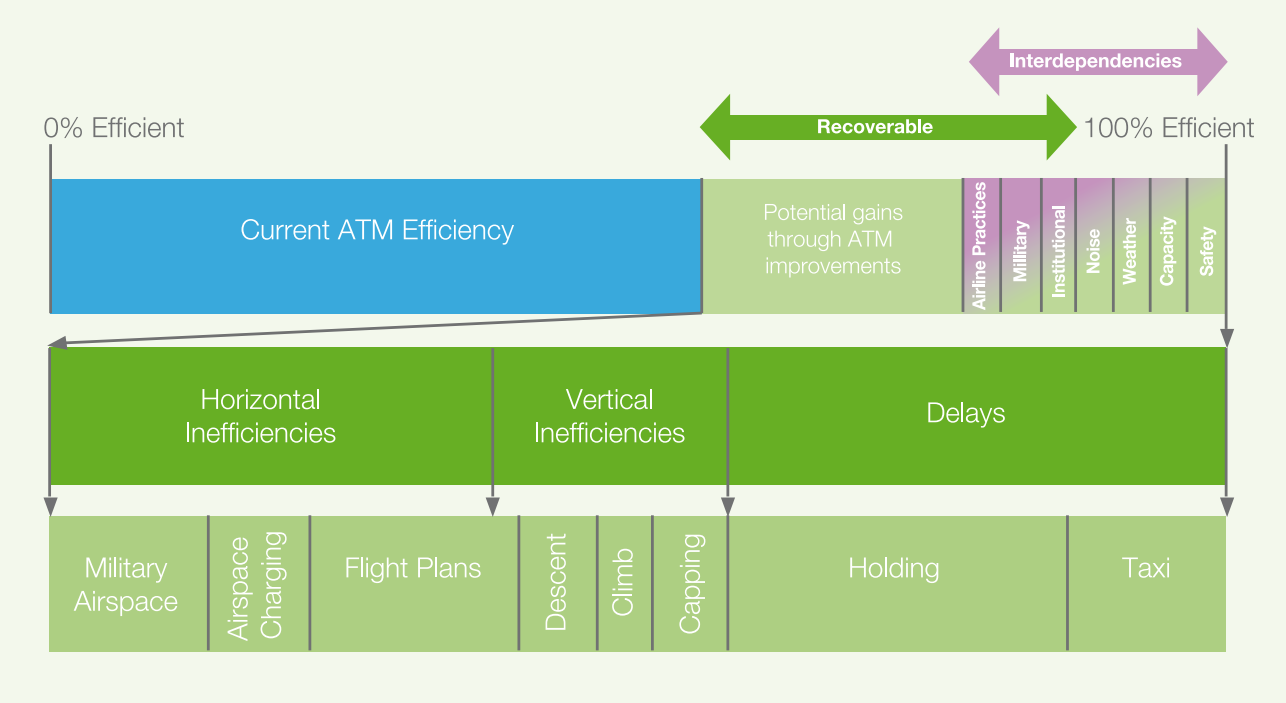



Figure 2 —
Notional view of ATM efficiency goals and the impact of increased air traffic

Figure 3 —
ATM inefficiency categories (notional scales)

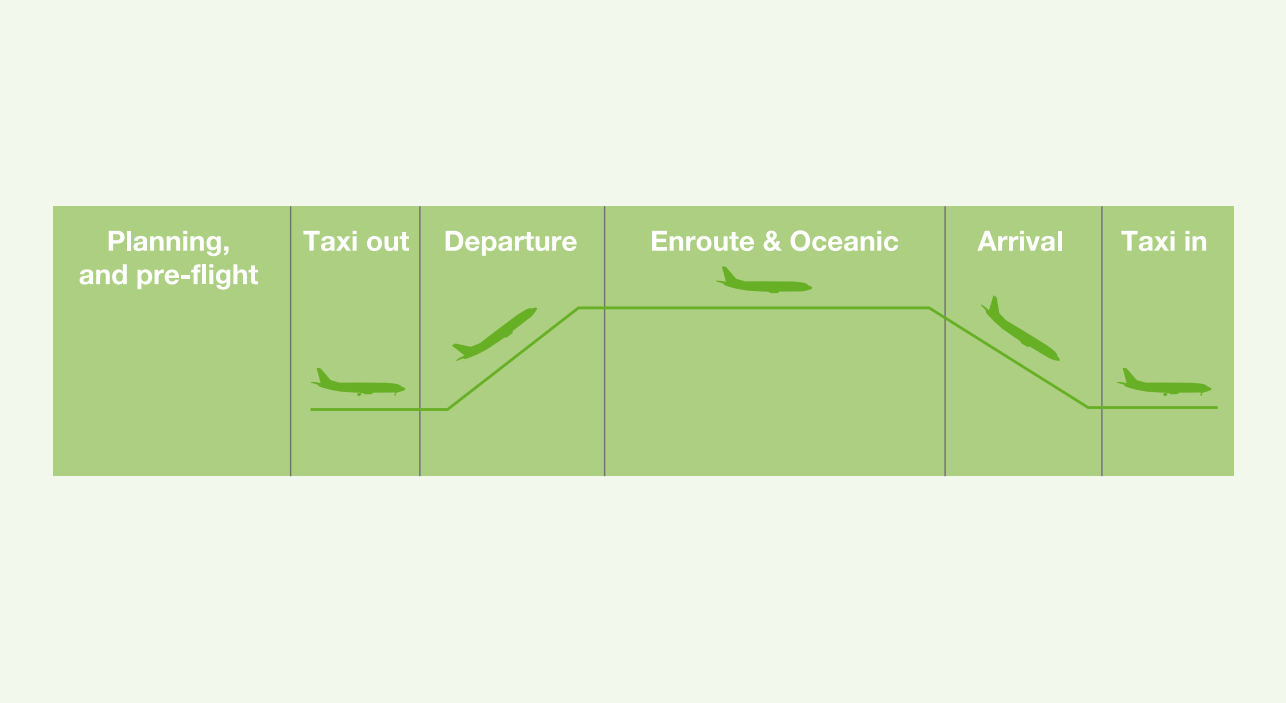



to fly a less efficient route or at sub-optimal altitudes. Reduced noise around the airport itself is extremely challenging as creation of "new" noise (even if overall noise is reduced) is heavily rejected by communities.

e. Airline practices – airlines operate their network schedules to accommodate passenger demand; however, optimal routes or altitudes may not always be available, either because of congestion, lack of ground infrastructure, lack of flexibility on the part of the flight planning system or avionics, or lack of fully integrated situational knowledge.
f. Airport Practices – the location and configuration of airport runways and taxiways has a significant impact on ATM efficiency and environmental impact (especially community noise). Any runway and taxiway efficiency improvements require long term strategic planning.
g. Military – civil aircraft generally must route around military airspace and other types of restricted airspace, thereby flying less than optimal routes and increasing fuel use.
h. Institutional – aircraft often fly less than optimal routes due to fragmented airspace. Different regions/countries may have different operating procedures or charging mechanisms or require set overfly altitudes and routes that lead to less than optimum fuel-efficient routing.
i. Mixed fleet equipment capability – aircraft have useful lifetimes of over 25 years. Older aircraft do not, in general, have the same technology and capabilities as the most recent models. This mixing of capabilities adds inefficiencies as the system must still support the less capable.

All the ATM interdependencies are illustrated conceptually in Figure 3. We acknowledge that the adoption of modern technology could improve one interdependency while adversely affecting another. For example, Performance Based Navigation (PBN) can increase terminal area airspace capacity often at the cost of a concentration of flight paths in one region. Where this can be accomplished over non-residential areas there are major noise benefits for communities. However due to past land use planning decisions, many existing airports are surrounded by residential areas that cannot be readily avoided.

Figure 4 —
Phases of Flight




Experience with new arrival procedures by CANSO members shows that reducing overall noise often creates areas of "new noise"[7]. This concept of "new" noise versus existing noise is an important consideration when developing new ATM procedures and requires collaboration with the local community to find solutions to manage noise, capacity and efficiency. These issues cannot be addressed solely by the ANSP, airport operator and airplane operators without community engagement.

Efficiency gains can be achieved by reducing the effect of the interdependencies. Examples include safely increasing en route airspace capacity with automation tools thereby reducing excess fuel needed for Air Traffic Control (ATC) routings around complex airspace. While ANSPs can directly influence some of the interdependencies listed above, the largest gains will come from ANSPs working closely with other industry stakeholders – Regulators, Airlines, Airports, Airplane Manufacturers, Avionics and Ground System Suppliers, and local Communities.

## 5.2_Understanding Inefficiencies by Phase of Flight

In order to define and understand the inefficiencies, we need to analyse the ATM system by phase of flight, as presented in Figure 4:

— Planning, pre-flight and gate departure
— Taxi-out
— Departure
— En route & Oceanic
— Descent and arrival
— Taxi-in

The difference between actual performance and an ideal/benchmark performance is referred to as flight inefficiency or an "opportunity pool". The inefficiencies for each phase of flight are defined as the difference between actual travel time, travel distance, or fuel use against an un-impeded or benchmark travel time, travel distance, or fuel use. The difference between actual travel time and benchmark travel time is delay. These flight phase inefficiencies are examined in the next sections. It is important to point out that these total "inefficiency" pools include unrecoverable portions related to the

[7] CANSO Environment Working Group, Noise White Paper draft September 2011.

| | En-route related delays over 15min. (EDCT/ATFM) | | | | Airport related delays over 15min. (EDCT/ATFM) | | |
|---|---|---|---|---|---|---|---|
| Region | IFR flights (M) | % of flights delayed >15 min. | Delay per flight (min.) | Delay per delayed flight (min.) | % of flights delayed >15 min. | Delay per flight (min.) | Delay per delayed flight (min.) |
| US | 8.6 | 0.1% | 0.05 | 44 | 1.6% | 1.0 | 66 |
| Europe | 5.0 | 5.7% | 1.8 | 32 | 3.3% | 1.2 | 36 |

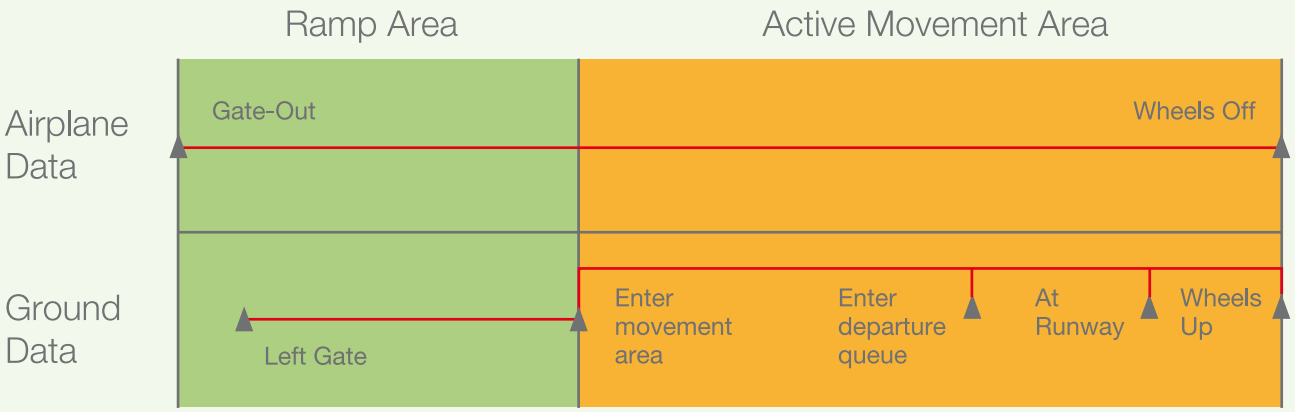



Table 1 —
ATM related departure delays over 15 minutes at main 34 airports

Figure 5 —
Key event times in taxi-out efficiency calculations

interdependencies described in Section 5.1. These pools provide insights into relative opportunities for improvement.

### 5.2.1_Planning and Gate Departure

Air Traffic Management driven gate departure holds are used to manage congestion at the departure airport, en route sectors or at the arrival airport. These delays are calculated with reference to the times provided in the last submitted flight plan (not the published departure times in airline schedules). Most delays are taken at the gate but some occur during the taxi-out phase. While ATM is not always the root cause of the departure holdings, how the gate departure holds are handled can have a considerable impact on costs to airspace users and utilisation of scarce capacity. Keeping an aircraft at the gate saves fuel but if it is held at the gate and a valuable capacity slot goes unused, the cost to the airline of the extra delay may exceed the extra fuel cost. Table 1 compares ATM-related departure delays over 15 minutes attributable to en-route and airport constraints for the top 34 Airports in the U.S. and Europe for 2010[8]. These averages show the delay impacts averaged over all flights and the average for just the flights that were actually delayed by holds.

### 5.2.2_Taxi-Out/Taxi-In

Nominal taxi-out/taxi-in time is the unimpeded time required to traverse the surface from the gate until the runway position prior to take off for taxi-out or from runway exit to the arrival gate for taxi-in. In theory, there may be hundreds of unimpeded times based on parking locations and runway combinations. In practice, however, ANSP's have developed approximations for these times using the data available in existing performance databases. The fidelity of the benchmark time is dependent on the breadth and accuracy of this data. Figure 5 shows key event times available from the airplane via ACARS[9] Out-Off-On-In (OOOI) data, from ground radar[10] or a surface movement guidance control system for taxi operations.

ATM performance on the surface is often separated into the Active Movement Area, where ATM exercises control and the Non-Movement Area (or Ramp Area) which is controlled by another entity such as the operator of the ramp. For aircraft reporting, two event times are recorded: a Gate-Out message which signals the start of taxi-time and the Wheels-Off message signalling the end of surface movement and the start of airborne flight. Ground-based systems offer the potential for more refined calculation of surface performance in the active movement area. However this data needs to be coupled with sophisticated algorithms that use the geometry of the airport surface to detect key event times.

The data above can be used to create a distribution of ground taxi-travel times. For ACARS equipped airplanes, taxi-out is defined as Wheels-Off minus Gate-Out time. These aircraft messages may also be used to detect the number of aircraft active on the ground in either a taxi-out state or taxi-in state which can be a surrogate for congestion on the ground. Periods of no congestion can be considered indicative of the ideal benchmark taxi time. Figure 6 presents the specific data for the top 20 of these 34 airports.

### 5.2.3_Departure Phase

The departure phase of flight is defined as the time the aircraft departs the runway (wheels-off) and traverses the departure airport terminal area – defined by a regionally appropriate ring (e.g. 40 nm) around the airport. Aircraft may be required to fly longer distances if they need to fly over a specific departure fix for noise abatement procedures or to ensure separation from other aircraft. These departure profiles often lead to sub-optimal altitudes and speeds, thus increasing fuel use. The orientation of the active runways in relation to the direction of travel can also cause aircraft to have

[8] US/Europe Comparison of ATM Related Operational Performance - 2012, Performance Review Commission, 2012

[9] Aircraft Communications Addressing and Reporting System

[10] Such as ASDE-X (Airport Surface Detection Equipment, Model-X)

to fly excess distance to connect to a specific route. In addition, these departure routings may be influenced by neighbouring airports, military or restricted airspace or environmentally sensitive areas. The inefficiency opportunity for this phase of flight can be calculated similar to that for the descent phase, described later.

### 5.2.4_Cruise (en route) Phase

Some efficiency studies calculate efficiency as the difference between actual flight distance and a non-wind adjusted great circle distance between airport reference points – which does not account for required terminal area traffic structure based on the runways in use. This structural extra distance is often an inherent inefficiency reflecting runway orientation and segregated arrival and departure flows. It may be considered a theoretical upper bound with limited potential for improving the true ATM efficiency.

For efficiency analysis, we recommend separating the airborne portion of the flight into three phases as depicted in Figure 7, departure terminal area, en route, and arrival terminal area[11]. The terminal environments are approximated by one ring (approximately 40 nm) around the departure airport and another larger ring (100 nm to account for arrival management planning) around the arrival airport. Each airport has to efficiently manage traffic for both rings to coordinate arrivals and departures.

Two great circle distances – the distance between the entry and exit points (D) and the distance between the two reference circles (G), define the upper and lower benchmark trajectories for the en route environment. Differences between the actual trajectory (A) and the benchmarks (D or G) provide indicators of en route inefficiency. A-D reflects ideal flight using the existing TMA interface, while A-G provides an upper-bound efficiency value for an optimal TMA interface between two city pairs. The actual trajectory is characterised by standard routes defined by specific altitudes and speeds that may be impacted by restricted airspace or other airspace use considerations.

To measure horizontal en-route efficiency, the Key Performance Indicator (KPI) used by Eurocontrol and others is direct “en-route extension”, as depicted in Figure 7. It is the extra distance flown or the difference between the length of the actual trajectory (A) and the minimum no-wind Great Circle Distance (G) between the departure radius and the arrival radius. This difference would be equal to zero in an ideal situation where each aircraft would be alone in the system, not subject to any constraints. Figure 8 compares the ex-route extensions from the main 34 airports for the US and Europe and the percent of flights impacted.

During the en route phase of flight, ATM may impose speed constraints or vector an aircraft for congestion or convective weather. In most regions of the world, aircraft may also elect to fly longer routes to avoid costly route charges, trading off the excess fuel cost against airspace use charges.

### 5.2.5_En route Long Haul and Oceanic Flight

For flights with cruise segments more than 1000 miles, great circle routes are typically not optimal in terms of both fuel and time. User Preferred Routings (UPR) allows for flights to take advantage of wind optimal routes. UPRs are in place to varying degrees worldwide but constraints exist where ATM infrastructure is lacking or the demand exceeds capacity for optimal routes, as experienced in the North Atlantic. Figure 9 shows an example of a wind optimal UPR with significant fuel and time savings. CANSO supports the International Air Transport Association (IATA) in implementing flex and UPR through Dynamic Airborne Reroute Procedures (DARP) where practicable across regions which allow airlines to fly more efficient routes based on current and forecast winds and temperatures rather than flying fixed route structures.

[11] US/Europe Comparison of ATM Related Operational Performance, Performance Review Commission, 2009

Figure 6—
Average taxi-out delays for the top 20 airports in Europe and the US

**Average additional time in the taxi out phase - 2010 (Only the first 20 airports are shown)**

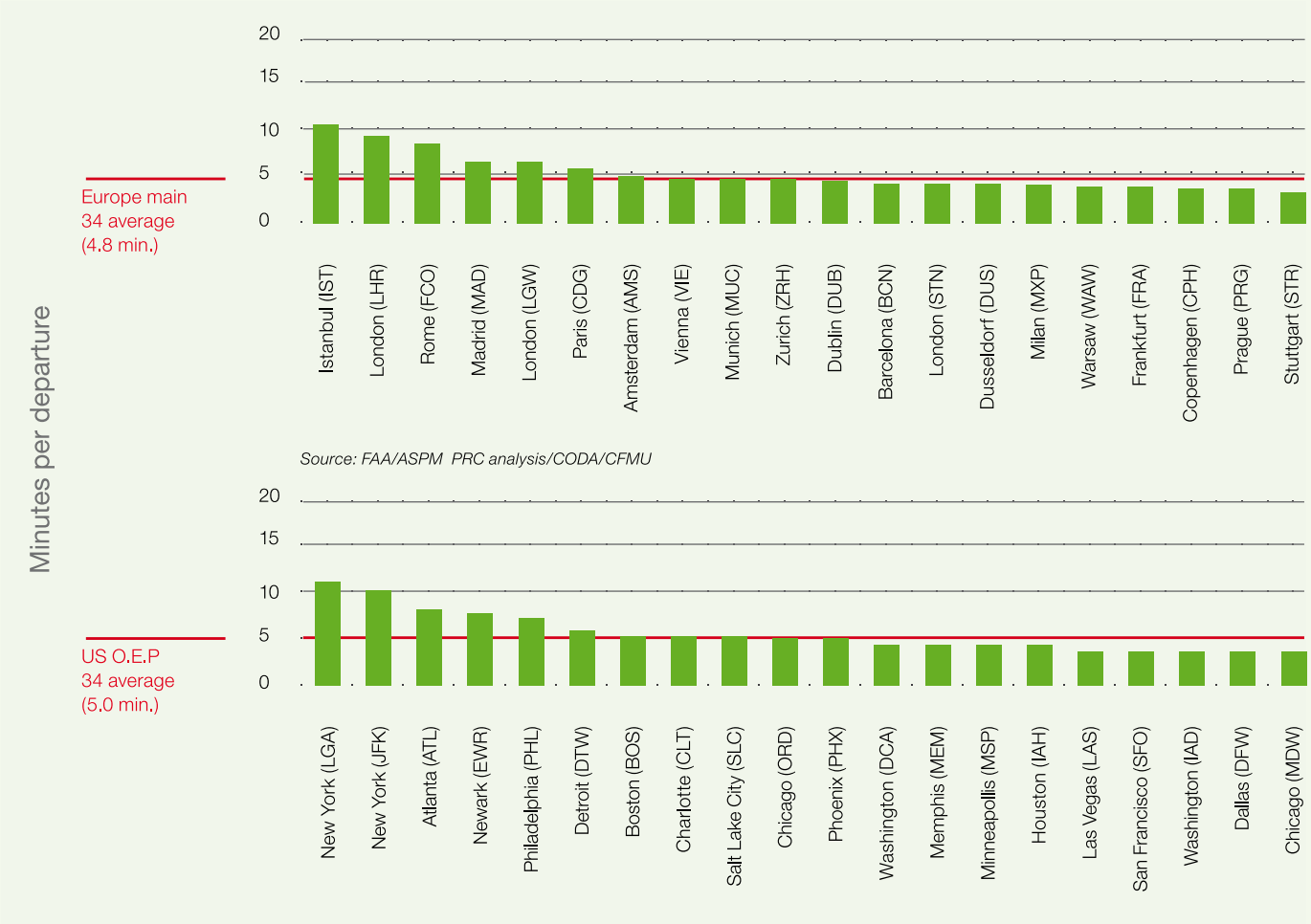



Figure 7 —
En-Route extension key performance indicator

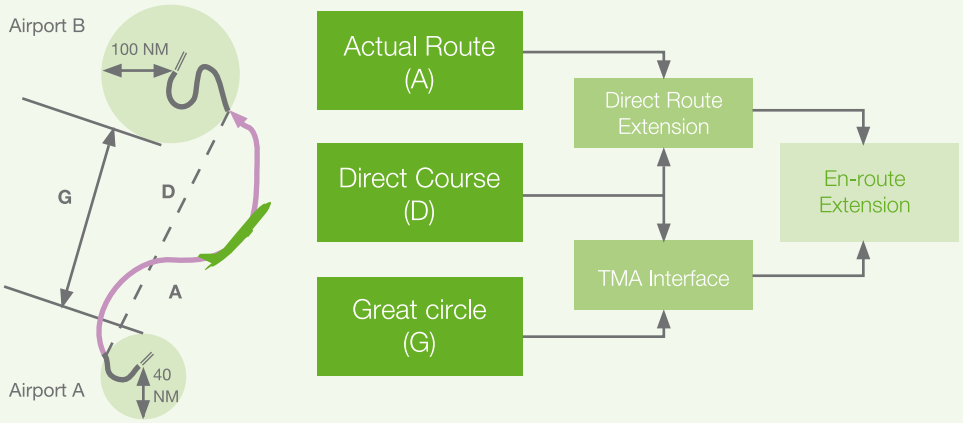


Figure 8 —
Comparison of excess distances flown for different flight lengths in the US and Europe

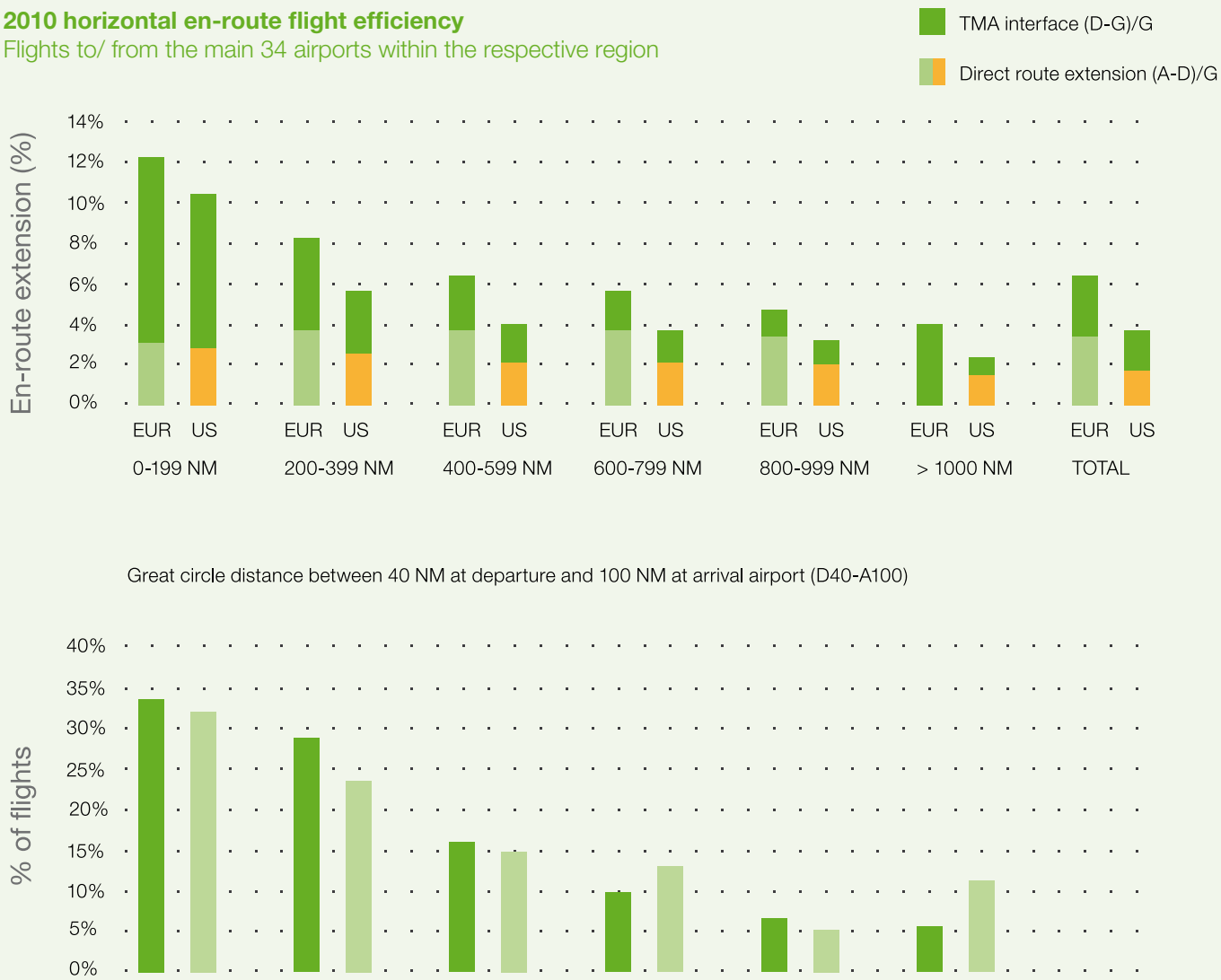



Figure 9 —
Example wind optimal oceanic route from Dubai to Brisbane[12]

[12] Courtesy of Airservices Australia
www.airservicesaustralia.com

Figure 10 — Inefficiencies within the descent phase

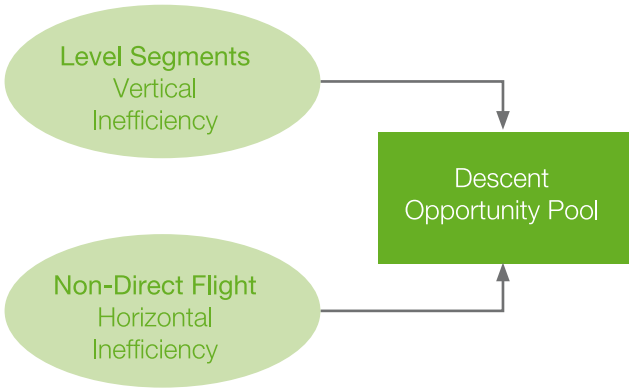



Figure 11 — Shifting level segment to cruise (a) distance/ (b) time perspective

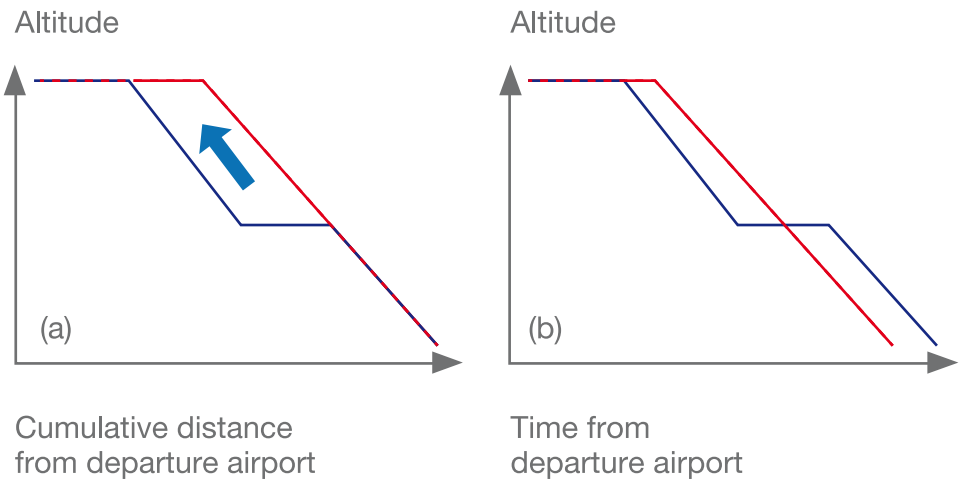



Figure 12 — Notional depiction of excess distance during descent

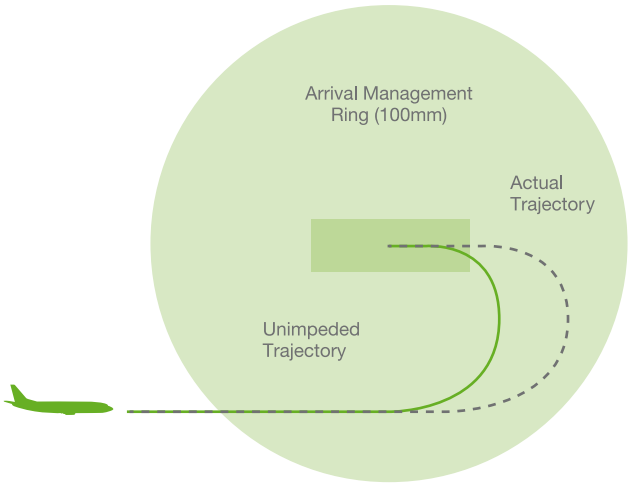


Figure 13a —
The descent opportunity pool for the top 34 airports in the US and Europe (in minutes)

**2010 average additional time within the last 100 NM miles (Only the first 20 airports are shown)**

## 5.2.6_Descent Phase

The descent phase may be evaluated as two inefficiencies; vertical (intermediate level-offs) and horizontal (extra distance flown). These inefficiencies, shown in Figure 10, average almost 3 minutes of extra flight time per aircraft at the 34 busiest airports in the US and Europe.

For the descent phase, excess distance and intermediate level-off segments are translated into time and fuel. The unconstrained benefit pool in the descent phase of flight is represented by the difference between an unimpeded horizontal and vertical trajectory and the actual trajectory flown. This benefit pool represents the net amount of time or fuel that could be saved with more “optimal” trajectories.

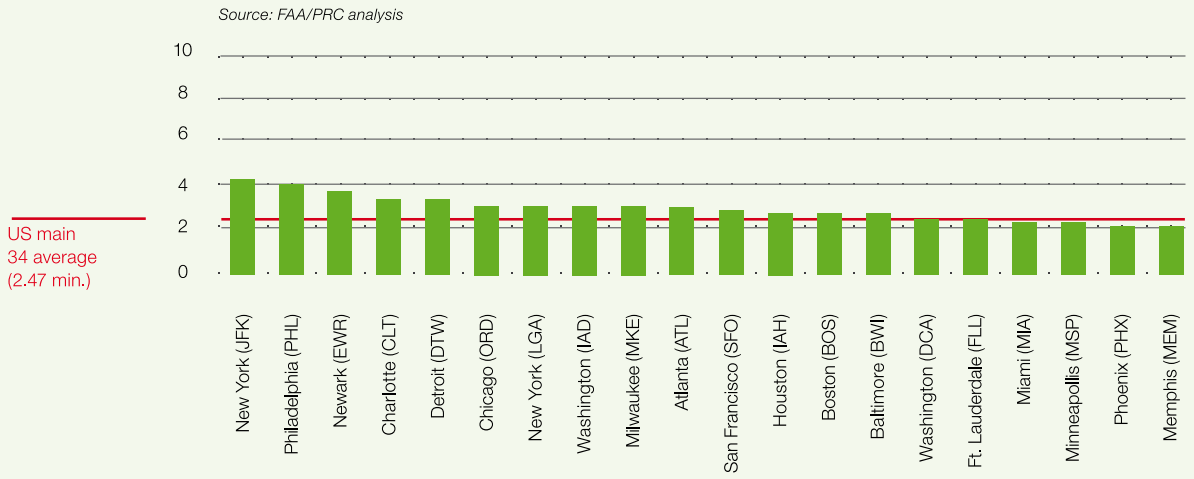
One difficulty in assessing the difference between actual and unimpeded time and fuel is that both are affected by factors such as wind, temperature, aircraft weight, engine type, and airframe performance. This methodology uses available data to identify both the ATM constraints that impact the vertical and horizontal trajectories as well as the impact of those constraints on the excess time and fuel burn. This two-tiered approach allows for separate insights into the benefits available for the vertical and horizontal dimensions.

Vertical inefficiency is assessed in two parts: (a) the additional fuel to fly the same horizontal distance compared to an unconstrained optimal vertical trajectory and (b) the additional fuel required to fly the additional distance assuming both have an optimum vertical profile.

Horizontal inefficiency is calculated by comparing the actual distance flown with an ideal benchmark distance. The excess distance is then translated into excess fuel use at cruise level. This two step process provides a means to eliminate double counting vertical and horizontal inefficiencies and is equivalent to the true benefit pool.

Evaluating the Vertical Opportunity Pool – The main components of the vertical opportunity pool are the level flight segments flown at lower altitude. To increase efficiency and reduce fuel burn, level flight segments at lower altitude are assumed to be flown at cruise altitude. In moving level flight segments from a lower altitude to a higher altitude, this method assumes the distance covered for each segment will be identical; however, speed and fuel use will be different.

Figure 13b —




To cover the same distance at higher altitude, less time is needed and less fuel is used overall. Figure 11, shows the distance (a) and time perspective (b) of shifting level segments to higher cruise altitudes.

By extending the cruise phase (higher speed) and removing the level segment, the overall time is shortened. As illustrated in Figure 11 (a), this assumes flying distance is the same before and after moving level flight segments. However, as shown in Figure 11 (b), it assumes that flying time is unconstrained and the flight could arrive early, conflict free.

Evaluating the Horizontal Opportunity Pool – After evaluating the vertical opportunity, the vertical trajectory is optimised and the excess distance associated with vectors or holding is left. The main driver for the horizontal opportunity pool is assumed to be the excess distance flown compared to a benchmark unimpeded distance. Figure 12 illustrates this excess descent distance within the arrival management ring used by Eurocontrol for analysis of excess distance.

From the horizontal efficiency perspective, the black (dashed) trajectory is the actual trajectory; the green (solid) trajectory is a nominal (unconstrained) trajectory. In cases of holding or extended downwind legs the difference between the two horizontal trajectories may be much greater. This total excess distance is converted to equivalent time at the cruise phase to obtain the horizontal fuel opportunity component.

Integration of Horizontal and Vertical Opportunity Pools – For the unconstrained scenario, the benefit pool is simply the sum of benefit pools from the horizontal and vertical phases. In the descent phase, aircraft may be required to slow down or fly excess distances at high altitude level flight in order for ATM to merge or space arriving aircraft to a meter fix or arrival fix, to route aircraft to a particular runway, or vector them for safe separation. Adding short dog-legs at high altitude can prevent undesirable low altitude level segments and allow aircraft to be merged and sequenced for nearly continuous descents to the airport with a net total fuel savings. Figure 13 shows the descent opportunity pool for the top 20 airports in Europe and the US in 2010.

## 6
## Opportunities to Reduce Inefficiencies in Each Phase of Flight

In this section, we address the opportunities to reduce the inefficiencies and highlight the collaboration required among multiple stakeholders to accomplish these desired gains. While new capacity is key to improving flight efficiency, as demand increases a large role of ANSPs in ATM is to best manage "necessary" delay on a daily basis. Managing where and how delay is absorbed when airport capacity is constrained must clearly consider fuel efficiency while maximising runway throughput. Overarching all of these opportunities is the need to not only encourage, but accelerate the introduction of new air and ground technologies and procedures for communications, navigation and surveillance wherever they would most effectively improve ATM and flight efficiency.

### 6.1_Planning and Pre-Flight

Close cooperation between airplane operators, airport operators and the ANSP through shared network information during weather upsets or other airspace impacts (such as runway closures, special airspace closures, etc.) will improve the operator's flight planning efficiency. Similarly, to improve overall air traffic flow management and reduce congestion, ANSPs require enhanced automation to evaluate the collection of filed flight plans against existing constraints and quickly offer equitable alternatives to operators that minimise the delay or flight path impact. These alternatives could include the opportunity to fly more fuel efficient speeds with early departures, and higher Mach speeds for later departures. To achieve individual airline goals there must be equitable treatment and an assurance that good preflight decision making isn't penalised later in the flight path. This approach needs to balance "global" efficiency objectives against individual efficiency impacts.

### 6.2_Gate Departure and Taxi-out

During departure peaks, aircraft can wait in long queues consuming fuel. In major areas of the world to reserve a spot in the queue, the aircraft must physically take a slot in line. Aircraft that are delayed on the ground often burn excess fuel during cruise to "make up the time." Recent efforts have shown progress in reducing taxi times and emissions through Collaborative Departure Queue Management in the US and the European Airport Collaborative Decision Making concept in Europe. These concepts manage the number of aircraft in the departure queue to minimise the amount of time that aircraft are actually in line with engines running while ensuring maximum use of the runways. These efforts require that the airport, ANSP, and airlines work together to maximise use of the airport surface while minimising fuel burn.

### 6.3_Departures

Departure operations could be made more fuel efficient with improved departure routes that reduce the "wasted distance" inside the 40 nm ring so aircraft can proceed on a continuous climb in a preferred direction. Community engagement with airports, airlines, and ANSPs is essential to finding implementable solutions.

### 6.4_En Route and Oceanic Airspace

In the en route phase of flight, recent research has shown the potential of saving fuel and emissions due to optimising altitude, speed, or both, with a range in benefits. ANSPs should facilitate the "Flexible Use of Airspace" (FUA) to maximise the shared use of civil/military airspace. ANSPs should implement approval of User-Preferred Routes (UPR) to improve the horizontal and vertical portions of a flight trajectory. As aircraft become

ever more digitally enabled, they will become an increasing supplier and user of current information such as winds and turbulence. As integrated data processing and weather modelling continues to advance, the data some aircraft provide will be returned as improved near term forecasts for flight planning and dynamic re-routing for later aircraft.

In oceanic airspace, regulators, ANSPs, and aircraft operators have been able to increase capacity, and reduce delays, through the use of Automatic Dependent Surveillance–Contract (ADS-C) and Controller Pilot Data Link Communications (CPDLC), as well as the enhanced navigation capabilities associated with Required Navigation Performance (e.g. RNP4). UPRs and DARP have enabled significant reductions in fuel burn, flight time, and $CO_2$ emissions, while reductions in lateral and longitudinal separations (down to 30 miles lateral/30 miles longitudinal in some oceanic airspace) has increased capacity and given increased opportunities for optimum altitude (and block altitude) clearances. Trials of both ADS-B and ADS-C climb/descent procedures show promise of additional opportunities for such clearances.

Improved coordination for flight through military airspace when not in use can improve en route flight paths. Airlines may need more dynamic rerouting processes to take advantage of airspace openings.

Finally, increasing en route sector capacity may also reduce delays associated with aircraft routings around congested airspace.

## 6.5_Descent

Much has been written about Optimised Profile Descents (OPDs) and Tailored Arrivals (TAs) which remove level segments during descent to allow for a fuel efficient arrival. However, OPDs/TAs may not be feasible during congested periods because they result in unused capacity. Missing arrival slots during congested periods adds overall delays and inefficiencies. The concept of slowing aircraft in cruise to reduce arrival congestion helps to minimise controller actions on descent aimed at absorbing needed delay. By moving a portion of necessary delay from the descent phase to cruise makes the resulting descent move closer to an OPD while maintaining maximal runway throughput.

Many ATM Arrival Manager (AMAN) Tools don't include the capability to automatically move aircraft forward in a sequence – if two aircraft have the same estimate for the runway – one will be delayed, even if it is possible to increase speed and remove delay for the second aircraft. Current research also indicates it is more efficient for the entire peak of arriving aircraft if selected aircraft at the beginning of a rush period "speed up" to avoid creating congestion. Although these few early aircraft may consume more fuel the net result is a more "global" reduction in fuel use by the following aircraft.

ANSPs, working with regulators and aircraft operators are using speed control and Controlled Times of Arrival (CTAs) to manage fuel and terminal congestion (also referred to as "linear" holding). The worldwide pool of fuel savings during descents and arrivals at congested airports potentially represents the most significant opportunity for ATM efficiency improvement. Realisation of these efficiencies will be enabled by the introduction of future ATM technologies such as data communications between aircrew and controllers and ADS-B to enable the flight crew to maintain a speed or time interval behind a leading aircraft. With data communications ATM will be able to uplink arrival times and potential routes directly to the flight crew and into the Flight Management System (FMS) for review and implementation. While data communications and associated uplink of complex trajectories may be a longer term solution, there are near term opportunities to refine

Figure 14 —
Stakeholder collaboration by phase of flight

| Phase of Flight / Stakeholder | Planning & Pre-Flight | Taxi-Out Taxi In | Departure | En-Route | Arrival |
|---|---|---|---|---|---|
| Regulator | M | M | M | H | H |
| ANSP | M | M | M | H | H |
| Airport/ATC Facility | M | H | H | H | H |
| Ground Equip Suppliers | M | M | M | H | H |
| Airplane OEM | M | M | M | H | H |
| Avionics Suppliers | L | M | M | H | H |
| Airplane Operators | H | H | H | H | H |
| Local Community | L | M | H | L | H |

existing procedures and gain much of the benefit from assisted flow management. Success is more dependent on procedures and a commitment for collaboration from ANPS, airlines, regulators, and airports than any particular technology. Some of these concepts are in the research arena but offer the potential to incorporate these methodologies into ATM automation.

## 6.6_Stakeholder Involvement

As outlined above, the aviation industry today has a unique opportunity to deliver immediate benefits in the form of increased capacity, reduced delays, increased efficiency, and reduced noise, fuel burn and emissions. There may be different ATM candidate solutions for different regions, but each phase of flight requires collaboration by different stakeholders. Figure 14 presents an idealisation of stakeholder's level of engagement (high, medium, low) for collaboration in each phase of flight.

## 7
## Current Efficiency Improvements Worldwide

In this section, we offer a sampling of the myriad projects worldwide where industry stakeholders are currently working together to increase efficiency and in so doing, reduce costs, fuel burn, and $CO_2$ emissions. For each region, projects are listed by phase of flight, stakeholders are highlighted, and benefits documented.

### 7.1_Europe

#### Taxi-Out
(Regulator, ANSP, airport, airlines, ground handling)

Europe has been very successful in the implementation of European Airport Collaborative Decision Making (A-CDM) to reduce taxi delays on the ground, thereby reducing fuel use and emissions.

European Airport CDM is part of the Eurocontrol Airport Operations Programme and represents collaboration between Eurocontrol, Airports Council International, and IATA[13]. As of third quarter 2011, over 20 European airports shown in Figure 15 and major airlines were participating in various stages in the Europe A-CDM project (http://www.euro-cdm.org/airports.php) highlighting the collaboration between the airport operator, airlines, ANSP, Eurocontrol Central Flow Management Unit (CFMU), and ground handling agencies.

A-CDM became operational at Munich Airport in June 2007, making Munich the first European airport to implement Airport CDM as a standard procedure. This project consisted of the sharing of data between Munich airport operator Flughafen München GmbH (FMG), the German ANSP Deutsche Flugsicherung (DFS), airlines, handling agencies, ground handling agencies, and the European CFMU. The collaboration has led to better management of airport and airline resources, reduced turn times, and overall reduction in delays.

Similarly, Paris-Charles de Gaulle (CDG) joined the group in November 2010. The use of Collaborative Pre Departure Sequence tools (C-PDS), connected to the CFMU and developed with the stakeholders (ADP, DSNA and EgisAvia), results in better slot compliance and reduced number of missed slots. The C-PDS allows more stable traffic flow and reduces taxi times, apron and taxiway congestion, and queues at the CDG runways. A-CDM at CDG is estimated to cut aircraft taxi time of by 2 to 4 minutes and contributes to sustainable development by cutting $CO_2$ emissions by 44 tonnes per day.

#### En Route Oceanic
(ANSP, airlines)

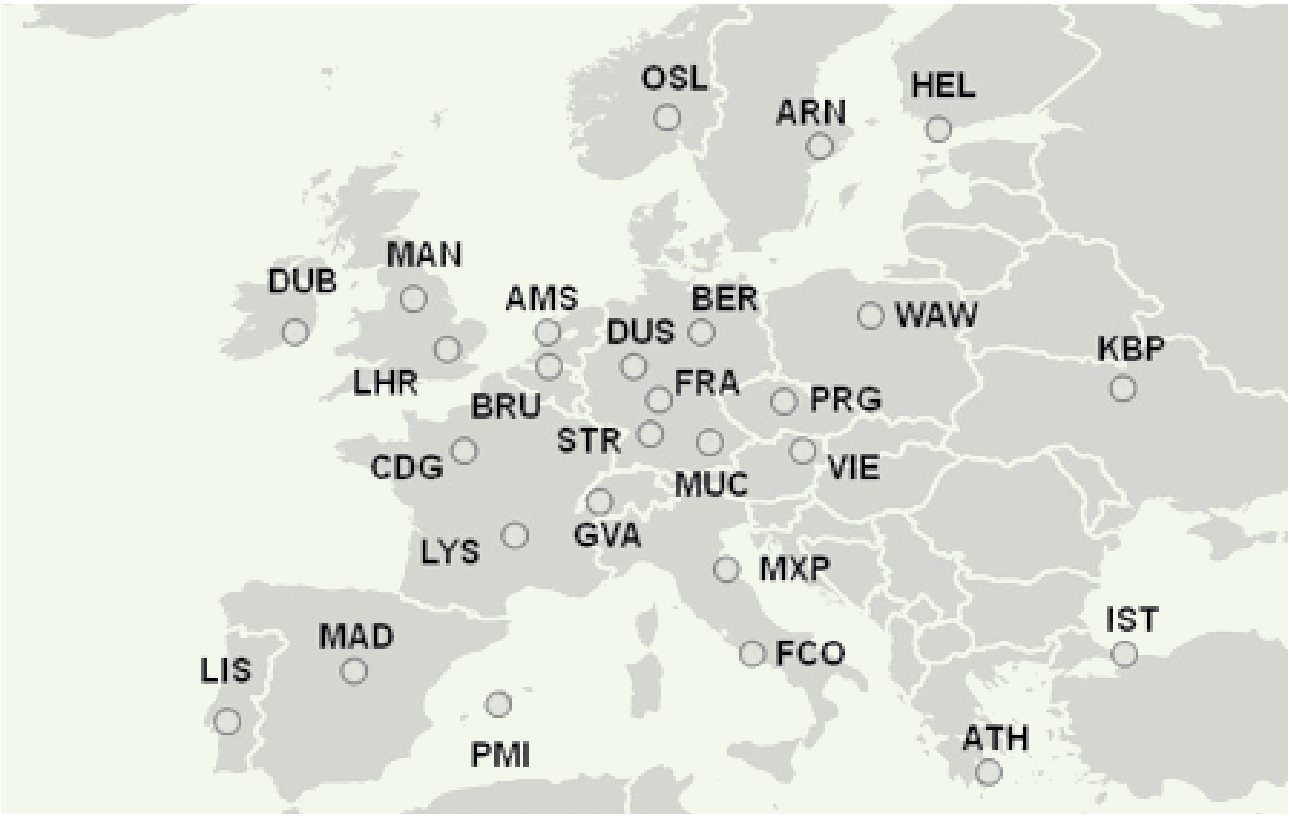
The Irish Aviation Authority (IAA) and UK National Air Traffic Services (NATS) embarked on the ENSURE (EN Route Shannon Upper airspace REdesign) project to enable airlines to fly direct routes over Ireland into oceanic airspace. The project was launched in December 2009 allowing for a full year of operation in 2010 to enable the airlines to confirm the savings that were predicted by simulation. Training was provided to all high level radar controllers for a seamless operation; briefings were provided to airlines, IATA, Eurocontrol, and adjacent centres on what was planned; coordination was arranged with and agreed to by UK NATS, and regulatory approval was sought and granted. The airlines confirmed the predicted savings and they requested a further extension of this free route airspace. This was accommodated in cooperation with UK NATS by launching a new project called Night Time Fuel Savings Routes (NTFSR) across Ireland and UK airspace which allows direct routings to selected destinations during the night, resulting in further benefits.

#### Descent
(ANSP, airport, airline, ground infrastructure provider)

Europe has been very successful in developing of a variety of arrival management tools to assist air traffic controllers with metering and spacing into

[13] European Airport CDM, available on the web at http://www.euro-cdm.org/airports.php

Figure 15 —
Airports participating in the European Airport-CDM Project




the terminal area. Eurocontrol has encouraged the development and implementation of different Arrival Management (AMAN) tools, reducing vectoring, fuel burn and emissions. A summary of the airports using AMAN tools is presented in Figure 16[14].

At Zurich Airport for example, collaboration between the ANSP -- Skyguide, Zurich Airport, and ground system provider Barco have resulted in the development and use of the Computer-assisted Approach and Landing Management (CALM) system, which helps to smooth the traffic flow into Zurich by providing traffic advisories to air traffic controllers.

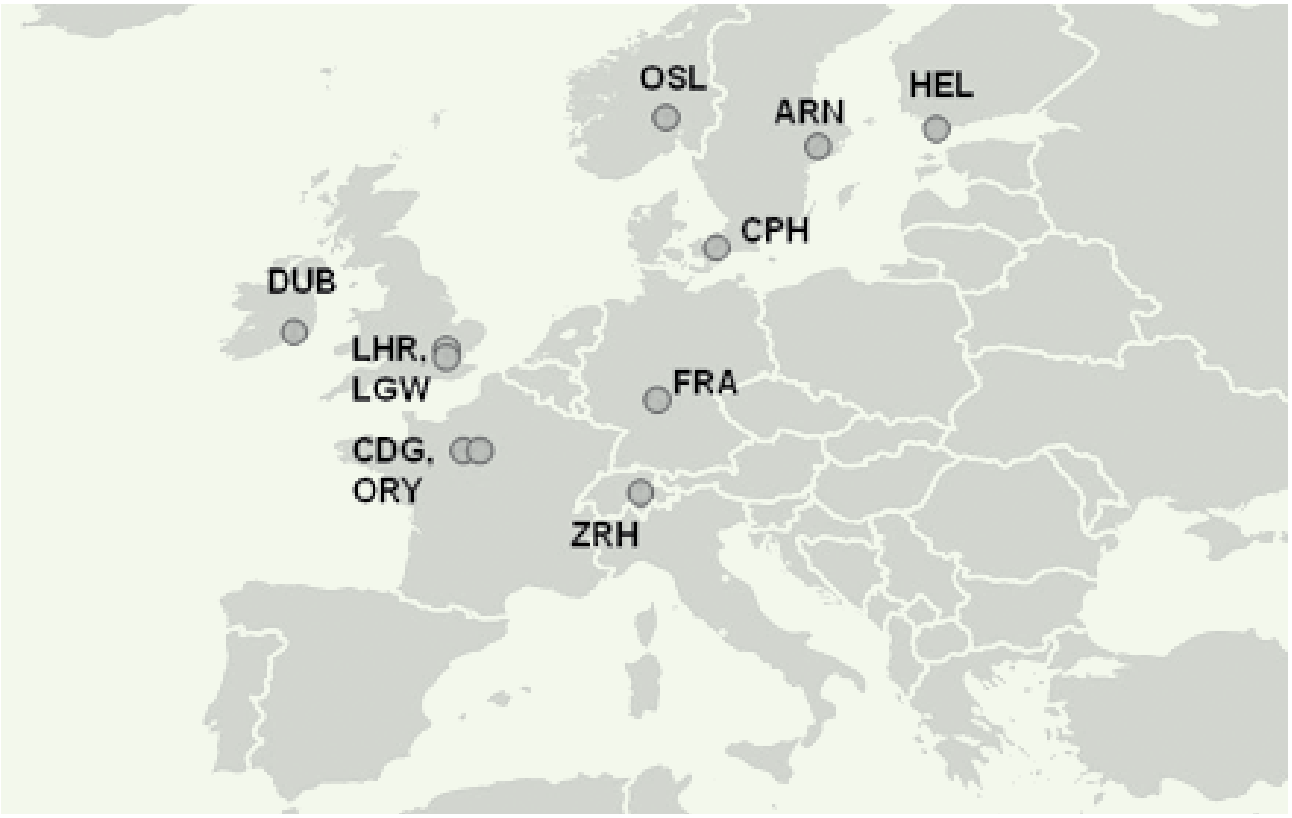
In the Netherlands, Amsterdam Schipol Airport, the Dutch ANSP LVNL, KLM Royal Dutch Airlines, and Eurocontrol Maastricht Upper Area Control Centre collaborated to perform trials using the Speed and Route Adviser (SARA) tool for speed advisories to enable optimised profile descents into Amsterdam Schipol Airport. On average, SARA flights flew 2.4 nm less per flight within the terminal area with a corresponding reduction in level flight.

Paris-Charles de Gaulle is using the MAESTRO tool for arrival management within the Paris en-route centre to monitor the airport capacity and smooth the traffic flows on all entry points in the Paris TMA.

UK NATS has performed trials with United Airlines for arrivals into Heathrow with significant fuel savings. The savings are based on a procedure to absorb necessary delay in cruise instead of holding stacks around the airport. In the trials, selected United aircraft transiting the North Atlantic were given delay targets to absorb in cruise and were then able to bypass the holding stacks. Fuel savings resulted from more fuel efficient cruise speeds as well as eliminating the fuel normally burned in the stack. Currently NATS is working on implementing “linear holding” for North Atlantic flights as an effort to improve overall fuel efficiency for Heathrow arrivals.

[14] AMAN Status Review 2010, Eurocontrol, December 2010.

Figure 16 —
European airports and ANSPs using various Arrival Management (AMAN) Tools




## 7.2_Americas

### Taxi-Out
### (ANSP, airport, airlines)

In the United States, the FAA is evaluating several surface management concepts to reduce taxi time, fuel burn, and emissions. Collaborative Departure Queue Management (CDQM) manages the length of runway departure queues so that aircraft can reduce their physical queue time while ensuring that runways are fully used[15]. In this concept, the airline receives an allocation of slots to enter the airport movement area rather than specific assigned times. The airline may then use these entry slots into the airport movement area rather than coordinate with other airlines or ATC. CDQM has been implemented within the FAA's Surface Decision Support System and has been tested at Memphis International Airport since 2009. Another concept, the "N control" concept, tested at Boston Logan Airport, uses statistical analysis to determine when the number of active aircraft on the airport surface saturates the departure flow rate. This concept applies gate hold procedures to aircraft requesting push back if the number of aircraft on the airport surface has reached this saturation point. Another concept using Airport Surface Detection Equipment, Model X (ASDE-X) was used by the Port Authority of New York and New Jersey and the airlines to successfully implement departure queue management at the John F. Kennedy Airport in New York, while one of the primary runways was undergoing reconstruction. This procedure was used successfully from March through June 2010, with substantial fuel savings to the airlines[16].

[15] Collaborative Departure Queue Management: An Example of Airport Collaborative Decision Making in the United States, Ninth USA/Europe ATM RE&D Seminar, Brinton, C., Provan, C., Lent, S., Prevost, T., Passmore, S., 2011.

[16] Benefits of Virtual Queuing at Congested Airports Using ASDE-X: A Case Study of JFK Airport, Ninth USA/Europe ATM RE&D Seminar, Bhadra, D., Knorr, D., Levy, B., 2011.

### Departure
### (ANSP, airport, and airlines)

Atlanta International Airport, the FAA, The Mitre Corporation (MITRE), and Delta Airlines have worked together to implement Area Navigation (RNAV) Standard Instrument Departures (SID) since 2005. Delta Airlines has reported significant benefits including reduced mileage flown on the departures, an earlier time to climb, reduced taxi times, and reduced voice communications. Similar benefits have been reported at Dallas-Ft. Worth International Airport, Las Vegas McCarran International Airport, Los Angeles International Airport, and Phoenix International Airport[17].

### En Route to Descent
### (ANSP, airlines, aircraft manufacturer, ground infrastructure provider)

The FAA has been working on several projects aimed at improving ATM efficiency in the transition from en route cruise to the terminal area. The Three Dimensional Path in Arrival Management (3D PAM) Project is a collaborative effort between the FAA, National Aeronautics and Space Administration (NASA), The Boeing Company, airlines, and other industry participants[18]. 3D PAM uses a combination of ground and airborne automation to compute and execute advisories for a conflict-free trajectory from cruise altitude to a time-based metering fix at the Terminal Radar Approach CONtrol (TRACON) boundary. While maximising throughput and avoiding separation conflicts, 3D PAM trajectories use optimal profile descents to improve efficiency. Although 3D PAM relies on existing flight deck automation for maximising efficiency benefits and minimising pilot workload, new procedures are required to ensure that this automation gets used to its full potential in the arrival domain. 3D PAM is under development at the Denver Air Route Traffic Control Centre (ARTCC).

The Initial Tailored Arrivals (ITA) Project is a collaborative initiative between the FAA and The Boeing Company with airline partnership and NASA support. Tailored Arrivals incorporate currently underutilised flight management system (FMS) functions and Future Air Navigation System (FANS) 1/A equipment onboard oceanic aircraft together with ground automation known as 'Ocean 21' Advanced Technologies & Oceanic Procedures (ATOP) to increase the efficiency and arrival capacity. The FANS equipment receives the TA clearance from Ocean 21 and the FMS then executes a trajectory-based arrival route and profile optimised vertically and laterally from cruise altitude to the runway threshold. Currently this project is limited to the use of Oceanic FANS equipped aircraft and the Ocean 21 system and is only performed at select coastal city airports. In the US, ITAs have been conducted at San Francisco, Miami, and Los Angeles International Airports. The Attila™ Aircraft Arrival Management System developed by the ATH Group, is a tool used by the airlines to track their aircraft in the system, calculate estimated times of arrival, and make small timely corrections to each aircraft's speed to drive optimal solutions for the airline's network of flights[19]. The Attila™ system currently operates independent of the ATC system in that arrival times are provided to pilots by dispatchers. As soon as flights enter the cruise phase they are given a time to cross the terminal area meter fix. Attila™ may speed aircraft up early in the "rush" to maximise overall throughput. While speeding aircraft up may increase full burn for those individual flights, overall delay can be reduced and system fuel burn can be minimised. Attila™ takes advantage of airline information on which aircraft have the highest priority to reduce time (meet connections, increase on-time, etc). An FAA funded Attila™ trial has taken place where the system attempts to help manage arrival flows from two airlines into Charlotte airport. Full benefits from a fuel savings standpoint require participation from all aircraft.

[17] Statement of Dr. Agam Sinha Before the House Committee on Transportation and Infrastructure, Subcommittee on ATC Modernization and NextGen, March 18, 2009, Washington, DC.

[18] Summer/Fall 2010 Metrics/Benefits Analysis Report 4D Advanced Arrivals, FAA, September 2010

[19] The Attila Managed Arrivals System, available on the web at http://www.athgrp.com/index.html.

Other time based metering tools for terminal congestion are used by throughout major airports in the US. Fuel savings can be improved by using aircraft capabilities to support achieving metering times where practicable.

### Descent
### (ANSP, airport, airlines, ground infrastructure provider)

RNP arrival procedures were trialled at Portland International Airport in Portland, Oregon, enabling a significant reduction in the variability of flight tracks and reducing both fuel and emissions. Ronald Reagan Washington National Airport in Washington, DC, permit RNP enabled aircraft to fly a precise path along the Potomac River while avoiding prohibited airspace. RNAV and RNP procedures have been used to deconflict arrival and departure procedures at nearby airports and thus accommodate more arrivals and departures in congested airspace.

## 7.3_Asia Pacific

### En Route to Descent
### (ANSP, airport, airlines)

The ATM Long Range Optimal Flow Tool (ALOFT) is used to help sequence arrivals into Sydney International Airport. There is a curfew in place at Sydney from 11 pm to 6 am and though international arrivals depart in order to make the curfew, this is not always the case. Without a coordinated approach to managing arrivals, airlines were incentivised to arrive earlier in order to improve their position in the arrival queue. In order to manage the demand, ATC would put aircraft in holding patterns outside of Sydney. Airservices Australia implemented ALOFT so that arriving aircraft are provided with a time up to 1000 nautical miles from the airport to arrive at a metering fix located 160 nautical miles from Sydney. This allows aircraft to use their FMS capabilities to best manage fuel burn associated with meeting a time constraint. The aircraft are then issued an additional time to arrive at a 40 nautical mile meter fix using their AMAN system (MAESTRO). Both the times at 160 and 40 nautical miles allow sufficient pressure for ATC to fine-tune the sequence and manage additional flow and separation changes as needed – while guaranteeing that no slots for arrival are missed. This ALOFT process will continue to be refined as technology and automation are introduced[20].

### Descent
### (ANSP, airlines, airports, ground service provider)

Airways New Zealand has been using Collaborative Flow Management (CFM) to manage arrivals. CFM in New Zealand uses ground delays to manage terminal area congestion at the destination airport, similar to the US and Europe. The difference is that in New Zealand the calculated arrival times are used throughout the flight. These times are transmitted to aircraft operating companies between two and three hours prior to Estimated Off Block Time (EOBT). The Controlled Time Of Takeoff (CTOT) and Controlled Time of Arrival (CTA) times are established through an online “reservation” system based on the latest flight plan information as modelled by the ATM system and the declared capacity for the destination airport, as determined by the ANSP. The operations team can manipulate their fleet times to prioritise or optimise the management of their network but cannot manipulate other flights without mutual agreement between the operating companies and approval of the CFM coordinator. The optimised departure times are provided to aircrew by their flight ops team using ACARS or pre-departure messages no later than 25 minutes prior to EOBT but can be modified and updated prior to takeoff. Once the flights are airborne, the aircrew is required to conform as closely as possible to the filed flight plan. Any fine tuning of the actual arrival sequence remains an operational ATC responsibility and this will be further enhanced with the introduction of

[20] From conversations with CANSO member Airservices Australia.

[21] From conversations with CANSO member Airways New Zealand.

BARCO's AMAN tool and the use of the "Required Time Arrival" (RTA) function[21].

In Japanese Airspace, the major sources of congestion are the metropolitan airports and their surrounding terminal areas. Today, operations in the arrival phase lead to inefficiently flown paths and high controller workload. Japanese ATM is planning to implement "traffic synchronisation", ICAO's tactical measure, allowing the control of trajectories beyond sector boundaries. In this context, new sequencing tools and new strategies to integrate traffic synchronisation and demand/capacity balancing will be needed.

RNP design and implementation at Brisbane is a clear example of aircraft manufacturer, airline, ANSP, and regulator working towards a common goal [22]. The initial RNP 0.3 design criteria commenced seven months prior to implementation at Brisbane; initial designs were distributed to ATC for review and tested in the Qantas 737 flight simulators before being flight checked. An Online Training (OLT) package was developed for air traffic controller training; the package targeted the specific elements of change within each operational unit; completion of the OLT package was mandatory for all air traffic control personnel prior to their participation in the Brisbane Green project. Qantas pilots undertook theoretical and simulator training to qualify for RNP instrument approaches generally; importantly no additional training was required for these RNP qualified pilots to participate in the project. New pilot/controller phraseologies were developed in conjunction with the regulator and airline participants; these phrases were also applicable to other locations where RNP was being introduced and were standardised throughout Australia. Transparent and collaborative safety activities between the airline, ANSP and regulator were a foundation to the project's success – this included the safety framework, data collection, and reporting with continual oversight by the Australian Regulator (Civil Aviation Safety Authority).

## 7.4_Eurasia

ANSPs in Eurasia have formed the "Coordination Council of Eurasia" to enhance operational efficiency in dealing with ATM issues affecting neighbouring States and to develop agreed proposals in the area of ATM to be submitted to national aviation administrations. The membership of this group includes the ANSPs of Eurasia and permanent observers from industry and airlines.

The Coordination Council (CC) has working subgroups to manage the various specialist tasks needed to support the objectives of the council. These include inter alia:

- harmonisation of ATM regulatory documents of "Eurasia" CC States;
- support to bilateral Agreements between national ATM enterprises of "Eurasia" CC States;
- organisational and technical issues of language training provision for Air Traffic Control Officers (ATCOs);
- development of proposals to ensure seamless flights of all airlines;
- organisational and technical issues of RVSM implementation;
- organisational and technical issues of Flight Plan (FPL) 2012 implementation;
- establishment of automated Air Traffic Flow Management (ATFM) system for "Eurasia" CC States, including deployment of the International Air Navigation Service (IAS) ensuring its interoperability with Eurocontrol;
- establishment of automated flight safety assessment system;
- interoperability of satellite communications network of Central Asia with the similar satellite communications network of Russia in the interests of ATM;
- Development of interfaces between national ATM data bases.

[22] http://www.airservicesaustralia.com/wp-content/uploads/RNP_Brisbane_Green_Project_Stage1_Report.pdf.

The Federal State Unitary Enterprise, State Air Traffic Management Corporation of the Russian Federation (State ATM Corporation) has drawn up a modernisation programme called the "Joint ATM system Modernisation of the Russian Federation (2009-2015) – which has been approved by the Government[23]. This programme aims to increase flight safety and airspace efficiency through the modernisation of the Russian Joint ATM System, and to optimise airspace use by means of innovative equipment and technology. The programme is comparable with other modernisation programmes such as SESAR in Europe and NextGen in the US.

Among the key measures contained within the programme is the consolidation of area control centres, enhancement of terminal and en route Air Navigation Service (ANS) provision, modernisation of aeronautical telecommunications and data link networks, implementation of a single airspace management system, transition to Communication, Navigation and Surveillance (CNS)/ATM based technologies as well as establishment of integrated civil military automated ATC systems.

The consolidation of area control centres is well advanced. The process is due to be complete by 2015 when 13 regional centres will take the place of the existing facilities. By the end of 2010, two such centres had already been established: In Moscow, the Automated ATC Centre Branch, and in Rostov-on-Don, the South Air Navigation Branch. In 2011, a consolidated centre at Khabarovsk will begin operations. Just a couple of years ago the number of area control centres totalled 118. Today there are 69 and the programme remains on track to complete the task by 2015.

Between 2009 and 2015 investment in the modernisation programme is estimated to exceed EUR1 billion. In addition to the resources appropriated by the State ATM Corporation, the Russian Government renders assistance by allocating funds from the federal budget. In 2010, the major items of investment included consolidation of the area control centres, installing terminal ATC automation equipment in accordance with the federal targets; and ATM system modernisation in preparation for Reduced Vertical Separation Minima (RVSM) implementation.

During the coming years, 100 short-range navigation systems and over 100 terminal, en-route and secondary radars will be deployed. Over 50 satellite communication stations, 770 VHF/HF voice communication and Automatic Terminal Information Service (ATIS) stations are to be modernised. Additionally, 100 full-scale and visual simulators will be implemented. The scope of work is significant and it has to be carried out over large distances, often in harsh weather conditions.

### 7.5_Africa – IATA service

Airlines and air traffic authorities are being continuously challenged by existing airspace structure. In certain areas, flight routings offered by Air Traffic Control (ATC) services have been slow to keep pace with the rapid changes of airlines' operational demands, especially for long-haul city-pairs[24].

Across the southern Atlantic and over the African continent, regional route structures, built many years ago, have become outdated and are becoming constraining factors due to their inflexibility. IATA has worked with key stakeholders to help introduce more flexible routings, mainly in less dense traffic areas. This work is called iFLEX (IATA Flexible Routings). Two major airlines, Emirates and Delta are already involved in the project, and are confident that iFLEX can be developed to significantly change the way they operate. Using what is already available on the airplane and within ATC ground systems, the move from Fixed to Flex can easily be accomplished in an orderly and efficient manner. The obstacle is to challenge the traditional way of thinking. Implementing iFLEX does not require

[23] http://www.canso.org/cms/streambin.aspx?requestid=7C56A539-46FB-49A2-B79B-7F2580EEE587

[24] http://www.iata.org/whatwedo/airport-ans/infrastructure_strategy/Documents/iFLEX.pdf

any changes to the airlines/aircraft nor to the ANSPs or their systems. The IATA Guidance Material will provide the 'science' to implement the programme globally and on a sustainable basis.

The iFLEX programme builds on existing best-practices, current technology and with solutions that can be implemented across several FIRs or regions in day-to-day operating conditions. All new Flex Routes generated will be validated in real-time for Notices to Airmen (NOTAMs), airspace restrictions and en-route weather conditions. The resulting flight plans will use a combination of existing infrastructure, waypoints, latitude/longitudes, fixed-airways with new Flex Routes where possible to obtain an optimised trajectory given the winds for that period. It will require close coordination with ICAO, states, ANSPs and airlines.

## 7.6_Middle East

At the first Middle East Airspace User and Stakeholder Engagement (MEAUSE) Conference held in November 2010, Middle Eastern ANSPs and Airspace Users, both civil and military, discussed future plans for the region and the necessary framework and consultation needed to achieve this. One of the outcomes of this conference was the establishment of the CANSO MEAUSE Workgroup.

The MEAUSE Workgroup that specifically engages ANSPs, airspace users and other aviation stakeholders to build lasting relationships aimed at the transformation of ATM performance[25].

Prior to the creation of the MEAUSE Workgroup the region did not have a permanent consultation mechanism for aviation stakeholders to support the development of a future vision and plans.

The development of an ANSP's plans for the future requires a detailed analysis of operational needs and requirements in order to create the optimum investment plan to implement the required projects. The execution of these projects must be done in a timely manner to ensure that the ground infrastructure of the CNS/ATM elements match the airspace users' airborne system equipage plans.

The ANSPs' business case for their projects is therefore directly dependant on the airspace users' future plans. This is especially true for systems that require both ground and airborne elements such as Automatic Dependent Surveillance – Broadcast (ADS-B), Satellite Based Augmentation System (SBAS), FANS-1/A, Ground Based Augmentation system (GBAS), and Aeronautical Telecommunication Network (ATN).

To build a harmonised future vision and plan in the Middle East requires a consultation platform to help aviation stakeholders:

- Identify challenges
- Understand requirements and develop solutions
- Translate requirements and solutions into project elements
- Develop an implementation plan for all project elements

Unfortunately, the Middle East region does not have a consolidated CNS/ATM plan with an implementation timeframe that is agreeable to all ANSPs and airspace users. This situation made the development of future plans for both ANSPs and airlines very risky since financial investments in future projects are based on many assumptions and few facts while project benefits cannot be guaranteed.

The MEAUSE Workgroup has developed several surveys for ANSPs, airlines, airports and the military to gain an understanding of their future plans with regards to specific CNS/ATM elements. An analysis of the surveys has clearly shown the areas to refine and harmonise future plans to ensure that collectively goals and objectives are met.

The benefits for this harmonised future CNS/ATM plan for the Middle East region include:

- Addressing regional challenges and developing recommendations and solutions
- Ensuring that the benefits of the modernisation projects are realised and all stakeholders see a

[25] http://www.canso.org/cms/streambin.aspx?requestid=602CB48B-5844-4146-A70A-16EA5D8C73CC

Table 2 —
Summary of environmental benefits of AIRE-1 Flights in 2009

| Domain | Location | Trials Performed | CO2 Benefit/flight |
|---|---|---|---|
| Surface | Paris, France | 353 | 190-1200 Kg |
| Terminal | Paris, France | 82 | 100-1250 Kg |
| | Stockholm, Sweden | 11 | 450-950 Kg |
| | Madrid, Spain | 62 | 250-800 Kg |
| Oceanic | Santa Maria, Portugal | 48 | 90-650 Kg |
| | Reykjavik, Iceland | 48 | 250-1050 Kg |
| | Total | 1152 | |

return on their investments
— Creating a consolidated timeframe for implementation that is agreeable to all stakeholders.
— Establishing a positive business case for the CNS/ATM project elements

The MEAUSE Workgroup brings substantial change for the Middle East by creating a platform for the continuous engagement of all the stakeholders to shape the future vision and plans for the region.

## 7.7_Oceanic & Remote Regions

### Regulator, ANSP, airlines, aircraft manufacturers, avionics suppliers, ground infrastructure providers

Since 2009, Nav Canada has used ADS-B Out in the Hudson Bay to reduce separations between trailing aircraft from 80 nm to 5 nm in remote airspace. ADS-B equipped and authorised airlines get preferred routing while non-equipped airlines are accommodated. The traffic density of ADS-B equipage ranges between 50 and 60%. Approximately 30 airlines operating over 800 aircraft with ADS-B Out are operating in the Hudson Bay and seeing substantial savings in fuel and emissions.

Airservices Australia was the first country to implement ADS-B continent-wide, delivering the ability to provide 5 nm separation throughout its en route airspace. The ground network in Australia uses 29 ground stations to provide complete coverage of airspace above FL290 and quite a lot of coverage below that, to the ground at many locations. Airservices provides ADS-B services wherever ADS-B coverage is available and Airservices expects to extend that coverage commencing next year. Airservices has an agreement with Indonesia to exchange ADS-B data where their airspaces join.

The FAA has implemented ADS-B Out for low altitude helicopter operations in the Gulf of Mexico since December 2009. ADS-B equipped aircraft fly dedicated altitudes to enable radar-like handoffs and permit direct routings from Houston Centre and the Gulf Coast Approach Controls. For equipped aircraft, ATC required separation was reduced from 12 nm to 5 nm. Equipped operators have seen wait times for clearance delivery reduced from 45 minutes down to 2 min and fuel savings due to direct routings of 90 to 100 lbs/flight.

## 7.8_Collaboration Among Regions

### AIRE

The European Commission and the FAA launched the Atlantic Interoperability Initiative to Reduce Emissions (AIRE)[26] in 2007. In 2009, AIRE-1 executed 1,152 commercial flight trials with 18 stakeholder partners in five different locations. Each of the flight trials were aimed at improving environmental performance of flights using current technologies with improved operational procedures[27]. The European trails are summarised in Table 2 with AIRE-1 partners and projects shown in Figure 17 below.

In the US, AIRE demonstration flights have included surface, terminal, en route oceanic, and gate-to-gate flights from and within the US. Surface demonstrations have focused on Collaborative Departure Queue Management at Memphis and Orlando[28] International Airports. The goal of these projects has been to enable data sharing between the FAA, airlines, and airport operators to reduce taxi times and the use of Auxiliary Power Units on the airport surface.

Starting in 2008, AIRE demonstration flights for en route oceanic focused on the collaboration between FAA and NAV Portugal to allow partner airlines to modify the routing of their flights while en route DARP allow a FANS-1/A equipped aircraft to request a reroute clearance to take advantage of favourable tailwinds or minimise headwinds. In 2008, Air Europa participated with flights from Madrid to Havana, Santo Domingo, and Caracas. The project was expanded in 2009 and 2010 to include Lufthansa Airlines. This procedure became fully operational and available for eastbound and westbound flights through New York Oceanic Airspace in 2010.

The first transatlantic gate-to-gate AIRE demonstration flights with Boeing aircraft were flown in April 2010. Air France and American Airlines participated with flights from Paris to Miami involving DSNA, UK NATS, Nav Portugal and the FAA. In 2011, FAA partnered with NAV Canada, UK NATS, DSNA, and Air France to optimise Airbus A380 transatlantic gate-to-gate flights from New York JFK to Paris CDG.

### ASPIRE

Asia and Pacific Initiatives to Reduce Emissions (ASPIRE) was started in February, 2008 as a collaboration between the FAA, Airservices Australia, and Airways New Zealand. Since the original formation, the Japanese Civil Aviation Bureau, the Civil Aviation Authority of Singapore, and AeroThai have also joined as ANSP members[29]. ASPIRE promotes the implementation of Air Traffic Management environmental best practice and has established a work programme of initiatives to deliver improved environmental outcomes across the Asia Pacific.

For example, User Preferred Routes (UPRs) are cleared lateral profiles, customised for each individual flight, to meet the specific operator business needs for that flight using DARP as the in-flight procedure to modify the lateral profile to take advantage of current winds. The minimum lateral and longitudinal separation standard in oceanic airspace where ground based navigation, surveillance, and voice communication are not available is 30/30 nm. Time based arrival management are traffic flow management procedures and ATC decision support tools to sequence arrivals into high density airspace that improve efficiency by shifting delays to the less congested en route phase of flight. Optimised Profile Descents (OPDs) and Tailored Arrivals (TAs) improve fuel efficiency during the arrival phase of flight. Departure optimisation enable unconstrained climb to cruise level and track to route start point and oceanic trajectory. These procedures minimise low altitude vectoring and the need to level off at interim altitudes.

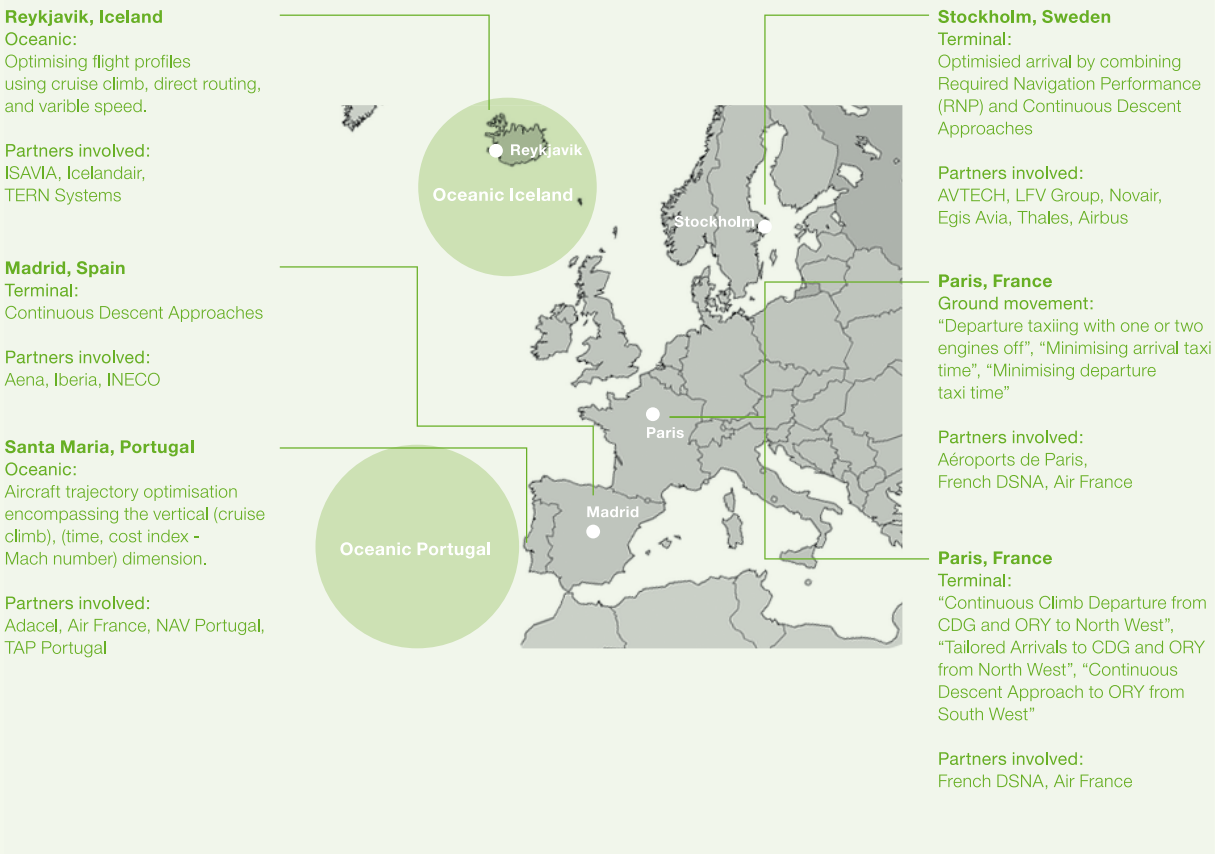
[26] http://www.sesarju.eu/environment/aire

[27] Delivering Green Results: A summary of European AIRE project results in 2009, SESAR Joint Undertaking, 2010.

[28] http://www.faa.gov/nextgen/implementation/portfolio/trans_support_progs/aire/flights/surface/

[29] ASPIRE – Asia and Pacific Initiative to Reduce Emissions, Annual Report, 2011.

Figure 17 —
2009 SJU AIRE-1 partners and projects




## INSPIRE

Building on the success of the ASPIRE partnership, the Indian Oceanic Strategic Partnership to Reduce Emissions (INSPIRE) was established in March 2011 between Airservices Australia, Air Traffic Navigation Services (ATNS) of South Africa, and Airports Authority of India. INSPIRE is a collaborative network of partners and peer organisations across the Arabian Sea and Indian Ocean region dedicated to improving fuel efficiency and sustainability of aviation. Airlines partners include Emirates Airline, Etihad Airways, Virgin Australia, and South African Airways.

## 8
## Opportunities for Stakeholder Collaboration for ATM Efficiency Improvement

This section offers suggestions for how key stakeholders, who are affected by each others' actions, can work together for genuine mutual benefit.

The key stakeholders in the aviation industry include ANSPs (along with air traffic controller organisations), airports and the communities surrounding airports, regulators, airlines, aircraft manufacturers, avionics and ground infrastructure suppliers. They are all inter-related as presented in Figure 18. Their interactions affect both the efficiency and inefficiency in the ATM system and directly impact the pace of change. Only by working together can the interdependencies be addressed and inefficiencies reduced.

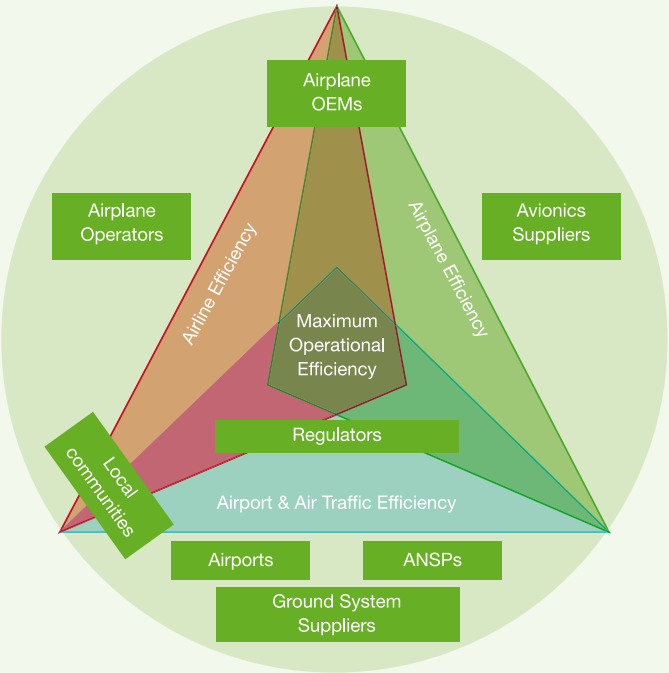
ANSPs are responsible for the management of flights throughout the airspace structure. They manage the overall flow and direct aircraft to ensure safety of flight. They need to work closely with regulators to accelerate implementation of new procedures and technology to increase airspace capacity and reduce environmental impact. They must collaborate closely with airports and airport authorities and acknowledge airplane operators' priorities to optimise operations. ANSPs need to shifting roles from directing to "managing" flights once the tools, training, and safety analyses are in place. Industry can help accelerate this transition through detailed modelling, simulation and new collaborative trials.

In the near term, ANSPs can support the fuel efficient management of necessary delay due to congestion by bringing airlines and airports together to "broker" system level efficiencies while maintaining equity. Successes in Airport CDM and virtual queue management can be applied to the arrival process to curb the "rush-to-wait" incentives in the system today.

Airport operators are responsible for the management of the airport environment, including the roads leading to and from the airport, the terminal building, and the management of the airside. Airport operators must work closely with: city planners to make sure the roads leading to and from the airport can accommodate passengers; with airplane operators to accommodate efficient passengers and freight transfer; with regulators to implement new standards; with ANSPs to optimise airspace procedures, while also engaging with the local community to manage growth and pave the way for new efficient operations. Airport and Airplane Operators, ANSPs, and the Local Community should develop metrics for local efficiency and develop a sustainability framework that takes into account the potentially competing environmental objectives of minimising both noise and local emissions – while planning for and managing future growth. Airport operators can help bring airlines together with ANSPs to create efficient and equitable procedures as they did for Airport CDM.

Regulators are responsible for accelerating the development of new guidance material, criteria, policies, and procedures that enable improved operations that will reduce aviation's environmental impact. They must work closely with ANSPs, airports for master plan development, communities, international government bodies for global harmonisation, airplane operators to prioritise the most desirable functional priorities and airplane manufacturers to determine an efficient way to implement new onboard technologies and capabilities. Regulators need to implement lean principles to accelerate the change process without sacrificing safety. With closer airplane Original Equipment Manufacturer (OEM), regulator and ANSP focused collaboration, the development of guidance material, criteria, and policies for new operational capabilities could likely be reduced from 5-10 years to 3-5 years. Regulator responsibilities may include establishing rules for ensuring compliance of new procedures. Having regulator participation supports the assurance that

Figure 18 —
Stakeholders working together for maximum ATM efficiency




new investments will be returned to the ANSPs and aircraft operators in the form of cost savings, capacity enhancements, and other direct benefits.

Airlines, meaning all airplane operators including passenger, cargo/freight carriers, business, and general aviation must accommodate passenger or customer demands, must manage an integrated network of flights while often having to implement different requirements from various international regulators. Airplane operators must collaborate to work for coordinated implementation of common, interoperable standards that meet their business objectives while not imposing unreasonable requirements on general aviation. Airplane operators need to support airport operators with local community engagement to “find a way” to implement new, efficient airport approaches. Airlines have a business incentive that naturally focuses on their competitive advantages. More focus is needed on benefits that will benefit the aviation system as a whole. Other stakeholders outlined above must support airlines with incentives for a longer term focus.

Aircraft manufacturers must continue to work closely with regulators, ANSPs, avionics, and ground system suppliers to develop, implement, and certify new technology, operational capabilities, and corresponding procedures that enhance gate-to-gate efficiency in a more cost effective manner. Through the stimulus of competition, aircraft manufacturers work closely with their airline customers to determine the new functionality that offers the most operational benefits. The challenge of certifying this new capability cost effectively however, requires closer up-front collaboration with OEMs, avionics suppliers, regulators and operators to seek process improvements wherever possible. To accomplish ATM efficiency approaching 98% by 2050 requires collaboration between the airplane manufacturers,

regulators, operators and ANSPs to accelerate harmonised implementation of new ATM systems.

Avionics/ground system suppliers will continue to work closely with aircraft manufacturers, ANSPs, and regulators to develop, implement and certify new technologies and operational capabilities to accommodate increased air traffic demand, while simultaneously enabling more efficient aircraft travel. Avionics suppliers have the added challenge and responsibility to cost effectively create new operational capability across the aircraft type spectrum that helps reach a critical mass of equipage in the fleet. When the procedures are in place through OEM, ANSP and airport collaboration to take advantage of new technology, the critical mass may become the "tipping point" required by airlines to obtain the benefits of their investment. Ground system suppliers have the challenge of creating solutions for ANSPs with regional differences and challenges. Their research must focus on the most forward thinking solutions that benefit all stakeholders.

Communities in the vicinity of airports are sensitive to noise and emissions from operations at any nearby airports. Their cooperation is essential to enabling growth and enabling new operations at the airport. Local communities need to find representatives that can express community concerns while also appreciating the economic role played by the airport and the aviation industry and recognise the industry goal for reducing global emissions as well as local noise.

## 9
## Industry Challenge and Next Steps

### 9.1_Sharing of Best Practices

We must take advantage of sharing best practices across the ATM spectrum.

a. The CANSO Environmental Working Group has written several reference documents to serve that purpose. The Working Group set up a Metrics & Methodologies Subgroup that for the past 3 years has been driving towards consensus and developing guidance on performance measurement methodologies for ATM contributions towards aviation's $CO_2$ emissions. The subgroup has written "Methodologies for Calculating Delays/ Improvement Opportunity Pools by Phase of Flight" to provide ANSPs guidance on the recommended data sources and software for calculating potential benefits, recommended procedures for developing benchmark times, calculations for specific phases of flight, and the process for accumulating the opportunity pool into a national airspace system-wide pool. To that end, ICAO has developed the ICAO Fuel Savings Estimation Tool (IFSET) to assist member States in estimating fuel savings in a manner that is consistent with the models approved by the Committee on Aviation Environmental Protection (CAEP) and aligned with the ICAO Global Air Navigation Plan. A quantified common understanding of fuel saving opportunities across stakeholders will help accelerate progress.

b. The CANSO Environmental Working Group has written other white papers that serve as a collection of best practices from members on specific topics. The white paper on noise highlights noise issues, identifies best practices for managing airspace changes related to noise, and documents areas where stakeholder support must be obtained to achieve broader goals.

c. The white paper on speed control focuses on the potential for fuel savings during peak periods of arrival demand at congested airports. The case studies presented show that much improvement can be made using today's technologies both on the ground and in the aircraft. Success needs to be based on improving today's procedures as opposed to waiting for an optimum solution. The CANSO Environmental Working Group will continue to write papers of interest to members.

## 9.2_Collaboration is Key

We must take advantage of opportunities to work together. Programmes such as European Airport CDM bring together Eurocontrol, Airports Council International, and IATA to reduce fuel burn on the airport surface. Programmes like AIRE, ASPIRE, and INSPIRE bring together ANSPs, airports, and regulators from different regions in an effort to reduce fuel burn and emissions through every phase of flight. Though the regions may differ, the airlines that participate in these trials operate in each of those regions and help to bring policies and procedures together for mutual benefit. It is only through collaboration that we can identify information that can be shared for mutual benefit.

## 9.3_Let's start today

The opportunity and the needs are clear. The challenge is great and if industry steps up to implement the following seven steps, together we can accelerate change.

a. Improve the collective understanding of the operational benefits of more efficient ATM operations. This requires clear problem definitions by phase of flight in each primary stakeholder domain (ANSP, operator, community, etc.) as well as clear and common efficiency metrics and performance indicators that lend themselves to measuring operational improvements. From this, industry can quantify the achievable benefits to the user community and share successes from early implementers.
b. Increase stakeholder collaboration. Through increased collaboration, the industry can identify and prioritise the changes that reduce fuel use, increase operational efficiency, reduce $CO_2$ emissions (within evermore challenging local noise limitations) and improve each stakeholder's bottom line. This prioritisation will improve the management of limited public and private investments required to update ATM infrastructure and airborne systems and reduce implementation risks.
c. Accelerate operational trials and procedures that take advantage of existing aircraft capabilities. Modern aircraft are already able to navigate with unprecedented accuracy, predict their future locations more accurately than ground based systems, and relay position and trajectory information to others. New operations and procedures must be accelerated to take advantage of these investments in performance based navigation systems, ADS-B equipment, and digital communications capability. The work already being done with ANSP cooperation (such as RNAV/RNP approaches, continuous

descents, and I-Flex routing) is essential to accelerating early efficiency implementation. Continued trials looking at airspeed control or CTA's to manage terminal congestion is also key to our future success.

d. Accelerate "real time" collaborative decision making through enhanced information sharing. Real time information sharing between operators and ANSPs permits coordinated taxi and takeoff times (minimising ground fuel consumption and enabling less contingency fuel thereby lowering airborne fuel use). Likewise, near real time information sharing will enhance flight time predictability, arrival management efficiency, and user preferred route adjustments in the event of significant wind or weather changes. The ability to negotiate takeoff, arrival times, and route changes in a safe and timely manner minimises fuel use, $CO_2$ emissions, and costs.

e. Reduce airspace restrictions that lead to inefficient operations. This step is a primary emphasis for Eurocontrol's Single European Sky concept. However, there are still opportunities for improved collaboration on shared airspace use and approval of user preferred routes. International agreements should be negotiated on airspace usage costs to minimise inefficient flights by operators based on business decisions.

f. Accelerate the approval process for new procedures and operations. This step goes beyond step "c" and calls on industry to collaborate and apply lean principles that will accelerate the implementation process and timeline while managing certification costs for new procedures and operations based on new technical capability.

g. Promote common best practices in ATM to ensure international harmonisation. The ICAO led Aviation System Block Upgrades (ASBU) plan provides an excellent opportunity for global collaboration on airspace interoperability and efficiency[30]. Both SESAR in Europe and NextGen in the U.S. are mapping future initiatives into the ICAO paradigm in preparation for formalizing the plan at the 12th Air Navigation Conference in November 2012. The ASBU plan identifies a structured approach for coordinating regional changes to aviation systems (air and ground) that lead to global harmonisation and enhanced capability. The plan provides an opportunity for multiple stakeholders to work with regional agencies to plan an orderly implementation. Operators, ANSPs and regional governments will need to coordinate deployments of air and ground capabilities to reduce costs to all stakeholders and eliminate performance differences across regions.

These steps require commitment to a shared objective – improved operations for all. The time is right to start working together on each of these steps today.

[30] GANIS (Global Air Navigation Industry Symposium) Working Document, ICAO Aviation System Block Upgrades, "The Framework for Global Harmonization", Aug 2011.

## 10
## Glossary

3D-PAM
3 Dimensional Path Arrival Management

ACARS
Aircraft Communications Addressing and Reporting System

A-CDM
Airport Collaborative Decision Making

ADS-B/C
Automatic Dependent Surveillance – Broadcast/Contract

AIRE
Atlantic Interoperability Initiative to Reduce Emissions

ALOFT
ATM Long Range Optimal Flow Tool

AMAN
Arrival Management (ATM Arrival Manager)

ANSP
Air Navigation Service Provider

ARTCC
Air Route Traffic Control Centre

ASDE-X
Airport Surface Detection Equipment, Model X

A-SMCGS
Advanced Surface Movement Guidance and Control System

ASBU
Aviation System Block Upgrades (ICAO)

ASPIRE
Asia and Pacific Initiatives to Reduce Emissions

ATAG
Air Transport Action Group

ATC
Air Traffic Control

ATCO
Air Traffic Control Officers

ATIS
Automatic Terminal Information Service

ATM
Air Traffic Management

ATNS
Air Traffic and Navigation Services

ATOP
Advanced Technologies and Oceanic Procedures

ATS
Air Traffic Services

CANSO
Civil Air Navigation Services Organisation

CAEP
Committee on Aviation and Environmental Protection

CALM
Computer-assisted Approach and Landing Management

CARATS
Collaborative Actions for Renovation of Air Traffic Systems

CC
Coordination Council

CDM
Collaborative Decision Making

CDQM
Collaborative Departure Queue Management

CDS
Collaborative Departure Scheduling

CFM
Collaborative Flow Management

CFMU
Central Flow Management Unit (Eurocontrol)

CNS
Communication Navigation Surveillance

CPDLC
Controller to Pilot Data Link

C-PDS
Collaborative Pre-Departure Sequence

CTA
Controlled Time of Arrival

CTOT
Controlled Time of Takeoff

DARP
Dynamic Airborne Reroute Procedures (or Programme or Planning)

DSNA
Direction des Services de la Navigation Aérienne

DFS
Deutsche Flugsicherung

EDCT/AFTM
Expected Departure Clearance Time / Air Traffic Flow Management

EOBT
Estimated Off Block Time

ENSURE
EN Route Shannon Upper airspace REdsign

ETOT
Estimated Take Off Time

EUROCONTROL
European Organisation for the Safety of Air Navigation

FAA
Federal Aviation Administration

FANS
Future Air Navigation System

FMG
Flughagen München GmbH

FMS
Flight Management System

FPL
Flight Plan

GANIS
Global Air Navigation Industry Symposium

GBAS
Ground Based Augmentation System

IAA
Irish Aviation Authority

IAS
International Air Navigation Service

IATA
International Air Transport Association

ICAO
International Civil Aviation Organization

iFLEX
IATA Flexible Routings

IFSET
ICAO Fuel Savings Estimation Tool

INSPIRE
Indian Ocean Strategic Partnership to Reduce Emissions

KPI
Key Performance Indicator

LVNL
Luchtverkeersleiding Nederland

MITRE
The Mitre Corporation

NASA
National Aeronautics and Space Administration

NATS
National Air Traffic Services

NextGen
Next Generation Transportation System

NOTAM(s)
Notices to Airmen

NTSFR
Night Time Fuel Savings Routes

OEM
Original Equipment Manufacturer

OLT
Online Training

OOOI
Out, Off, On, In (ACARS message)

OPD
Optimum Profile Descent

PBN
Performance Based Navigation

RNAV
Area Navigation

RNP
Required Navigation Performance

RTA
Required Time of Arrival

RVSM
Reduced Vertical Separation Minima

SARA
Speed And Route Advisor

SBAS
Satellite Based Augmentation System

SESAR
Single European Sky ATM Research

SID
Standard Instrument Departure

STAR
Standard Arrival Route

TA/ITA
Tailored Arrival/Initial Tailored Arrival

TMA
Traffic Management Advisor

TRACON
Terminal Radar Approach CONtrol

UPR
User Preferred Route

## Appendix A
## European Airport CDM Projects

Table A1.
Status of current European A-CDM Projects

| Airport | ANSP | Airline |
|---|---|---|
| Amsterdam Schipol | LVNL | KLM |
| Arlanda | LFV | SAS Norwegian |
| Athens International S.A, Eleftherios Venizelos | ATC Hellenic CAA | Olympic Airlines, Aegean Airlines |
| Barcelona | | |
| Berlin-Schönefeld | DFS Deutsche Flugsicherung GmbH | |
| Brussels | Belgocontrol | Airline Operators Committee, Brussels Airlines, Thomas Cook |
| Dublin | Irish Aviation Authority | Main Airlines operating at DUB (Ryanair, Aer Lingus, Aer Arann, Cityjet, British Midlands, etc.) |
| Dusseldorf | DFS Deutsche Flugsicherung GmbH | |
| Frankfurt | DFS Deutsche Flugsicherung GmbH | Deutsche Lufthansa |
| Geneva | Skyguide | |
| Helsinki | Finavia | Finnair (Hub AO), Blue 1 (Hub AO), Air Finland (Hub AO) , SAS (AO, as a parent company of the Blue1), Finnish Commuter Airlines (hub AO) |
| Istanbul | DHMI | THY A.O (AO), OHY AIRLINES A.S. (AO) , MNG AIRLINES (AO), ATLASJET HAVACILIK A.S.(AO) |
| Kiev Boryspil | UkSatSE | Ukraine International Airlines, Aerosvit, AOC, Alexandr Goryachev |
| Lisbon | NAV (ANSP) | TAP (major AO); PGA (AO), SATA (AO), |
| London Heathrow | NATS-NSL | Aircraft Operators – Represented by the AOC including British Airways, bmi, Air Canada, Virgin, Lufthansa |
| Lyon | DSNA (Direction des Services de la Navigation) | AOC: Airlines Operator Committee |
| Madrid | AENA | Iberia |
| Manchester | NATS | Airlines – via AOC / Working Group Member |
| Milan Malpensa | ENAV | AOC (Airline Operators Committee) |
| Munich | DFS Deutsche Flugsicherung GmbH | AOC, Deutsche Lufthansa |
| Oslo | Avinor | SAS, Norwegian |
| Paris CDG | DSNA | Air France, AOC: Airlines Operations Committee |
| Prague | Air Navigation Services of Czech Republic | Czech Airlines |
| Rome Fiumicino | ENAV | ALITALIA , AOC: Airline Operators Committee |
| Stuttgart | DFS Deutsche Flugsicherung GmbH | |
| Vienna | Austro Control GmbH | Austrian Airlines |
| Warsaw | Polish Air Navigation Agency (PANSA) | Lot Polish Airlines (LOT) |
| Zurich | Skyguide | |

## Appendix B
## AMAN tools in use by airports and ANSPs in Europe

Table B1.
Airports, ANSPs, and AMAN tools in use in Europe

| Airport | ANSP | AMAN Tool | Ground System Provider |
|---|---|---|---|
| Paris CDG | | MAESTRO | Egis-Avia |
| London Heathrow | UK NATS | OSYRIS | Barco |
| Frankfurt Main | DFS | 4D PLANNER | DFS, DLR |
| London Gatwick | UK NATS | OSYRIS | Barco |
| Zurich | Skyguide | CALM (OSYRIS) | Barco |
| Copenhagen Catsup | | MAESTRO | Egis-Avia |
| Paris Orly | | MAESTRO | Egis-Avia |
| Oslo/Gardermoen | | OSYRIS | Barco |
| Stockholm/Arlanda | | MAESTRO | Egis-Avia |
| Dublin | | MAESTRO | Egis-Avia |
| Helsinki/Vantaa | | MAESTRO | Egis-Avia |

**CANSO –**
The Civil Air Navigation Services Organisation – is the global voice of the companies that provide air traffic control, and represents the interests of Air Navigation Services Providers worldwide.

CANSO members are responsible for supporting over 85% of world air traffic, and through our Workgroups, members share information and develop new policies, with the ultimate aim of improving air navigation services on the ground and in the air. CANSO also represents its members' views in major regulatory and industry forums, including at ICAO, where we have official Observer status.

For more information on joining CANSO, visit www.canso.org/joiningcanso

**THE BOEING COMPANY –**
The Boeing Company is the world's largest aerospace company and leading manufacturer of commercial aviation jetliners and defense, space and security systems. The company's 170,000 employees support airlines and government customers in 150 countries.

Boeing is working with government, industry and airline partners around the globe to improve the world's air traffic system. By applying expertise in the areas of modeling and simulation, airspace design, systems integration and navigation services, Boeing's Air Traffic Management team is at the forefront of creating the infrastructure for a transformational air traffic management system.

For more information, visit www.boeing.com/boeingedge

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- Aeronautical Radio of Thailand (AEROTHAI)
- Aeroportos de Moçambique
- Air Navigation and Weather Services, CAA (ANWS)
- Air Navigation Services of the Czech Republic (ANS Czech Republic)
- Air Traffic & Navigation Services (ATNS)
- Airports and Aviation Services Limited (AASL)
- Airports Authority of India (AAI)
- Airservices Australia
- Airways New Zealand
- Austro Control
- Avinor AS
- AZANS Azerbaijan
- Belgocontrol
- Bulgarian Air Traffic Services Authority (BULATSA)
- CAA Uganda
- Civil Aviation Authority of Bangladesh (CAAB)
- Civil Aviation Authority of Singapore (CAAS)
- Civil Aviation Regulatory Commission (CARC)
- Department of Airspace Control (DECEA)
- Department of Civil Aviation, Republic of Cyprus
- DFS Deutsche Flugsicherung GmbH (DFS)
- DSNA France
- ENAV S.p.A: Società Nazionale per l'Assistenza al Volo
- Entidad Pública Aeropuertos Españoles y Navegación Aérea (Aena)
- Estonian Air Navigation Services (EANS)
- Federal Aviation Administration (FAA)
- Finavia Corporation
- GCAA United Arab Emirates
- General Authority of Civil Aviation (GACA)
- Hellenic Civil Aviation Authority (HCAA)
- HungaroControl Pte. Ltd. Co.
- Irish Aviation Authority (IAA)
- ISAVIA Ltd
- Kazaeronavigatsia
- Kenya Civil Aviation Authority (KCAA)
- Latvijas Gaisa Satiksme (LGS)
- Letové prevádzkové Služby Slovenskej Republiky, Štátny Podnik
- Luchtverkeersleiding Nederland (LVNL)
- Luxembourg ANA
- Maldives Airports Company Limited (MACL)
- Malta Air Traffic Services (MATS)
- NATA Albania
- National Airports Corporation Ltd.
- National Air Navigation Services Company (NANSC)
- NATS UK
- NAV CANADA
- NAV Portugal
- Naviair
- Netherlands Antilles - Curaçao ATC (NAATC)
- Nigerian Airspace Management Agency (NAMA)
- Office de l'Aviation Civile et des Aeroports (OACA)
- ORO NAVIGACIJA, Lithuania
- PNG Air Services Limited (PNGASL)
- Polish Air Navigation Services Agency (PANSA)
- Prishtina International Airport JSC
- PT Angkasa Pura II (Persero)
- ROMATSA
- Sakaeronavigatsia Ltd
- S.E. MoldATSA
- SENEAM
- Serbia and Montenegro Air Traffic Services Agency (SMATSA)
- Serco
- skyguide
- Slovenia Control
- State Airports Authority & ANSP (DHMI)
- State ATM Corporation
- The LFV Group
- Ukrainian Air Traffic Service Enterprise (UkSATSE)

**Gold Associate Members - 14**

- Abu Dhabi Airports Company
- Airbus
- BT Plc
- FREQUENTIS AG
- GroupEAD Europe S.L.
- ITT Corporation
- Lockheed Martin
- Metron Aviation
- Raytheon
- SELEX Sistemi Integrati S.p.A.
- Sensis Corporation
- Telephonics Corporation, ESD
- Thales
- The Boeing Company

**Silver Associate Members - 55**

- Abu Dhabi Department of Transport
- Adacel Inc.
- ARINC
- ATCA – Japan
- ATECH Negócios em Tecnologia S/A
- Aviation Advocacy Sarl
- Avibit Data Processing GmbH
- Avitech AG
- AZIMUT JSC
- Barco Orthogon GmbH
- Booz Allen Hamilton, Inc.
- Brüel & Kjaer EMS
- Comsoft GmbH
- Dubai Airports
- EADS Cassidian
- EIZO Technologies GmbH
- European Satellite Services Provider (ESSP SAS)
- Emirates
- Entry Point North
- Era Corporation
- Etihad Airways
- Fokker Services B.V.
- GE Aviation's PBN Services
- Guntermann & Drunck GmbH
- Harris Corporation
- Helios
- HITT Traffic
- Honeywell International Inc. / Aerospace
- IDS – Ingegneria Dei Sistemi S.p.A.
- Indra Sistemas
- INECO
- Inmarsat Global Limited
- Integra A/S
- Intelcan Technosystems Inc.
- Iridium Communications Inc.
- Jeppesen
- LEMZ R&P Corporation
- LFV Aviation Consulting AB
- Micro Nav Ltd
- The MITRE Corporation – CAASD
- New Mexico State University Physical Science Lab
- NLR
- Northrop Grumman
- Northrop Grumman Park Air Systems AS
- NTT Data Corporation
- Quintiq
- Rockwell Collins, Inc.
- Rohde & Schwarz GmbH & Co. KG
- Saab AB
- SENASA
- SITA
- STR-SpeechTech Ltd.
- U.S. DoD Policy Board on Federal Aviation
- Washington Consulting Group
- WIDE