# AVIATION GROWTH AND GLOBAL WARMING

An independent analysis of the aviation industry's initiatives to de-couple air traffic growth from greenhouse gas emissions

Produced by PMI Media Limited, May 2007

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**Registered Office:**
**61 Davigdor Road, Hove, BN3 1RA, UK**
**Tel: +44 1273 724 238**
**info@pmi-media.com**
**www.pmi-media.com**

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## Executive summary

The object of this study is to collect all quantifiable and reliable data, from sources friendly, unfriendly and neutral to the aviation industry, which will provide forecasts of aviation's growing impact on the formation of greenhouse gases and the measures being taken by governments, aircraft and engine manufacturers, aircraft operators, airports and air navigation service providers (ANSPs) to mitigate the climate-change impact of aviation.

Industry (here defined as aircraft and engine manufacturers, aircraft operators, airports and ANSPs) is undertaking a range of measures which it hopes will ensure aviation will grow to meet expected demand (at an average of between 4%-5% per year), without governments capping aircraft movements as a result of public concern over aviation's contribution to the formation of greenhouse gases.

Some of these efforts are easy to quantify (such as the development of new engines with easily-measurable carbon dioxide [CO2] and nitrogen oxide [NOx] emissions) and others are less so (such as manufacturing attempts to create aircraft with lighter airframes).

There are, in essence, two types of improvement to environmental performance that industry is making: strategic and tactical. Strategic measures involve the development of an aircraft or engine which, when made available to the market, can deliver a quantifiable decrease in green-house gas emissions, at source. Examples of these include the "Clean Sky" engine which in 2020 could enter the market with CO2 emissions reduced by 50% over current levels. Or the advent of the Boeing 787 in 2009, which should be 20% more fuel efficient than aircraft such as the Boeing 767-200.

Tactical improvements include annual potential improvements in fuel performance and operating efficiencies (such as flying shorter routes) or the introduction of retrofitable technologies (such as winglets and engine technical inserts) which can produce immediate and quantifiable benefits.

This report has analysed the principal technology and operating improvements now available to aircraft operators, and considered what, if any, benefits they will bring and when they can be delivered.

The civil aircraft fleet of 17,300 aircraft emits 610 million tonnes of carbon dioxide a year. Industry improvements (more fuel-efficient aircraft, better air traffic management) could account for fuel-burn improvements of between 1% and 1.5% a year. But with greenhouse gas emissions rising at around 4% a year in the wake of expected traffic growth that still leaves a major gap which will need to be controlled if aviation growth is to be contained within globally-agreed targets of carbon emissions, argue organisations such as the Aviation Environment Federation.

But how accurate is that 1-1.5% figure? That is some of the core work of this study.

The study compilers have assembled all current fuel-efficiency programmes underway by airlines, manufacturers, airports and air traffic control organisations to look at what level of carbon dioxide savings are possible through current and future fuel-saving initiatives especially in the near-term, between 2007 and 2015 – when a new generation of more fuel-efficient aircraft and engines will probably be available. Using the widest range of sources available the following CO2 emission reductions have been calculated against actual and potential aviation emission improvements.

**Emission improvement programmes - underway**

| Emission improvement programmes | Total tonnes of CO2 emissions saved per year |
|---|---|
| Technical insertion programmes to current generation engines | 210,600 |
| Equipping fleets with new more efficient aircraft types | 1,240,000 |
| Lighter interior structures, fittings | 5,840,000 |
| More accurate flight planning | 350,000 |
| Airspace redesign – IATA work on shorter routes | 14,000,000** |
| Introducing CNS/ATM concepts | 3,050,000 |
| **Total** | **24,690,600** |

**Emission improvement programmes – potential**

| Emission improvement programmes | Total tonnes of CO2 emissions potentially saved per year |
|---|---|
| Adding winglets and making minor aerodynamic improvements to current aircraft types | 585,160 |
| Equipping fleets with more fuel-efficient aircraft | 1,436,102** |
| MRO improvements | 1,265,090 |
| Replacing APUs with GPUs and frequency converters | 610,000 |
| Introducing continuous descent approaches | 2,100,000 |
| More efficient airport taxiing operations | 6,205,000 |
| **Total** | **12,201,352** |

*** IATA reports "up to 15 million tonnes of CO2 savings" – see section 2.7.1. Report authors have estimated this figure to be 14 million.**

****This represents the full potential of CO2 savings if current expenditure patterns on new aircraft continue.**

Technologies which offer savings but are unlikely to produce quantifiable improvements within the next 10 years - such as alternative fuels – have also been analysed. But they have not been included in the tables as it is unlikely they will deliver measurable improvements within the immediate time-frame of the study.

The conclusion is that real and potential savings of nearly 37 million tonnes of CO2 emissions are possible on an annual basis from the range of fuel-saving intiatives currently underway by industry. These represent real savings of just over 4.0% of CO2 aviation-related CO2 emissions with *potential* annual cuts of a further 2%.

Why is there such a disparity between these findings and the conclusions of bodies such as the 1999 UN's International Panel on Climate Change (IPCC) which in 1999 produced, for the first time, a set of data on which governments could base their climate change policies?

Most estimates of aviation's annual technical improvement programmes rely for their 1-2% annual fuel performance improvement on new air traffic management (ATM) concepts, the acquisition of more fuel-efficient aircraft by airlines (typically, 15% from one generation to the next) and minor improvements by engine manufacturers.

The IPCC, non-governmental organisations (NGOs) and academic organisations recognise there are three ways in which emissions from aircraft could be reduced without affecting the number of flights taken: improvements in air traffic management; other improvements in operational efficiency and improvements in technological efficiency.

But none of these reports and studies takes full account of the "quiet revolution" over the last eight to nine years in the information technology (IT) networks in which aircraft fly - the new ability for airliners to fly dynamic routes, to optimise fuel-efficiencies and match aircraft performance to prevailing weather data, unlike the fixed routes most fly today. This IT revolution has impacted on all aspects of air transport; from more precise flight briefings (so the pilot does not have to carry excessive reserves of fuel), to better flow control techniques (delays can be dealt with on the ground, with engines off, not in the air), better maintenance, repair and overhaul (MRO) (cleaner aircraft, better fuel performance) to better ATM, so aircraft can use jet-streams to minimise fuel burn and "glide approaches" into airports.

There have been other "under the table" improvements in efficiency which have been developed quietly in recent years, in contrast to the more headline-grabbing initiatives such as research into alternative fuels. These include, *inter alia*

:

- Lower-weight interior fixtures and fittings – including seats
- Higher load factors among low-cost carriers which have meant some increased demand has been met by aircraft with higher load-factors, rather than new aircraft services
- Better fleet-planning tools which have allowed airlines to serve their route networks with fewer aircraft.

These "off-line" efficiency saving measures have the potential to lower further greenhouse-gas forming emissions – but as many of these measures are difficult to quantify they have not all been included in the list of potential emission improvement programmes.

The study has identified a number of key enabling technologies/research areas which all sectors of the industry have identified as sectors for major investment. The following tables outline these sectors.

This is not an entirely comprehensive list – for example it does not take into account inherent efficiency improvements in new generation engines such as the General Electric GEnx and the Rolls-Royce Trent 1000, or aerodynamic improvements in upcoming aircraft such as the Boeing 787. However it does outline the key efficiency improvement programmes where quantifiable benefits and timescales have been made available.

**Manufacturing – engines**

| **Key technologies** | **Potential fuel-saving/efficiency improvements over current systems** | **Timescale** |
|---|---|---|
| UEET | Fuel consumption improvements of 15% | On-going* |
| EEFAE** | Lower CO2 emissions, lower life cycle costs by 30% and improved reliability by 60%. | 2008-2015 |
| CLEAN | 20% improvement in CO2 emissions | By 2020 |
| VITAL | Lower CO2 emissions | 2008 technology prototype |
| TALON | Lower NOx emissions by 30% | On-going |
| Geared turbofan | Lower CO2 emissions by 40% over 2006 levels | 2015-2018 |
| ANTLE | Lower CO2 emissions by 10% | 2008 |
| TECH insertion (CFM-56) | Specific fuel consumption 10-15% improvement | 2007/2008 |
| LEAP 56 | Lower CO2 emissions by 50% | 2015-2018 |
| V2500 Select | 1% fuel saving efficiencies | 2008 |
| NEWAC | Lower CO2 emissions by 6% | 2010 |
| Open rotor | Lower CO2 emissions by 60% | 2015-2020 |

**Manufacturing – airframes and systems**

| Key technologies | Potential fuel-saving/efficiency improvements over current systems | Timescale |
|---|---|---|
| ALCAS | Unquantifiable at present | 2009 |
| Composite structures 50% of aircraft airframe weight | Potential weight savings 3-5% | 2008/9 |
| All electric controls to replace hydraulic systems/distributed power systems | Electrical component numbers cut by 35%; wire segments by 40%; weight can be reduced by 40%; installation time reduced by 60%; and reliability improved by 20% | 2010/2011 |
| Airbus aerodynamic improvements | 25% fuel efficiency improvements | 2020 |
| KATnet consortium/ AWIATOR | Decrease the structural weight of new aircraft by 5% through applying new load-control strategies and by 10% using new devices. | On-going |
| Winglets | 2%-4% improvements in fuel efficiency | Available now |

**Alternative fuels**

| Key technologies | Potential fuel-saving/efficiency improvements over current systems | Timescale |
|---|---|---|
| USAF synthetic fuel-blend trials | Unquantifiable | On-going |
| Volvo Aero, SAS, Swedish Civil Aviation Authority and Oroboros (funded by Vinnova) alternative fuel study | Unquantifiable | On-going |
| Virgin Fuels/bio fuels | Up to 80% reduction in all noxious emissions | On-going |
| Electric drive/fuel | Unquantifiable | On-going |

| | | |
|---|---|---|
| cells | | |
| Other fuels – hydrogen and LPG | Unquantifiable | On-going |

**Airline operations**

| **Key technologies** | **Potential fuel-saving/efficiency improvements over current systems** | **Timescale** |
|---|---|---|
| Re-equipping with new aircraft | Fuel consumption of 15% improvement | Available now |
| Improved MRO | Up to 4% improvements in operating costs recorded | Available now |
| Improved flight planning | 0.5% improvement in operating costs recorded | Available now |
| Flying at optimum altitudes | Flying lower may reduced NOx impact but increase fuel burn and CO2 emissions up to 6%. Balances have to be calculated | Available now |
| Reducing weight in the cabin, through lighter materials, lighter passenger services equipment. | Up to 850 kg per aircraft savings in weight possible | Available now |

**Airports**

| **Key technologies** | **Potential fuel-saving/efficiency improvements over current systems** | **Timescale** |
|---|---|---|
| Taxiing using electric drive/high speed tugs | 8,000 kg of fuel per aircraft operation savings possible | 2009/2010 |
| Alternatives to APUs | More than 2% savings on annual fuel bills possible | Available now at airports which have invested in mobile GPU/frequency converter systems |

**Air traffic management**

| **Key technologies** | **Potential fuel-saving/efficiency improvements over current systems** | **Timescale** |
|---|---|---|
| Airspace redesign | Annual improvements currently running at more than 6 million tonnes of CO2 saved a year (IATA) | On going |
| SESAR/NextGen | 10% improvement in flight efficiencies | 2020 |
| Continuous descent approaches | 200kg of fuel saved per approach | Available now at selected airports |
| CNS/ATM concepts (including RNAV/RNP, CPDLC and ADS-B) | 12% improvements in CO2 emissions over 1998 | 2007/2008 on selected routes |

* "On-going" refers to programmes which are underway with no clear delivery date for the new technology/procedure

**Comprising, *inter alia*, ANTLE and CLEAN

**Studies and recommendations**

The two reports which have the most comprehensive and scientifically-based explanation of the effects of aviation on the atmosphere and the likely consequences of this are the IPCC "Aviation and the Global Atmosphere" and the Stern Review. The other reports over this in varying degrees of detail but essentially defer to the IPCC report.

The IPCC report, 'Aviation and the Global Atmosphere' set the benchmark for the description of what the negative impact actually is and how it is induced. The report gives a detailed breakdown of all of the emissions which are deemed to have a harmful effect on the environment and induce global warming – carbon dioxide (CO2), water ($H_2O$), nitric oxide (NO) nitrogen dioxide ($NO_2$) (collectively known as NOx), sulphur oxides ($SO_xO$) and soot. All of the subsequent studies agree that these are the harmful agents who lead to global warming due to the effects they have on ozone ($O_3$), methane ($CH_4$), UV radiation and clouds.

There is very little agreement between the world's governments as to what should be done to curb greenhouse gas emissions from aviation. Actions vary from none to extensive; Switzerland and Sweden have adopted similar measures to control pollution by charging increased landing fees based on NOx and hydrocarbon emissions. Norway and the UK have developed “offset” policies for government employees, where the government buys quotas for the emissions caused by the trip.

National aviation regulators often find themselves with seemingly contradictory remits – on the one hand to promote the interests of the domestic aviation industry while curbing the excesses of unrestrained growth. Governments, too, face conflicting pressures – on the one hand to liberalise air traffic agreements between states and regions to increase aviation competition and bring down prices, while on the other hand to curtail man-made emissions of greenhouse gases. The recently signed EU-US liberalised transatlantic agreement could create 72,000 jobs across the US and the European Union and result in an additional 200,000 tonnes of freight travelling between the two continents, according to recent study by consultancy Booz-Allen Hamilton. Passenger traffic between the USA and the EU could rise by 26 million passengers over five years and could generate as much as EUR12 billion ($16 billion) in economic benefits on both sides of the Atlantic.

One approach by governments in Europe has been to advocate the growth of “responsible flying” where individuals can offset their aviation carbon emissions. Germany’s Federal Environment Ministry, in association with Germanwatch and the Forum Anders Reisen, has the “Atmosfair” initiative directed at people who cannot, or do not want to avoid flying, but, who are concerned about the effects of flying on climate. Passengers will be able to calculate how much greenhouse gas emissions their flight will cause and pay a voluntary contribution to ensure that equivalent emissions are saved elsewhere. The money raised goes towards climate protection projects in developing countries and passengers can pay the contribution either at the time they book their ticket or directly on the “atmosfair” website.

Recent mounting evidence, such as the release of the February 2007 IPCC report, on the speed with which climate change is occurring and man’s contribution to the process, is increasing pressure on governments to take action. US Energy Secretary Samuel Bodman said that his country supports the findings of the most recent IPCC report: “We agree with it, and the science behind it is something that our country has played a very important role in,” he said. “We estimate that the US has invested more in climate-change science than the rest of the world combined,” he added, claiming that the US had spent $29 billion since 2001 in climate-related science and technology programmes.

“If demand keeps growing at 4.3% a year airports will be severely constraining traffic growth in 2025,” according to Victor Aguado, director general of EUROCONTROL, speaking in January 2006. “Demand will have increased by a factor of 2.5 and despite a 60% capacity increase of the airport network on twice the volume of 2003, traffic will be accommodated. Demand corresponding to 3.7 million flights year cannot take place…. The top 20 airports will be saturated at least 8 to10 hours a day.”

At the end of February 2006, the then French President President Jacques Chirac announced his government would start levying a new tax on passengers from July 2006 to finance development in poorer parts of the world. The new tax will range from Euro1 (for intra-EU coach class fares) to Euro 40 for first-class intercontinental business fares. Proposals to put a ceiling on aircraft movements at European airports has been a feature of regulatory responses to airport development plans for many years.

Bringing airlines, along with maritime transport and forestry, into the emissions trading scheme was one of the Commission's main objectives for post-2012 action. Including internal EU flights within the trading scheme would cover 80% of emissions from aviation within the 25-member bloc, estimates the Commission. In deciding to take unilateral action on this issue it concluded, in September 2005, that bringing aviation into the EU's ETS would be the most cost-effective way of reducing the climate change impact of aviation. The EU's Environment Council on 20 February 2007 agreed to cut greenhouse-gas emissions by 20% by 2020 to reduce global warming. The agreement included the addition of aviation in the EU's Emissions Trading Scheme (ETS). German airlines said that they would join the emissions-trading scheme from 2011.

May 2007.
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Ulm and Brighton

## Introduction

### 1.1 Reason and methodology to the report

May 2007. The peak demand for air travel is just a few weeks away and the airline industry is healthier than it has been for years.

"People want to travel and they are doing it in record numbers," said IATA Chief Executive Officer Giovanni Bisignani in May 2007. "The fact that airlines are meeting that demand with newer, more fuel-efficient aircraft and near-record load factors bodes well for the bottom line and should lead to an industry profit of US$3.8 billion in 2007."

Some of the highlights of the recent boom, according to IATA, include:

- Comparing the first three months of 2007 to the same period in the previous year passenger demand was up 7.0% with average load factors of 74.9%. Freight demand increased 2.7%.
- Carriers in the Middle East continued their three-year trend of double-digit passenger demand growth in March with a year-on-year increase of 20.4%.
- In a similar month-by-month comparison between March 2007 and March 2006 African carriers reported an 11.9% increase boosted primarily by new and expanded routes to the Middle East and Asia. Strong economies drove demand for carriers in Europe (8.2%), Asia (6.9%) and North America (5.0%). Latin American carriers, which continue to be affected by industry restructuring, reported the smallest increase at 0.5%.

Order backlogs for Airbus and Boeing – the world's largest two major airliner manufacturers – are at an all-time high and the EU and USA have recently concluded an agreement which will liberalise air services between the two regions, leading to an expected fares war across the Atlantic.

Yet not all is rosy with the industry. There are increasing public concerns about the contribution that air travel makes to the generation of man-made greenhouse gas emissions, the major driver in global warming effects.

The civil aircraft fleet of 16,500 aircraft emits 610 million tonnes of carbon dioxide a year[1]. Thanks to the increasing liberalisation of air services, the emergence of new low-fare carriers and strong GDP growth in key aviation areas (China, India and the Middle East), this amount is unlikely to fall in the near future unless the market takes the kind of enormous dip in fortunes that followed the events of September 11.

Air traffic achieved a 14% annual growth rate in 2004, greater than at any time in the previous 25 years followed by growth rate of 7%, well above the historical annual average.[2]

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[1] Aviation Environment Federation figures, May 2007
[2] Airbus, Global Market Forecast, 2006

"Driven by a strong economy, new entrants, large emerging markets and increasing liberalisation, air travel has grown nearly 30% since 2000, the strongest recovery in aviation history," according to Airbus. "Over the 2006-2025…world passenger traffic is expected to increase by 4.8% per annum. This traffic growth, combined with fleet renewal, will require the delivery of 21,860 new passenger aircraft with more than 100 seats. The number of passenger aircraft in service will more than double from 12,676 at the end of 2005 to 27,307 in 2025."

Such levels of growth sit awkwardly with the concept of having to restrain markets in the face of a potential global environmental crisis. Until recently, empirical scientific knowledge of the extent of the aviation industry's contribution to greenhouse gas emissions was unclear. But the 1999 UN's International Panel on Climate Change (IPCC) produced, for the first time, a set of data which governments could use to inform their climate change policies. Although the IPCC findings have drawn some criticism, subsequent research - and other IPCC reports – has tended to support rather than negate the original findings.

According to the original IPCC report, aircraft accounted for 3.5% of global warming from all human activities in 1990 and aircraft greenhouse emissions will continue to rise and could contribute up to 15% of global warming from all human activities by 2050. The IPCC estimated that radiative forcing from all aircraft greenhouse gas emissions is a factor of two to four times higher than that from its carbon dioxide (CO2) emissions alone.

Carbon dioxide is not the only problem. According to the Aviation Environment Federation:

"Nitrogen oxides (NOx) and water vapour from aircraft engines are important greenhouse gases. Water vapour contributes to the formation of contrails, often visible from the ground, which in turn are linked to an increase in the formation of cirrus clouds. Both contrails and cirrus clouds warm the Earth's surface magnifying the global warming effect of aviation. Together, NOx and water vapour account for nearly two-thirds of aviation's impact on the atmosphere. Hence any strategy to reduce aircraft emissions will need to consider other gases and not just CO2.[3]"

The IPCC working group (WG) III report "Climate Change 2007: Mitigation of Climate Change" assessed the latest scientific knowledge on the mitigation of climate change and constitutes the final part of the IPCC's Fourth Assessment Report.

WG III concludes that global emissions must start to fall within the next 15 years and then be cut to around half of 1990 levels by 2050 if the world is to have a fair chance of preventing irreversible and possibly catastrophic global changes. The report projects that unless urgent action is taken global

[3] *Climate Change Fact Sheet*, Aviation Environment Federation

emissions in 2030 will be 25-90% higher than today, making it all but certain that global warming will reach dangerous levels.

The main findings of the report are:

- Without action, global greenhouse gas emissions will be 25% to 90% above current levels by 2030, with the highest growth levels in the transport sector.
- Two-thirds or more of the global emissions growth will come from developing countries, but per capita emissions in 2030 will still be substantially higher in developed countries than in developing nations. Limiting average global warming to 2°C above the pre-industrial level will require by 2050 a cut in greenhouse gas emissions of more than 50% of current levels.
- Such low emissions scenarios can be achieved at a cost of less than 3% of global GDP by 2030, a fraction of the overall growth over this period.
- Emissions equivalent to 6 Giga tonnes of CO2 – more than the EU's total annual emissions - can be avoided at no cost at all through eliminating wasteful practices. Particularly in the building sector, 30% of emissions can be avoided by 2030 at no cost.

The picture is therefore not entirely bleak. According the European Environment Agency (EEA) in May 2007 the EU-15's greenhouse-gas emissions decreased by 0.8% between 2004 and 2005, representing a decrease of 1.5% compared with 1990. Emissions in the EU-27 decreased by 8% compared with 1990, mainly due to de-industrialisation in central and eastern European states, which have now joined the EU. The EEA released the main findings of its Annual European Community Greenhouse Gas Inventory 1990-2005 and Inventory Report 2007 on 7 May 2007.

Countries that show the biggest decreases in greenhouse-gas emission - Germany, Finland and the Netherlands - have shifted their energy sources to decrease the use of fossil fuels, notably coal.

There is increasing pressure, especially in Europe, for air travel growth to be trimmed until technical improvements in emissions (estimated by the AEF and other campaigning organisations to be between 1-2% a year) can be made equal to increases in traffic growth – estimated to be between 4-5% over the next 15 years). This would mean introducing taxes on flights to curtail demand – to around 1-2% a year.

Naturally the aviation industry – airlines and manufacturers – argue that such measures are not needed. According to the Air Transport Action Group (ATAG), the aviation industry body which highlights the measures being taken by the industry to mitigate environmental impact:

- Aircraft entering today's fleets are 70% more fuel efficient than they were 40 years ago. Carbon monoxide emissions have been

simultaneously reduced by 50%, while unburned hydrocarbon and smoke have been cut by 90%.
- Research programmes aim to achieve a further 50% fuel and CO2 saving and an 80% reduction in oxides of nitrogen (NOx) by 2020.
- Enhancements in air traffic management have the potential to reduce fuel burn by 6-12%, while operational improvements can bring an additional 2-6% fuel saving.
- Per passenger kilometre, air transport uses less than 1% of the land required for transport in the European Union.
- Air transport covers the shortest distance between two points, generally 30% below ground transportation means.

The most recent IPCC report notes that aviation contributes a global total of 2% to worldwide emissions of CO2 – about the same as the United Kingdom. This figure is unchanged from the IPCC report of 1999, although the report noted that this proportion could rise to 3% by 2050.

But with the aviation industry looking at unprecedented levels of growth, this 2% could rise to 15% by 2050 – though the aviation industry believes "the most likely level will be around 5-6%."[4]

The greatest concern currently (May 2007) is the amount of CO2 and NOx emissions. Not only are these major contributors to man-made climate change effects, but they are also relatively easy to measure.

Most estimates of aviation's annual technical improvement programmes rely for their 1-2% annual fuel performance improvement on new air traffic management (ATM) concepts, the acquisition of more fuel-efficient aircraft by airlines (typically, 15% from one generation to the next) and minor improvements by engine manufacturers.

The IPCC, NGOs and academic organisations recognise there are three ways in which emissions from aircraft could be reduced without affecting the number of flights taken: improvements in air traffic management, other improvements in operational efficiency, and improvements in technological efficiency.

"There are two ways in which air traffic management could help to ameliorate the climate impacts of aviation," according to the Environmental Change Unit (ECU), Oxford University[5] ( http://www.eci.ox.ac.uk/research/energy/downloads/predictanddecide.pdf). "The first is to reduce inefficiency in current flight patterns. The second is to encourage flight patterns which take account of prevailing atmospheric conditions in order to minimise the impacts of the non-CO2 emissions from aviation….Overall, the IPCC Special Report on Aviation and the Global Atmosphere (1999) estimated that enhanced air traffic management had the potential to lead to a global saving of 6–12% of total fuel consumption, and

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[4] Sweden's LFV Group

[5] *Predict and decide* – Aviation, climate change and UK policy, Environmental Change Unit (ECU), Oxford University

this is consistent with the scale of savings expected from the EC Single European Sky initiative…The second way in which aviation impacts could be offset by changes in air traffic management practices is by encouraging more 'environmentally friendly' routing and scheduling of planes….Whilst such techniques may form part of a long-term solution to the environmental impacts of aviation, it is clear that they could increase the amount of carbon dioxide used, since routes avoiding regions of contrail formation could be longer… In short, then, changes in air traffic management could lead to some increases in efficiency, estimated to be in the order of 6% to 12%."

"The IPCC points out that these operational measures include increasing load factors (carrying more passengers per aircraft), eliminating non-essential weight, optimising aircraft speed, limiting the use of auxiliary power (e.g. for heating and ventilation) and reducing taxiing."

According to the ECU, the IPCC estimated that the potential scale of emissions reductions from such measures was relatively small (2–6%).

Technology options are defined as improvements in airframe and engine design and the possible use of alternative fuels. But many believe that airframe and engine manufacturers' fuel-efficiency targets are more aspirational than realistic.

None of these reports and studies takes full account of the work undertaken by technology suppliers and infrastructure providers in optimising aircraft efficiencies, using current-generation aircraft. Estimates in industry's own ability to improve fuel burn performance has relied on the IPCC's 1999 study. But over the last eight to nine years there has been an "off-line revolution" in the information technology (IT) networks in which aircraft fly, the impact of which are not obvious. As military aircraft and assets are slowly entering the net-enabled age – where information flows between space-based, airborne and ground-based surveillance platforms and command centres, to create a dynamic picture of the battlefield – so the civil aviation industry is also on the first steps to entering a net-enabled world. What this will ultimately mean is that airliners will soon be able to fly dynamic routes, to optimise fuel-efficiencies and match aircraft performance to prevailing weather data, unlike the fixed routes most fly today. On-board sensors will be able to adapt the aircraft's performance to its environment, allowing more aircraft to operate safely in busy airspace areas and on the airport ramp. This IT revolution impacts on all aspects of air transport; from more precise flight briefings (so the pilot does not have to carry excessive reserves of fuel), to better flow control techniques (delays can be dealt with on the ground, with engines off, not in the air), better maintenance, repair and overhaul (MRO) (cleaner aircraft, better fuel performance) to better ATM, so aircraft can use jet-streams to minimise fuel burn and "glide approaches" into airports.

There have been other "under the table" improvements in efficiency which have been developed quietly in recent years, in contrast to the more headline-grabbing initiatives such as research into alternative fuels. These include, *inter alia*

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- Lower-weight interior fixtures and fittings – including seats
- Higher load factors among low-cost carriers which have meant some increased demand has been met by aircraft with higher load-factors, rather than new aircraft services
- Better fleet-planning tools which have allowed airlines to serve their route networks with fewer aircraft
- New, more efficient, power sources at airports which mean aircraft do not have to rely on their APUs.
- The opening up of new airspace sectors along polar routes and across oceans.
- Increasing demand for more fuel-efficient turbo-prop aircraft in the regional aircraft market, rather than jets.

What impact do all the aviation industry's technical fuel efficiency/emission reduction measures really have on system-wide CO2 emission levels?

The publishers of this report gathered an expert panel of independent airline, manufacturing and ATM experts[6] to examine the potential benefits of each programme, quantifying, where possible, results. The work took into account the fact that all environment improvements involve trade-offs (see table one below)

**Table one: Environmental trade-offs**

| | **Improvements** | **Disadvantages** |
|---|---|---|
| Continuous descent approaches | Reduced noise, reduced fuel burn/CO2 | |
| Nacelle modifications | Reduced noise | Increased fuel burn/CO2 |
| Increased engine pressure ratios and temperatures | Reduced fuel burn/CO2, reduced hydrocarbon (HC) and carbon monoxide (CO) | Increased NOX |
| Reduced cruise altitude | Lowered O3 increases, fewer contrails | Increased fuel burn/CO2, increased NOX |
| Improved aerodynamic efficiency and reduced weight | Reduced CO2, reduced noise, reduced NOX | |
| Increased engine bypass ratio | Reduced fuel burn, reduced noise | Increased NOX |
| Operations changes | Reduced contrails | Increased fuel burn, CO2 |
| Reduced polar flights | Less effects on the stratosphere | Increased fuel burn, CO2 |
| Steep climbs | Reduced noise | Increased fuel burn, CO2 |

*Source: University of Illinois at Urbana Champaign*

6 See appendix four

But because of the current concentration of activity on CO2 and to a lesser extent NOx emissions, the report has focused on the environmental benefits of programmes which have specifically targeted a reduction in CO2 emissions.

Assessments of potential savings in CO2 emissions were then divided between those which are already taking place and for which funds have been committed and detailed programmes set out – and potential improvements from industry "best-practice." The results were unexpected.

The study then brought together high-level (aspirational) government and industry strategic targets for aviation emission reduction programmes (a top-down approach) with  empirical data from airline, airport and ATM operations, to generate in a single location an independent assessment of the aviation industry's own efforts to mitigate the climate-change impact of growing air transport movements.

While many of these strategic research programmes (NGATS/NextGen, SESAR, Clean Sky, UEET) offer substantial performance improvements in cleaner emissions the results are unlikely to feed through in industrial quantities much before 2015. More esoteric airframe designs (blended wings) and operations (flying in formation) also offer substantial improvements in aircraft greenhouse gas emissions – but they are most unlikely to deliver results before 2020. Yet these projects are important to the study to underline the long-term research which offers potential environmental benefits after the current generation of engine, airframe and operations designs and procedures reach ultimate level of maturity.

The study therefore has concentrated on the near term (2010-2017) potential improvements in emission performance, based on current technology concepts.

Data for the study was gleaned from a wide range of sources, sympathetic and unsympathetic to the aviation sector. Sources are referenced throughout the report and in the PMI-Media download library.

## 2. The aviation industry's response to the challenge of climate change

### 2.1 Introduction

"When linking aviation with climate change, there exists a misconception that a given increase in traffic will produce an identical increase in CO2 emissions. "This is simply not the case", according to the Ulrich Schulte-Strathaus, Secretary-General of the Association of European Airlines. "The aviation sector has been able to de-couple emissions growth from traffic growth. Fuel consumption is expected to increase only by 3% in the next years, whereas traffic will grow by at least 4%."

Yet Mr Ulrich Schulte-Strathaus's comments, for many, appear little more than a rearguard action against the mounting charges of environmental irresponsibility being levelled at the industry. After all, the science tells its own story: since 1990, CO2 emissions from aviation – which are directly related to the amount of fuel consumed – have increased by 87% and now account for around 3.5% of total 'human activities' contribution to climate change. The IPCC has estimated that this share will grow to 5% by 2050 – undermining efforts made by other industrial sectors to fulfil Europe's Kyoto commitments**.**

New generations of aircraft are increasingly fuel efficient, which means the individual footprint of each new aircraft is declining. According to Airbus:

"The replacement of more than 7,200 older aircraft with new-generation models will further improve the fuel efficiency of the world's fleet. The improvement in operating costs at a passenger or trip level, has been and will always be a key driver in the aviation industry, whether from a manufacturer or airline perspective. As fuel is the highest cost item of airline operation, aircraft competitive evaluations are largely based on fuel consumption characteristics…air travel has become increasingly fuel efficient, with an estimated 37% reduction in consumption per 100 passenger kilometres over the last 20 years, from eight litres in 1985 to five for today's aircraft fleet. This has been achieved through more efficient aircraft, operations and engines. This improved aircraft efficiency has come from the ongoing introduction of technological innovations into new aircraft programmes, a trend that will continue. New generation aircraft such as the A380 and the A350 (to be introduced in the next few years) all consume less than three litres of fuel per 100-passenger kilometres. As well as technology, a better allocation of capacity has resulted in load factors achieving historic highs (averaging from 69% in 2001 to 75% in 2005), improving fuel efficiency by 9% from 2001 to 2005. In future, further improvements can also be expected through more efficient traffic control and management. According to the Association of European Airlines (AEA) up to 18% of fuel burn, with its associated emissions, could be reduced by avoiding holding patterns at congested airports or by more direct routings."

New, more efficient aircraft will be used more efficiently, taking up the demand for new travel with, in the short-haul market, more point-to-point services. Low-cost carriers have driven the demand for new services but they have done so using aircraft more efficiently than before (more seats filled, more new fuel-efficient aircraft in service, more direct routes, more services per day).

According to Boeing.

“In an environment of high fuel prices, replacement of older airplanes is accelerated. Airplanes that are retired are those that are no longer in service at the end of the forecast period….Newer airplanes are used more intensively than older ones: around nine flight-hours a day for a current-generation single-aisle airplane in passenger service compared to seven to eight hours a day for a 15-year-old airplane and as low as two to three hours a day for a 25-year-old converted freighter.”

Unfortunately, although each new aircraft type is up to 15% more efficient than the aircraft it replaces the number of *new* aircraft – rather than replacements – required to meet the demand for new air services more than cancels out the gains possible within the replacement cycle.

In a November 2006 study by QinetiQ[7] to assess the growth of CO2 emissions from civil aircraft for the year 2030, five different scenarios were analysed, ranging from no aircraft fuel efficiency improvements to a likely technology scenario plus a $100 per tonne CO2 cost. In the study, the total annual distance covered by the global civil aircraft fleet was forecast to grow by 149% from 2002 to 2030, with the seat-kilometres forecast to grow by 229%. “The case with the most technological advance (that with $100/tonne CO2 cost) was forecast to produce 22% less CO2 in 2030 than the case without the extra incentives. However, even this case was forecast to produce nearly twice as much CO2 in 2030 as in 2002.”

**Table two: Global fuel burns and CO2 emissions in teragrams (tonnes x 10 to the power of 6) – based on a 229% growth in seat-kilometres 2002-2030.**

| | Fuel Burn 2002 (Tg) | Fuel Burn 2030 (Tg) | Ratio of Fuel Burn to 2002 |
|---|---|---|---|
| Case 1 | 155.18 | 510.54 | 3.290 |
| Case 2 | 155.18 | 442.45 | 2.851 |
| Case 3 | 155.18 | 395.50 | 2.549 |
| Case 4 | 155.18 | 348.92 | 2.248 |
| Case 5 | 155.18 | 307.63 | 1.982 |

7 *Forecasts of CO2 emissions for civil aircraft for the IPCC*, QinetiQ, November 2006

| | CO2 production 2002 (Tg) | CO2 production 2030 (Tg) | Ratio of CO2 production to 2002 |
|---|---|---|---|
| Case 1 | 489.29 | 1609.74 | 3.290 |
| Case 2 | 489.29 | 1395.06 | 2.851 |
| Case 3 | 489.29 | 1247.02 | 2.549 |
| Case 4 | 489.29 | 1100.15 | 2.248 |
| Case 5 | 489.29 | 969.96 | 1.982 |

From these figures it appears that even using the most fuel efficient technologies possible, the industry will not be able to completely sever the link between growth in new services and CO2 emissions.

### 2.1.1 The key technologies in which investment is needed to improve the environmental performance of civil aircraft

According to the "Clean Sky" consortium of European aerospace industries, which has pledged Euro 1.7 billion over the next five years to develop more efficient, environmentally-friendly and cost-effective aircraft, the answer lies in six domains:

- New, less polluting engines
- New loads and flow control management systems
- New aircraft configurations
- New low-weight materials
- New aircraft energy management systems
- New mission and trajectory management systems

If research efforts in these areas are successful, then the Clean Sky initiative will, by 2015 or so, have developed civil aircraft technologies that will deliver a 50% reduction in CO2 emissions through drastic reduction of fuel consumption and 80% reduction of NOx emissions over current standards.

One of the significant aspects of the Clean Sky programme is the programme designers' plan to bring forward some of the key enabling technologies for environmental improvement in the "Vision 2020" document to an earlier entry-into-service date.

IATA's fuel campaign in 2006 identified US$1.8 billion in potential savings worldwide, equal to 15 million tonnes of CO2. According to Juergen Haacker, IATA director of operations[8] the 7,000 new aircraft – with their new engines – that will replace older models over the next 10 years promise a further 20% improvement in fuel efficiency as well as emissions (see sections 2.7.1 and 2.7.2).

[8] *Orient Aviation*, February 2007

IATA fuel strategy encompassed negotiating more direct air routes with air traffic service providers. A further element in fuel wastage involves delayed departures, where pilots then speed up during the flight to recover time.

### 2.2 Manufacturing: research and development programmes to develop new, less polluting engines

#### 2.2.2 Introduction

Developing cleaner burning engines is the most important single technology advance which can cut aviation-generated greenhouse gas emissions at source. But what do we mean by cleaner-burning? In engine technology an improvement in one area can often be offset by a drop in performance in another area.

"It is clear that, through technological and operational advances, civil aviation has the potential to reduce its impact on climate substantially," according to "Air Travel – Greener by Design", Report of the Science & Technology Sub-Group of the Royal Aeronautical Society, July 2005 (see: http://www.greenerbydesign.org.uk/_FILES/publications/GbD%20-%202005%20Science%20and%20Technology%20Report.pdf): /). "…In propulsion, the open rotor offers significant reductions in fuel burn, particularly for short- and medium-haul operations, but its commercial acceptability depends on rotor noise being brought within tolerable limits. Since approximately half the world's aviation fuel is burned on flights of 2,500km or less, there is a strong case for research to reduce open rotor noise. In airframe technology, weight reduction through increased use of advanced structural composites and drag reduction, particularly through the application of laminar flow control, hold out the promise of further significant fuel burn reductions.

"For large aircraft, the flying wing or blended wing-body configuration, possibly with laminar flow control, is potentially a highly fuel-efficient configuration for the future. It is clear that total environmental impact can be reduced by setting different priorities in design. For example, NOx emission can be reduced by reducing engine pressure ratio, and ozone generation by NOx might be reduced by optimising designs to cruise at lower altitudes. In both cases, the result is likely to be an increase in fuel burn, CO2 emission and operating cost. Contrail and cirrus cloud formation and ozone creation might also be reduced by operational measures, but at the expense of an increase in fuel burn. Neither design nor operating measures which increase costs are likely to be adopted, however, until there is a regulatory framework or system of environmental charging in place which puts appropriate weight on reducing impacts other than CO2 emission. It will be difficult to gain acceptance of any such framework without a more robust understanding than we currently have of the impact on climate of NOx, water vapour and of contrails and aviation-related cirrus. Equally, without this understanding, it is difficult to set priorities for research and forward-looking work in engineering design. For these reasons, the Sub-Group is firmly of the view that there is no higher environmental research priority than the effect of aviation emissions on the atmosphere and on climate."

According to the aviation industry environment group, the Air Transport Action Group (ATAG):

"In 2005, the total Jet A-1 fuel consumption represented 55 billion US gallons or 208 billion litres. This corresponds to average fuel consumption per flight hour of 970 US gallons or 3 metric tonnes. Each tonne of fuel burnt in the air or on the ground produced 3.16 tonnes of $CO_2$. Therefore, 55 billion US gallons of jet-fuel represent 540 million tonnes of carbon dioxide."

This study has taken the figure 610 million tonnes of carbon dioxide as a baseline figure for 2006 analysis.

The aviation industry has had a relatively successful track record in engineering both an increase to aircraft power over the last 50 years - at least in the civil domain – while decreasing noise and (to a lesser extent) Noxious emissions. The improvement in emissions has been largely driven by requirements to lower fuel consumption. According to Volvo Aero:

"Aircraft today now consume 0.2 of a litre per passenger per 10 km; in the 1960s this figure was 0.6 of litre….More efficient combustion has led to emissions of carbon monoxide falling by 80%, hydrocarbons and particles by 60%. In the latest aircraft, engineers have also succeeded in cutting emissions of nitric oxide by 60%."

However, the challenges currently facing engine manufacturers and researchers to develop new engines with lower greenhouse gas (especially $CO_2$) emissions and improved efficiencies are complex. Engineers in the 1970s faced with the conundrum of developing more powerful but quieter engines solved the problem with the introduction of high-bypass turbofans. No such quick-fix is available today and research efforts to improve fuel efficiency (and therefore emission performance) relies on developing lighter structural materials, real-time health monitoring and advanced combustion concepts.

However there have been some structural changes to aircraft engine design which have provided substantial benefits in key areas. An advanced double annular combustor (DAC) was introduced in 1995 into revenue service in Switzerland on a CFM56-5B engine for the Airbus A320, reducing $NO_x$ emissions by as much as 45% compared to a conventional combustor. The DAC features a new type of combustor, burning fuel in two stages, rather than in one stage, which means fuel is burnt at lower temperatures while the aircraft is in the cruise stage. The second combustion stage reduces the time the fuel/air mixture hangs in the combustor.

According to General Electric:

"Generally, to produce more thrust while burning less fuel, engines must operate at very high temperatures. The downside is that these temperatures tend to increase NOx. But remarkably, when used in conjunction with the low-emission DAC, NOx limits are kept well below the most stringent requirements."

Aircraft jet engines produce carbon dioxide (CO2), water vapour (H2O), nitrogen oxides (NOx), carbon monoxide (CO), oxides of sulphur (Six), unburned or partially combusted hydrocarbons (also known as volatile organic compounds, or VOCs), particulates, and other trace compounds. Aircraft engine emissions comprise, on average, around 70% CO2, a little less than 30% H2O, and less than 1% each of NOx, CO, Six, VOC, particulates, and other trace components (source: US Federal Aviation Administration).

When jet fuel is burned, hydrocarbons mix with atmospheric oxygen to generate the chemicals outlined in table four.

**Table 4. Emissions from aircraft fuel**

| Emission type | Operating regime | Environmental impact |
|---|---|---|
| Water vapour, becoming ice (visible as a contrail) | All | Greenhouse gas in stratosphere |
| CO2 | All | Greenhouse gas |
| CO | Low power, ground idle | Smog production and toxic smell |
| Unburned hydrocarbons (HC) | Low power, ground idle | Smog production and toxic smell |
| NOx | Take-off, climb, cruise | Smog production and acid rain |
| Smoke (soot) | Take-off, climb | Visibility nuisance |

Source: Jane's Information Group

Nevertheless, industry is forecasting that the next generation of engines powering aircraft such as the Boeing 787-9, Airbus A350-900 will continue the historic trend of improved litre/10km/passenger fuel consumption improvements at roughly equivalent rates as in the past.

These improvements will come, forecast many in the industry, as a result of some major state-funded strategic research efforts (such as Europe's ACARE initiative and NASA's UEET programme), complemented by other company and research house initiatives.

**The emissions challenge facing engine manufacturers**

"In a jet engine, the fuel and an oxidizer combust (or burn) and the products of that combustion are exhausted through a narrow opening at high speed. Modern jet engine fuel is primarily kerosene, the same fuel used to heat homes in portions of the U.S. Kerosene, flammable hydrocarbon oil, is a fossil fuel. Burning fossil fuels primarily produces CO2 and water vapour ($H_2O$). Other major emissions are nitric oxide (NO) and nitrogen oxide ($NO_2$), which together are called NOx, sulphur oxides ($SO_2$), and soot. Aircraft produce up to 4% of the annual global CO2 emissions from fossil fuels near the Earth's surface as well as at higher altitudes (25,000 to 50,000 feet). Scientists are still studying the effects of increased amounts of CO2 near the Earth's surface and in the upper atmosphere. ...Just as a car engine that runs efficiently produces less harmful exhaust emissions, the same is true for a jet engine. Incomplete combustion occurs at the lower power settings used for descent or when aircraft are idling or taxiing on the ground. This incomplete combustion results in CO and unburned hydrocarbon emissions that are contributors to local air quality concerns. The hotter the temperature inside the combustor, the more efficiently the fuel is burned. Unfortunately, these higher temperatures produce increased NOx emissions, so there is a trade-off. These increased NOx emissions contribute to ozone at cruise altitudes. Improvements in aircraft engine design have already resulted in a 70% decrease in CO emissions from their 1976 levels, but more needs to be done to reduce CO2, NOx, unburned hydrocarbons, and CO emissions.

"Ozone production and the recent thinning of the ozone layer are other environmental concerns that have been reported on throughout the world. What are they and why are they important? High concentrations of ozone near the surface of the Earth have been linked to respiratory diseases. But there is beneficial ozone. Ozone in the upper atmosphere (about 15 miles up) shields the surface of the Earth from the Sun's ultraviolet radiation. Increasing occurrences of skin cancer are being attributed to the thinning of this protective ozone layer…Oxides of nitrogen increase the production of ozone at typical cruise altitudes of subsonic air travel. These emissions are formed as a result of burning fossil fuels at very high temperatures. Therefore, aircraft emissions containing NOx increase the production of ozone. Aircraft emit significant amounts of NOx when their engines are at their hottest during takeoff and slightly smaller amounts while cruising.

"Aircraft also create contrails. Contrails and cirrus clouds both reflect sunlight that would otherwise warm the Earth's surface. At the same time, they absorb heat from the ground instead of allowing it to escape. Do they contribute to global warming or global cooling? The scientific community is still trying to answer that question."

Source: NASA

**Research challenges and opportunities – an engineering perspective**

There are many ways of reducing emissions, according to Volvo Aero.

“Future engines will have bigger fans in relation to the rest of the engine. This makes it more important to use lightweight materials such as carbon-fibre composites for fan casings. By putting heat exchangers in the engines’ exhaust, for example, or an intercooler in the compressor, fuel consumption, and thereby emissions of carbon dioxide, can be cut dramatically. Another area of development is to develop an engine with a geared fan making the fan slower without the turbine slowing down. This kind of engine would be quieter and more efficient, with lower fuel consumption.

“By increasing the pressure in the engine’s combustion chamber, carbon dioxide emissions can be cut, but this increases the emissions of nitric oxide…

“Fuel forms carbon dioxide and water upon complete combustion in air. But combustion is not always complete and that causes the build up of unwanted emissions of carbon monoxide (CO) and uncombusted hydrocarbons (UHC). Upon combustion at extreme temperatures, nitrogen reacts with oxygen in the air to form nitrous oxide which is another unwanted emission.

“When new jet engines are developed engineers want to optimise the combustion process to minimise unwanted exhaust emissions. The emission of carbon monoxide and uncombusted hydrocarbons is reduced mainly by improving the mixture of fuel and air in the combustion process. However, NOx emissions require the development of new combustion concepts. The main focus today is to create conditions in the combustion chamber so that combustion can occur under homogenous fuel and air conditions. This means that the absolute highest temperatures can be avoided (NOx forms at high temperatures). Another way to reduce NOx emissions is to allow combustion to develop slowly, i.e. with the excess air, which lowers the combustion temperature.

“Titanium and nickel base alloys are the two most common materials today; titanium for cold parts, such as the casing. For hotter areas we use the nickel base alloys.

“There’s a lot happening in engine innovation in fuel efficiency, according to Volvo Aero’s Anders Lundbladh. “But there are four important trends. The first is to make fans bigger, which gives the engines better traction in the air. The second thing is to increase pressure in the engines to turn fuel energy into mechanical energy more efficiently.

“The third trend is to make the geometry of the blades in the fan and compressors more complicated. For example, by creating curved blades or sweeping the blades so they lean both forwards and backwards, the airflow becomes smoother and less energy is used."

"The fourth area is utilising the heat emitted from the engine. This can be done with a heat exchanger. Heat exchangers can also be used to cool the air in the engine, just like is done on turbo charged engines in cars. We can then increase the pressure in the engine and in doing so use less energy.

"Ninety-five per cent of the energy used today goes into propelling the aircraft forward. Some improvements can be made to reduce the remaining 5%. A lot of energy is used to pressurise the cabin, and one idea would be to do this in a more efficient way. Fuel cells are something else we could use to provide energy. In the distant future perhaps we could propel entire aircraft using just fuel cells. This would have to be aircraft with superconductive engines. But this kind of technology would be 50 or possibly 100 years away."

**The problem with nitrogen oxides and jet engines**

"NOx means 'various oxides of nitrogen', of which the commonest are NO, $NO_2$ and $N_2O_4$. NO, nitrous or nitrogen (II) oxide, is a colourless gas once used for anaesthesia ('laughing gas'). $NO_2$, nitrogen (IV) dioxide, is a brownish-red gas which readily associates to form the colourless $N_2O_4$, nitrogen tetroxide. The atmosphere is almost entirely composed of the two elements involved, but they fortunately stay separate, about 78% nitrogen and 21% oxygen. The trouble is that, when air reaches the intense heat of a modern gas-turbine combustion chamber, the two gases instantly start combining. The solution is to get the atoms out of this white-hot environment as quickly as possible, and here it is appropriate to salute the designers of combustion systems. In early jet engines the combustion chamber was by far the largest part of the engine, whereas…today this component is dwarfed by the rotating machinery.

"Getting the nitrogen and oxygen out of the engine quickly is called reducing the residence time. In military engines, emissions come some way in importance behind performance, but in commercial turbofans this factor is of the highest significance. Two of the latest engines, the V2500 and GE90, both use combustion chambers with two concentric rings of fuel nozzles. The V2500 has 20 pilot-stage nozzles around the front of the chamber and 20 main-stage nozzles further back around the larger diameter of the mid-section.

"The main-stage nozzles are brought into action only on take-off, and are progressively shut down as the aircraft climbs into thinner air. Their short combustion length means that, in the crucial low-altitude, high-power phase, the gas has left the chamber before much N/O combination can take place. Tests have shown a reduction in NO emissions exceeding 50 %. The very large GE90 in effect has two sets of chambers, one concentrically inside the other.

"On take-off, the air from the compressor, at a pressure of some 42.2 $kg/cm^2$ (600 $lb/in^2$), encounters a diffuser which diverts most of it through an inner annulus where most of the fuel is burned. The large airflow means that the burners in this inner space operate at very lean fuel/air ratios, and the high velocity minimises NOx formation. The rest of the airflow passes through and around the outer (pilot) airspray nozzles. As the aircraft climbs, the engine-control computer gradually shuts down the inner nozzles, which, as they are not needed in long-range cruise, are designed for minimum emissions at high power settings. The continuously burning outer-annulus nozzles are tuned to minimise low-power emissions, principally CO and UHC.

"With each passing year the oxides of nitrogen stand out ever more clearly not only as the most offensive but also as the principal constituent (over 80% by mass) of all the legislated jet-engine emissions. Despite some industry pressure, the ICAO environmentalists have convinced everyone that even the initial legislated limits (Annex 16 Vol II, 2nd edition, 1993) were not tough enough. The original standard was spelt out as 40 + 2{pi}0/0 g/kN, where {pi}0/0 is OPR at sea level. Thus, for a modern engine of OPR 35 the limit was 110 g/kN.

"International meetings in December 1995 made these limits more stringent. The new limit is 32 + 1.6{pi}0/0, a cut of more than 20%. This harsher limit came into force on 1 January 2000, and applies to all aircraft registered after 1 January 1996. The intention is that it will later be made retroactive. It will not be easy for all the older engines to meet it. As the combustion chamber has to meet all operating conditions from sea-level take-off to high-altitude cruise or let down, it must always have a central fuel-rich zone where temperature is very high, and the residence time is relatively long.

"The longer the residence time, the lower the CO and HC. As noted above, following prolonged research by engine manufacturers and supporting laboratories, some of the latest large turbofans have DACs (double annular combustors), or staged combustion, with an inner liner in the form of two concentric rings, each with its own fuel burners. One ring of burners - it could be the inner or the outer - is called the main stage, and is used with a large airflow and lean mixture for take-off and all other high-power operation, minimising NOx. For ignition and all low-power operation the main stage is inoperative, and the engine runs exclusively on the other ring of burners which have a longer residence time and are designed for minimum HC and CO. Several engineering teams are seeking other answers."

Source: Jane's Aircraft Engines

### 2.2.3 State-funded research efforts to improve greenhouse gas emissions

In the USA, one of the most important pre-competitive strategic research programmes to improve the environmental and fuel consumption performance of aircraft engines is NASA's **Ultra-Efficient Engine Technology (UEET)** programme, the goal of which is to develop technology with the potential to reduce fuel consumption by 15% relative to today's state-of-the-art engines. For the average 777-200ER, this would reduce annual fuel costs by about $1 million and carbon dioxide emissions by about 11,700 metric tonnes.

The NASA Glenn Research Center began in fiscal year 2000 the six-year, $300-million Ultra-Efficient Engine Technology (UEET) programme. In fiscal year 2003, the UEET Program became a project within the Vehicle Systems Program in NASA's Aerospace Technology Enterprise.

According to NASA the two objectives of UEET are;

- to develop technologies to reduce nitrogen NOx emissions by 70% below 1996 ICAO regulations and
- to decrease CO2 emissions by dramatically increasing performance and efficiency.

"High-temperature engine materials, ultra-low-NOx combustor designs, efficient, highly loaded turbo-machinery, and propulsion-airframe integration analysis are technologies being developed at Glenn to meet these goals," says NASA. "Technology developed in the previous Advanced Subsonic Technology Program is being put into commercial production for large and regional aircraft to reduce NOx emissions 50% below 1996 ICAO regulations for landing and takeoff cycles. UEET will take the technology to the next quantum leap, reducing emissions to 70% below the ICAO regulations level. In addition, NASA-developed research will significantly reduce carbon monoxide, unburned hydrocarbons, and corresponding cruise NOx levels for the next generation of aircraft engines. Technologies are being developed for subsonic and supersonic commercial engine applications. In addition, key technologies from the UEET Program are critical to advanced engine technology programs within the Department of Defense, which relies on NASA technology in this area. "

The overall UEET project includes research efforts at Glenn, the NASA Langley Research Center, and the NASA Ames Research Center, as well as at the five US gas turbine manufacturers (GE Aircraft Engines, Pratt & Whitney, Allison Advanced Development Corporation/Rolls-Royce, Honeywell and Williams International), two major airframe companies (the Boeing Company and Lockheed Martin) and a number of universities and small businesses.

The Glenn facility has been studying new materials that can withstand the higher temperatures needed to reduce CO2 emissions by 8% to 15% for large aircraft. These new-high temperature materials allow engines to run hotter and cleaner without increasing weight. Newly-developed disk and airfoil blade materials enable subsonic engines to run at higher operating pressures and temperatures, which reduces $CO_2$ emissions and operating costs by reducing fuel consumption.

How can the temperature inside a jet engine during high-power operation be lowered without jeopardising the fuel efficiency gains and reduction of other emissions that are achieved with hotter engines? NASA Glenn is investigating new combustion chamber designs with features that lower peak temperatures.

Glenn's Advanced Subsonic Combustion Rig (ASCR) simulates gas turbine combustion conditions typical of future engines. Tests conducted in this facility provide information about $NO_x$ formation and other emissions including $CO_2$, CO, and unburned hydrocarbons at actual combustor operating conditions for future engine cycles.

According to NASA:

“Promising emissions reductions have been demonstrated with advanced fuel injector concepts at high operating pressures. Computer modelling is used to study how high temperatures and increased emissions are related. Computer predictions of the flow field inside a jet engine combustor can be used to show where high-temperature-NOx-producing regions are located so they can be reduced. This computer model will help find the best design for building and testing an actual combustor. The final result will be an advanced engine for subsonic and supersonic aircraft.”

NASA’s Glenn facility is also studying how fuel is injected in an aircraft's engine to optmise clean burning; lasers are used to visualise fuel-air flow patterns and make non-intrusive measurements in the combustion zone. Computer modelling and experiments using advanced laser diagnostics will help determine the best design of combustors for application to subsonic and supersonic aircraft.

“Low NOx combustors require materials that can withstand high combustion gas temperatures. Glenn researchers developed a new combustor liner, a ceramic matrix composite (CMC) material, which has survived for over 9000 hours at 2200 °F in laboratory tests. Achieving this combustor life was a major durability challenge. When this project began, state-of-the-art CMC had a less than 10-hour life at 1800 °F. In collaborative efforts, NASA Glenn and its partners have already demonstrated a 50% reduction (below the 1996 ICAO baseline) in NOx emissions in combustors for advanced subsonic engines. As a result of research in the 1990s, NOx emissions were reduced by 90% compared with today's engines in prototype combustor hardware for supersonic engines. New engines with low-emission combustors entering into service in 2002 will reduce local air quality concerns and enable airports and air traffic to grow and still comply with National Ambient Air Quality Standards.”

Meanwhile, the European Commission launched its largest-ever aero-engine research programme in March 2000, the Efficient and Environmentally Friendly Aero Engine **(EEFAE)** programme, costing Euro 101 million. Funding has come half from the European Commission and the other half from EEFAE's 20 industrial, university and research partners. The focus of the work has been on improving how the combuster burns fuel and recycles its by-products of heat and emissions while another goal is to reduce the weight and size of systems and components, such as gearboxes or the control system that regulates an engine's rate of combustion.

EEFAE has integrated previously-funded research programmes to achieve improvements in both the efficiency and environmental friendliness of gas-turbine-based aero engines – specifically through cutting carbon dioxide emissions through reduced fuel burn and reducing nitrogen oxide levels. Additional goals include lowering life cycle costs by 30% and improving reliability by 60%. The aim is to develop engine concepts for both wide- and narrow-bodied aircraft, and to halve the time needed to bring the new technologies to market. Engines based on the new technologies are expected to begin entering commercial service from 2008 to 2015.

The programme involves 19 partners from nine countries with overall co-ordination by Rolls-Royce. Two of the partners are universities, which are fully supported by the EC, while the remainder are research establishments and industrial companies participating on a shared-cost basis.

Near-term work on the programme has been accomplished through the ANTLE (see next section) research work and the CLEAN programme.

The narrow-body group CLEAN (Component vaLidator for Environmentally friendly Aero eNgine), headed by Snecma Moteurs and MTU also includes several of the ANTLE members. Eldim, Fiat, Techspace Aero and Volvo have been joined by ESIL (Ireland) and the CEPR Institute in a longer-term approach involving heat exchanger technology. The goal is to validate in CLEAN core technologies for a future Intercooled Recuperated Aero-engine (IRA) concept, which is capable of significantly reducing fuel consumption and emissions.

According to the European Commission, (see http://ec.europa.eu/research/growth/gcc/projects/in-action-eefae.html)

"CLEAN will incorporate an improved, high-efficiency HP compressor with active surge control, a low emissions axially-staged combustor and high-temperature HP turbine from Snecma. FiatAvio will support the design and manufacture of the combustor module. A new structural inter-turbine frame and a two/three-stage low pressure (LP) turbine will be provided by MTU. A low-cost turbine exhaust rear frame will be designed by Volvo. A new heat exchanger segment will be located in the LP turbine exhaust stream. The latter addition, derived from an MTU design, will decrease the fuel burn and substantially reduce the CO2 output.

Overall, the goal is to cut emissions by 20% for CO2 and a remarkable 80% for NOx. However, because of the considerable technical challenges to be faced, flight testing of a future IRA engine is unlikely to take place until 2015, while commercial service will not commence before 2020. The CLEAN engine will nevertheless be tested on a rig at the CEPR centre in Saclay, France, from mid-2003."

Meanwhile, the Commission and Snecma Moteurs launched a four-year Euro 90- million programme called **VITAL** (the EnVIronmenTALly Friendly Aero Engine (VITAL) programme), with Euro 50 million invested by the Commission - to significantly reduce aircraft engine noise and CO2 emissions. Snecma Moteurs is leading a consortium of 53 partners including all major European engine manufacturers, focusing on the low-pressure sections of the engine, evaluating new designs including counter-rotating fans, lightened fans, highly-loaded turbines and turbines with fewer blades, as well as more specific enabling technologies. According to Snecma: "The weight reduction will enable the development of very high bypass ratio engines that reduce noise by 5dB to 8dB, while also decreasing CO2 emissions. Each component will be validated along the program by large-scale aero-acoustic and mechanical rig tests."

VITAL was launched in January 2005 and one of the key areas for research is the reduction of weight of load-carrying structures and components. "There is actually a direct link between engine weight and the amount of carbon dioxide emissions," says Anders Sjunnesson, Project Manager for VITAL at Volvo Aero. "If you increase the engine fan size then you can reduce noise and fuel consumption. But if you build bigger fans the problem is that you increase the weight of the engine, meaning that the engine needs more throttle to take off, which once again increases fuel consumption…The challenge is then to build bigger fan modules, without increasing the engine's weight, especially when the aim is to develop structural engine components that weigh 30 % less than they do now. So what do you do? Well, you exchange conventional components made of titanium for lighter materials – carbon fibre composites…VITAL will develop and manufacture a fan module to conduct a full-scale test in 2008."

Other EC-funded research programmes also have engine efficiency benefits which should feed through to lower emissions. For example, the EU's vision of reducing aircraft noise by 10 decibels for each flight by 2020 is being supported by a series of funded research initiatives. One of these is **AIDA** – Aggressive Intermediate Duct Aerodynamics – which aims to develop an alternative design for an intermediate casing to reduce noise levels and carbon dioxide emissions. The project is being managed by Volvo Aero and has 16 participants, including the University of Cambridge, Rolls-Royce and Chalmers University of Technology. It started in 2004 and will end in 2008 and is worth Euro 8.2 million, with the EU contributing Euro 5.6 million.

According to the project leaders: "AIDA is focusing development efforts on flow channels in the intermediate casing and turbine section of the engine. A 20% increase in the deflection of air flows will help lower noise levels.

Emissions of carbon dioxide can also be cut by 2% with a more aggressive, shorter duct. So far the milestones set for the project have been met."

Other EU-funded engine research projects could also lead to emissions benefits. For example, the **SILENCE(R**) programme aims to reduce aircraft noise by up to 6 decibels (dB) by 2008. It comprises a consortium of 51 companies with the EU contributing half the funding. The total budget is over Euro 110 million. Other strategically important programmes include **FRIENDCOPTER,** to reduce helicopter engine and rotor-blade noise; TANGO, to develop lighter aircraft structures and **AWIATOR,** which aims to decrease aircraft weight and noise while improving performance.

**Engine emission reduction research and the ACARE programme**

The 2001 report "European Aeronautics: a Vision for 2020" (see http://www.acare4europe.com/docs/es-volume1-2/executive-summary.pdf) drawn up by a group of "wise men" to advise the European Commission on the future of the continent's aerospace industry, laid out a series of research objectives which Europe's civil aircraft manufacturers would need to achieve to ensure dominance of the market.

The report recommended the creation of the Advisory Council for Aeronautics Research in Europe (ACARE) to develop and implement a strategic approach to European aeronautics research. ACARE delivered its roadmap to achieving the Vision 2020 goals - The Strategic Research Agenda (SRA), in November 2002.

Europe's many different research organisations, government bodies and companies are therefore now all working in the civil aviation area to common goals – identified by the European Commission and its advisers – to ensure there is no duplication of effort. They will also all have enhanced access to European Commission funds for "pre-competitive" research and development work. This will also more closely link research work undertaken at national institutions to industry. To meet the goals of Vision 2020 the European Commission has identified four areas where European civil aviation organisations need - through access to strategic R&D programmes - to have a clear level of technical leadership: aircraft manufacturing competitiveness, meeting more stringent environment targets, improved safety/security and enhanced air transport capacity.

In the key area of competitiveness the Commission has set a target of reducing new airliner development costs and operating costs by 20% in the short term and 50%. It hopes to bring down direct operating costs through research into improved aircraft performance and reduction in maintenance and other costs. It also wants to increase passenger choice with regard to travel costs, time to destination, on-board services and comfort.

To achieve these objectives, the Commission has identified a number of key research areas where European organisations can apply for EU funding:
:

- Integrated design and product development
- Manufacturing
- Maintenance
- Aerodynamics
- Structural weight reduction
- Equipment weight and power take-up reduction
- Propulsion
- Crew workload reduction
- Cabin environment
- On-board passenger services
- New aircraft concepts and breakthrough technologies.

Other significant targets set by the Commission include:

- Reducing unburned hydrocarbons and CO emissions by 50% in the long term to improve air quality at airports
- Reducing external noise by 4-5 dB and by 10 dB per operation in the short and long terms, respectively. For rotorcraft, the objective is to reduce the noise footprint area by 50% and external noise by 6 dB and 10 dB over short and long terms
- Reducing the accident rate by 50% and 80% in the short and long terms, respectively
- Achieving a 100% capability to avoid or recover from human errors
- Increasing the ability to mitigate consequences of survivable aircraft accidents
- Reducing significant hazards associated with on-board hostile actions.

According to ACARE, the cost of achieving the Vision 2020 goals through the Strategic Research Agenda (SRA) would be around Euro 100 billion. The European Commission kick-started the funding process at the end of 2003 by announcing it would invest Euro 1.07 billion in aeronautical research projects as part of the Sixth Research Framework Programme.

**Table 5. Vision 2020 research**

**Key objectives of Vision 2020 research**

- A five-fold reduction in accidents
- Halving of perceived aircraft noise
- A cut in $CO_2$ emissions per passenger kilometre (halving of fuel consumption)
- An 80% cut in NOx
- An air traffic system capable of handling 16 million flights per year with 24-hour operation of airports (this already takes into account the first outcomes of the Single Sky Initiative).
- Transport quality and affordability
- More comfort for passengers
- 99% flight punctuality
- Continuous reduction of travel charges.

The importance of the SRA is that it indicates to the Commission the near-term areas where the funds need to go to reach the headline targets. The ACARE group has identified five “high-level target concepts” which need urgent research:

- the highly customer-oriented air transport system;
- the highly time-efficient air transport system;
- the highly cost-efficient air transport system;
- the ultra-green air transport system;
- the ultra- secure air transport system.

What this means is a new emphasis on research into technologies which lower the direct operating costs of airliners – the use of more lightweight materials, more fuel efficient engines. In its most recent SRA report ACARE has set the agenda for the direction of EU civil air transport research and development for the next 10 years. But as well defining the areas where money needs to be spent, ACARE also has a role in deciding how much money will be needed to achieve its headline goals and where and how it should be spent.

Beyond these high-level target concepts, Francois Quentin, Vice-Chairman of ACARE and Senior Vice-President Aerospace at Thales, outlined some more esoteric research programmes which would require serious investigation at some later stage.

“In propulsion, there are new forms of energy – solar, hydrogen, nuclear or beamed energy from the ground. New lifting forces will mean morphing aircraft shape, vectored thrust and plasma jet thrusters. In terms of guidance and control we should be looking at approaching 'total automation' through computer activation of increasingly robotic flight vehicles."

**2.2.4 Significant engine company initiatives to improve greenhouse gas emissions**

**Pratt & Whitney's** TALON (Technology for Advanced Low NOx) combustor reduced NOx emissions on the PW4000 by 30% versus the originally certified combustor. The next generation of TALONs are being designed make engines like the PW6000 even cleaner. Currently, Pratt & Whitney is developing new efficiency concepts through several advanced demonstrator programmes including the Advanced Technology Fan Integrator (ATFI) and the Joint Technology Demonstrator Program (JTDP). According to the company:

"The ATFI is a small-sized demonstrator based on the **Pratt & Whitney Canada** PW308 engine, focusing on swept fan technology plus advanced gear drive systems. The swept fan design brings the two advantages of better top-of-climb performance derived from increased fan flow capacity and reduced noise levels, enabling engines to meet the increasingly strict rules imposed by airports and regulating bodies. This same swept fan technology is being incorporated into the GP7000 116-inch engine, under development through a joint venture between Pratt & Whitney and **General Electric**. Pratt & Whitney has also teamed up with **MTU Aero Engines** for the JTDP, a PW6000-size demonstrator with a single-stage high-pressure turbine and an intermediate-sized high-pressure compressor. The program is developing parts and components for future gas turbine engines. In the initial series of tests, a new MTU six-stage high-pressure compressor demonstrated significant performance improvements."

As a result of the tests the new compressor has been incorporated into the PW6000 engine and is being jointly developed by Pratt & Whitney and MTU. MTU is developing the JTDP to validate low-pressure turbine technologies such as advanced aerodynamics, new materials and design concepts, while Pratt & Whitney is investigating new concepts and technologies such as low-emission combustors, performance and structural improvement features for high-pressure turbines, various bearing and seal upgrades and a new fuel-management unit.

Meanwhile, to improve real-time engine health monitoring Pratt & Whitney is developing advanced health management systems throughout all engine components. These self-diagnostic component-monitoring devices will be integrated into a propulsion health management system that aims to minimise unscheduled shop visits and improve the reliability and performance of components.

The timing launch of a new generation of narrowbody airliners to replace the current Boeing 737 and Airbus A320 families will depend on the success of engine manufacturers to produce a new "breakthrough" technology to improve fuel efficiency levels of the current types by at least 15-20%. Current “breakthrough” technologies which offer the best prospect for these include the geared turbofan and counter rotating fans.

"The PW8000 geared turbofan is the next leap in engine technology," according to Pratt & Whitney president Karl J. Krapek. "This engine…reduces operating costs as much as 10%, reduces fuel burn 9%, cuts noise levels significantly, and boosts reliability by eliminating more than half the airfoils in the compressor and turbine sections."

Pratt & Whitney has spent more than 10 years of research and over $350 million in developing the engine. In this concept the fan, which produces most of the thrust, is driven through a reduction gearbox, rather than being directly connected to the rest of the engine. "The gearbox between the fan and low-pressure compressor and turbine allows us to select the best possible operating speed for each engine section," says Krapek. "Each runs much more efficiently, allowing us to reduce the number of engine stages and parts.

“Fans operate best at slower speeds, while compressors and turbines run more efficiently at higher speeds. Therefore a gearbox allows the fan, compressors, and turbines to achieve their most efficient operating speeds, leading to a quieter engine with better fuel burn and fewer parts to maintain. The gearbox design also allows for a larger fan on the PW8000, which provides it with an efficient 11:1 bypass ratio… With 40% fewer stages than conventional turbofans of the same size and 52% fewer compressor and turbine airfoils, the PW8000 has 10% lower operating costs and nearly 30% less maintenance costs.” According to Pratt & Whitney, this means a typical 120-180 passenger aircraft will save $600,000 annually due to lower operating and maintenance costs and improved productivity. The new geared turbofan also features reduced emissions of at least 40% below the 1996 regulations. “This is a result of the engine's use of an advanced burner that produces fewer emissions,” says the company. The engine is scheduled for certification within the next two and a half years.

One of the design goals for engine efficiency is to increase as high as possible the bypass ration (that it, the ratio of cold air flowing around the engine core to the air which passes through the main combustion chamber); engine efficiency improves with high bypass ratios .

**Rolls-Royce** lead the ANTLE (Affordable Near Term Low Emissions) engine consortium to research teechnolgies to provide a:

- 12% reduction in carbone dioxide emissions
- 60% reduction in NOx emissions
- 20% reduction in acquisition costs
- 30% reduction in life-cycle costs
- 50% reduction in development cycle
- 60% improvement in reliability.

Work has been focused on the development of an advanced three-shaft unit incorporating a smaller number of higher efficiency components than at present. The major new design elements were a high-pressure compressor and intermediate- and low-pressure turbines. Further innovations included a low-cost turbine rear frame, revised lubrication system and distributed engine controls. The project also incorporated a new HP turbine and a UK-designed dual annular combustor. Rolls-Royce Germany was responsible for the high-pressure (HP) compressor, while **FiatAvio** delivered the intermediate-pressure turbine and **Industria de Turbo Propulsores (ITP)** in Spain took the lead for the low-pressure turbine. Other participants include **Eldim**, **Hispano-Suiza**, **Howmet**, Spain's **INTA institute**, **Lucas**, **Calidus** of the UK, **Techspace Aero** and **Volvo Aero**. Also involved in the ANTLE project were the universities of Florence in Italy and Luleå of Sweden.

Targets have been revised more recently to focus on a reduction of at least 10% in CO2 emissions and 60% in nitrogen oxides by 2008. Initial testing of the ANTLE engine has been concluded and the emissions reduction targets have been achieved, according to the company.

Rolls-Royce has also set its own goals for environmental improvement in civil engines. It aims to halve engine noise by 2010 relative to 1998 levels, achieve a 10% reduction in fuel consumption in all new engines (again, by 2010, compared with the equivalent model in 1998) and cut NOx by 50% relative to current regulations..

LEAP56, or “Leading Edge Aviation Propulsion” is **CFM International’s** key next-generation programme. According to programme director William Clapper the main objectives for LEAP56 are a reduction in operating and maintenance costs. “This will be achieved through a simpler, more robust design, using new materials and new control system technologies. Furthermore, improvements to the engine operating cycle and the combustion process will considerably cut both noise and nitrogen oxide emissions,” according to the company.

LEAP56 is  a follow-on to the TECH56 programme launched a few years ago, which will culminate in the introduction of major improvements on the CFM56-5B (Airbus A320) and CFM56-7B (Boeing 737) towards 2007, through the “Tech Insertion” package.

The goals of the programme – in terms of improvements over current CFM-56 engines are:

- Specific fuel consumption 10 –15% lower
- Maintenance costs 15 –25% better
- Initial on-wing life 25% longer
- Noise … ~15EPNd
- Emissions … 50% lower.

LEAP56 is aimed at a new class of more fuel-efficient and environmentally friendly 18,000-32,000 lb thrust engines for Airbus and Boeing when airlines replace the A320 and 737 families. The CFM56 is the best-selling gas turbine engine in commercial service — more than 17,000 are operating — thanks to its monopoly position on the Boeing 737 and the highest number of engine orders for the A320 family.

CFM is currently marketing CFM56-3 Advanced Upgrade kits, comprising three-dimensional aerodynamics (3-D aero) incorporated in the high-pressure compressor, along with new high-pressure turbine hardware. According to the company this provides CFM56-3 Advanced Upgrade operators with up to a 1.6% improvement in specific fuel consumption (which directly impacts fuel burn), as well as up to 25 degrees additional exhaust gas temperature (EGT) margin. “The additional EGT margin can translate to more than 3,000 additional hours on wing, reducing airline maintenance costs,” says the company.

Turbine improvements include new nozzle and shroud materials, a new blade coating, and improved cooling.

A320 engine competitor **IAE** is committed to updating its V2500, through the Select programme, a series of updates which will be launched into production in mid-2008. Early improvement targets of Select are a 1% improvement in fuel burn and a 20% improvement of time-on-the-wing.

**MTU** is leading the NEWAC (New Aero Engine Core Concepts) European technology programme launched in May 2006, backed by the EU under its Sixth Research Framework Programme. NEWAC will run for four years and aims to reduce CO2 emissions by 6% and NOx emissions by 17% through improvements to the engine core. Forty partners including Snecma, Rolls-Royce and Avio among the major players are jointly developing intelligent compressors, improving the combustor and integrating heat exchangers. The approach is to identify the potentials of the new technologies and bring the most promising among them to maturity.

According to the European Commission: “Emerging innovative core engines like the Active Core, Intercooled Core, Flow Controlled Core and Intercooled Recuperative Core will be able to appreciably reduce emissions and fuel consumption. In the course of the programme new components for these core engines will be built and tested.

NEWAC draws on the lessons learned from the now-complete CLEAN and ANTLE programmes. It also complements VITAL, led by **Snecma** under the EU’s Sixth Research Framework Programme, which attempts to optimise the engine’s low-pressure components. The findings of VITAL and NEWAC together will provide the European engine industry with a complete inventory of available and meaningful technologies to use in the development of future.”

Meanwhile, **Volvo Aero** and the Swedish Government are each investing SEK 63 million in the Volvo Aero’s development of lightweight components for more fuel efficient and thereby more environmentally compatible aircraft engines. Volvo Aero’s application “Swedish demonstrator for environmentally compatible aircraft engines” is receiving part financing from state agency

Vinnova of SEK 63 million, which will be paid in instalments from 2007 through 2010. Volvo Aero will invest the same amount during the period. Vinnova's aim with the so-called "Aviation technology and demonstrator programme" (Swedish acronym FLUD) is to promote sustainable growth in Sweden through needs-motivated research. Primarily, Vinnova wants to facilitate companies to participate in international commercial demonstrator programmes to increase the share companies have in commercial product development programmes, create national propagation effects, research institutes as well as small and medium-size (SME) companies to participate.

Much of **General Electric's** research into engine efficiency has been geared towards developing new coatings so turbines can operate more efficiently at high temperatures. According to the company: "The maximum efficiency for a General Electric (GE) gas turbine engine in 1995 was 54.5%. In order to improve efficiency and reduce operating costs for its turbines, GE wanted to raise the firing temperature of its gas-fired turbine engines. By applying thermal barrier coatings (TBCs) onto hot-path turbine engine components, turbines could operate at higher temperatures, thereby increasing efficiency without reducing component life…. Project researchers developed thermal spray technologies used to produce high-performance TBCs that contributed to an upgraded version of GE's 1996 F-series power plant model, raising its 54.5% efficiency to 56%."

In GE's latest GEnx engines - which will power the Boeing 787, 747-8, and Airbus A350 – the company is building engines up to 15% more fuel efficient, 30% quieter, and with significantly lower emissions than predecessors through a number of technology improvements:

- A new designed booster ( which accelerates and further filters airflow), reducing downstream wear
- A high pressure turbine made of advanced alloys and coatings withstand heat for long life.
- A fan case made from composite material which improves strength, is corrosion-free with lower weight than metal
- A low pressure turbine with fewer, more efficient parts and durable materials mean less waste and better performance
- Fan blades made from composite material which allows fewer parts, greater efficiency, lower noise and most resiliency
- A compressor of advanced aerodynamics and high compression improve fuel burn with fewer parts
- A combustor which burns fuel at lower peak temperatures while delivering our lowest emissions.

According to the company: "Exotic materials like powdered metal alloys and carbon fibre composites have been combined with our advanced design codes to optimise the entire propulsion system. And by incorporating our most advanced combustion technology ever, the result will be an engine that will produce fewer smog-causing emissions than the maximum allowed by 2008 international standards (94% fewer hydrocarbon emissions and 57% nitrogen emissions), while consuming at least 15% less fuel than the engines they replace."

The GEnx engine is scheduled to certify at maximum takeoff thrust of 75,000 lb in 2007 with entry into service in 2008 on the Boeing 787 Dreamliner. To date (May 2007), 17 customers have placed firm orders for more than 575 GEnx engines.

### 2.2.5 The propfan alternative

A further, radical alternative would be to re-equip small jet turbine powerplants with current-technology turboprops. CFM International is revisiting 1980s research into unducted fan – or "open-rotor" as it is now known. By eliminating the nacelle, open rotors reduce drag and weight, and open-rotor engines can be developed with bypass ratios of, potentially, 35:1 and more. It should have 10% better fuel efficiency than the LEAP56 proposal, according to the company.

Open-rotor technology is not new. CFM won the 1987 Collier Trophy for an open-rotor design, demonstrated in flight tests and rear-mounted on an MD-80; McDonnell Douglas, Boeing, Snecma and General Electric teamed produced the GE36 UDF.

These engines were developed in the early 1980s in response to the oil-price hike of 1973 and subsequent recession in the aviation market. But when fuel prices declined, so did interest in this noisy, if more fuel-efficient alternative.

Open rotors would be about 10% noisier than the LEAP56 engine and vibration issues still have to worked on  before production models can be brought to the market. But Snecma parent Safran is examining an open-rotor concept for a new single-aisle aircraft engine to appear in 2015[9].  The company is examining the concept of two counter-rotating composite fans to improve the efficiency of the blades and allow for slower speeds to reduce noise.

The turboprop sector, almost written off five years ago, is undergoing a major renaissance in recent years partly as a result of the environmental benefits of using this less polluting, if less powerful, technology.  Fuel burn advantages and lower emissions of Bombardier's 70-seat Q400 turboprop – over jet 70-seat competitors – offer a potential of up to 30% in fuel savings; year-over-year deliveries of Q400s during the fourth quarter of 2006 grew 71%. The company is looking into stretching the Q400to 90 seats.

Turboprop engine manufacturer Pratt & Whitney is currently (April 2007) increasing production to make 40% more engines in 2008 over 2007, due to the increase in demand. The manufacturer will build 250 PW100s in 2007, up from 60 a few years ago.

[9] *Flight International,* 17-23 April 2007

### 2.2.6 The "Clean Sky" industry initiative

One of potentially the most productive industry-lead pre-competitive research programmes currently underway is the "Clean Sky" initiative, being pioneered by the European aerospace trade association ASD. This Joint Technologies Initiatives (JTI) is the industry and European Commission response to developing a common research effort within the EU's Seventh framework programme.

The research work covers civil aircraft, rotorcraft, engines and systems technology demonstrations and validations to maximise the environmental benefits of new technology design. The key research areas are outlined below:

- An innovative aircraft architecture including an active wing and new concepts
- Innovative aerodynamic, structural and systems technologies for regional aircraft
- Rotor and drive system technologies and aerodynamics of rotorcraft
- Efficient and lightweight engine components and structure, ultra high by-pass ratio concepts, optimised power generation and control
- Aircraft/ rotorcraft energy management
- Vehicle control and mission management
- Air transport system model and simulation.

The Clean Sky initiative is focused on developing technologies that will deliver:

- 50% reduction in CO2 emissions through drastic reduction of fuel consumption;
- 80% reduction of NOx emissions;
- 50% reduction of external noise; and
- A green design, manufacturing, maintenance and disposal product life cycle.

The consortium undertaking environmental and efficiency improvements research within the Clean Sky JTI is known as SAGE (Sustainable And Green Engine) and comprises Rolls-Royce, Snecma, MTU, Volvo Aero and others.

The joint industry group has been set up as international legal entity including the Community (represented by the European Commission) and founding companies, established on the basis of Article 171 of the EC Treaty.

In terms of developing "cleaner" engines the consortium plans to deliver a number of engine demonstrators to test reduction in noise, emissions, fuel burn, maintenance and system technologies. The consortium will design, build and test a number of demonstrator vehicles and rigs to validate the benefits of innovative, environmentally-aware technologies in a realistic operating environment. These will comprise integrated technology demonstrators - high

BPR low-weight technologies; high efficiency components; new power generation for more electric engines; new controls for smart engines.

Test vehicles will be selected from a range of options, depending on technology maturity and timing of market requirement in the following sectors: wide-body, narrow-body, regional and helicopter variants.

Some of the technology options under test will include both novel module technology
within conventional architecture and radical architecture change in the following domains:

- Improved acoustic damping (post SILENCER technology liners);
- Low noise and light exhaust;
- More electric engine (post POA-MOET technologies);
- Low noise/low- weight fan
- Low-weight composite casing
- Hybrid low-weight structure
- Damping attachment
- Compact booster
- Low-weight LP turbine
- High performance/low-weight HPC
- New generation HPT
- Low leakage sealings
- Alternative fuel combustor

In terms of radical new architectures the joint venture will examine:

- Small, high-speed, high temperature core with lean-burn combustor
- Open rotors, contra-rotors, geared turbofan, “clean-sheet” powerplant/ installation
- Contra LP turbine.

One major positive event was the agreement by the Council of Ministers in late 2006 agreeing $45 billion of funding for the the seventh Framework Programme (FP7). FP7 will run from 2007-2013 and consists of four chapters: Co-operation; Ideas; People and Capacities. The first two will fund research, while the last two will build up the EU's tangible and intangible research capacity. According to the UK’s SBAC: “Of the six suggested joint technology initiatives, it is crucial that aeronautics and air transport (known as Clean Sky) is selected by the Commission as a priority. This programme will contribute to composite material development and more efficient engine technology, which will help to improve the environmental performance of aircraft .”

### 2.2.7 Conclusions

The aircraft/engine industry has made a great deal of the efficiency improvements which have been made over the last 50 years in commercial engine technology. But critics have said these efficiencies are not as significant as at first appears.

According to “The Myth and Reality of Aviation and Climate Change” report by A T&E / CAN-Europe:

“Past and future gains in aviation fuel efficiency have been widely debated. A commonly cited figure of 70% gains between 1960 and 2000 is widely used as a reference for the industry’s technological achievements.” This figure was published in the IPCC’s Special Report on Aviation and the Global Atmosphere (1999), which included a graph showing trends in the fuel efficiency of new jet aircraft coming onto the market between 1960 and 2000 (IPCC 1999; p. 298). This graph suggests the figure of 70% overall fuel efficiency gains between 1960 and 2000, and based on this figure the IPCC indeed concludes that: “The trend in fuel efficiency of jet aircraft over time has been one of almost continuous improvement; fuel burned per seat in today’s aircraft is 70% less than that of early jets.” (IPCC 1999)

The IPCC’s Figure 9-3 forms the background of 70% fuel efficiency claims. (Source: www.grida.no/climate/ipcc/aviation/avf9-3.htm) Recent research undertaken on behalf of T&E by the Dutch Aerospace Laboratory (NLR 2005) shows that this figure of 70% improvement is only part of the picture at best and that over the last 50 years aircraft fuel efficiency has in fact hardly improved at all….aircraft manufactured in the early 1950s – such as the Lockheed Constellation – were two to three times as fuel efficient as the early jets that succeeded them and virtually as fuel-efficient as the aircraft on sale today. The report states:

“From this figure the following observations may be made: If one takes new aircraft from the early fifties (i.e. the last piston-engine aircraft) as the baseline, it shows that these last long-haul piston-powered airliners were **as fuel-efficient** as today’s average turbojet aircraft. [emphasis added]. If one takes new aircraft from the early sixties (i.e. the first jets) as the baseline (as presented in the IPCC report), an improvement of 55% is found rather than the 70% presented in the IPCC report.”

All comparisons are, of course, invidious but comparing the efficiency and emissions performance of a piston engine with that of a modern jet is unrealistic – a Sopwith Camel is more environmental friendly than an F-22.

A 1940s piston-powered aircraft is no longer a viable aircraft. A Lockheed 749 Constellation (1947) had a range of 1,760 miles, a maximum of 81 passengers, a service ceiling of 25,000ft and was powered by four Wright R-33500C18-BD1 Cyclone 18-cylinder 2,500 hp engines.

The key question is what sort of emissions savings will the current state/industry research efforts produce, and by when?

Considerable research funds have been found on both sides of the Atlantic to suggest that the Vision 2020 goals of 50% reduction on CO2 per passenger km and 80% cut in NOx are attainable. Added to this, the progress reached on recent research into these areas (ANTLE, SAGE etc), suggests the technology will be available for new engine production, meeting these targets, by 2020.

According to Boeing the 787 (flying in revenue service in 2008) will feature a 20% reduction in $CO_2$ emissions over current generation aircraft (such as the Boeing 767).

**Table 6. Emission comparisons - measures per 100 passenger kilometres and assuming average modal load factors**

| SUV | Sedan | High speed train | Boeing 787 |
|---|---|---|---|
| 10.7 litres | 6.4 litres | 3.8 litres | 2.4 litres |

Source: Boeing

**Table 7. Potential reduction in greenhouse gas emissions through on-going industry, government and research organisations**

| **Emission improvement potential through engine manufacturing design improvements** | | |
|---|---|---|
| **Measure** | **Potential savings** | **Forecasting agency** |
| UEET/ Clean Sky/ACARE/manufacturer research and development programmes. | Reduced NOx emissions by 70% below 1996 ICAO regulations<br><br>Reduced $CO_2$ emissions by 8% to 15% for large aircraft - 50% reduction in $CO_2$ emissions by 2020 through drastic reduction of fuel consumption. | The Clean Sky/ACARE targets are much tougher than UEET, involving a considerable decrease in $CO_2$, without increasing emissions in other greenhouse gases. Probability of achieving target slightly better than even – though only for new-generation engines available in the post 2020 timeframe. NOx reduction targets should be easier to accomplish. |

**Table 8. Near-term improvements in greenhouse gas emissions by manufacturers**

| Emission improvement potential through engine manufacturing design improvements | Rationale for improvements | Total CO2 saved |
|---|---|---|
| Technical inserts for CFM and IAE aircraft engines available 2008/2009, producing 1%-1.6% improvements in fuel burn | CFM will produce 1,400 engines a year through 2010. IAE is delivering 300 engines a year. The technical improvements will make marginal improvements to Boeing 737 NG and Airbus A320 performance from 2009 onwards. According to GE "The upgrade kit provides a 1.6% fuel burn improvement over the base CFM56-3 engine which translates into 28,558 gallons of fuel saved per aircraft per year and 234 tons less CO2 emitted per aircraft per year."[10] With backlog order for the A320 and Boeing 737 families currently reaching more than 3,500 in May 2007, these new engine improvements will be delivered to at least 2,700 new single-aisle aircraft. | 631,800 tonnes between 2008-2010 – covering current backlog and delivery rates of A320 and Boeing 737 NG types, equating to 210,600 tonnes of CO2 saved a year. |
| GEnx available 2008 | See "replacement aircraft" section | 00 |

[10] Source: http://ge.ecomagination.com/site/index.html#cf56/envmodel

| | | |
|---|---|---|
| PW 8000 geared turbofan for 2015 – up to 40% emission improvements | Research at too early a stage to quantify improvements | 00 |
| LEAP-56 with 50% efficiency improvements by 2015 | Research at too early a stage to quantify improvements | 00 |
| New generation open-rotor engines – 10% better than LEAP-56 | Research at too early a stage to quantify improvements | 00 |

## 2.3 Manufacturing: research and development programmes to improve airframe and aircraft systems technology

### 2.3.1 Introduction

Most emission improvements will come in the longer term through reductions in engine emissions and in the shorter term through more efficient routings. But one major contribution to creating more environmentally-friendly aircraft in the future will be in the development airframes which are lighter and more aerodynamically efficient and in aircraft systems which contain lighter and more efficient sub-systems.

What this means is a new emphasis on research into technologies which lower the direct operating costs of airliners – the use of more lightweight materials, more fuel efficient engines, more reliable sub-systems and so on.

The new generation of civil aircraft currently entering service – or about to enter service shortly – are engineered in very different ways from previous aircraft. The Boeing 787, the Airbus A380 and A350 XWB will incorporate many new lighter, more efficient technologies which will decrease demand on the aircraft's engines over current types.

The Airbus A350 XWB will benefit from a 10% improvement in fuel saving, says the company, over current designs thanks to improvements in aerodynamic design in the following areas:

- Advanced riblets in the fuselage structure behind and above the flight-deck
- Wave drag control over the outer wing
- Natural or hybrid laminar flow across the nacelle, wing and empennage.

The "Clean Sky" JTI has outlined a number of key areas in potential aerodynamic performance for critical research:

- An innovative aircraft architecture including an active wing and new concepts
- Innovative aerodynamic, structural and systems technologies for regional aircraft .

### 2.3.2 Towards the lighter aircraft

Reducing weight aboard by one kilogram for each seat saves up to 9,000 gallons of fuel a year, according to IATA. The last 30 years have seen a steady growth in new lightweight materials on large air transport aircraft.

According to a recent study by E-Composites, composite materials in the aerospace market are forecast to grow over 10% annually during 2005-2010. "The global aerospace industry is estimated to use $4.6-billion worth of composite materials during 2005-2010. During this period, the global end product market for composites including radome, horizontal stabiliser, vertical stabiliser, flaps, floors, bulk heads, etc. is projected to reach $27 billion," says Dr Sanjay Mazumdar, E-Composites' Chief Executive Officer.

The Boeing 787 will comprise around 50% composites, by airframe weight.

On the A300, the first Airbus, the aircraft's structure comprised 4% composites, with titanium comprising a further 4%, steel 12% aluminum 77% and other materials 3%. The Airbus A310, which first flew in April 1982, included large numbers of composite materials in secondary structures – spoilers, airbrakes and rudder – and later versions featured composite primary structures. The A380 features just under 25% of composites in its structure. Around 50% by weight of the Boeing 787's structure will be built from lightweight composite materials (compared with only 12% of the Boeing 777) while for the A350 XWB up to 52% will be made from composites in the following areas:

- Composite wings
- Composite empennage
- Composite belly fairings
- Hybrid fuselage with large panels.

Meanwhile, titanium will be used in the landing gears, pylons and attachments – all combing to produce fuel savings of up to 5%, says the company.

Advances in lightweight materials have also been developed by aluminium suppliers.

The largest all-composite civil aircraft ever built was the Grob Strato 2C, a high- altitude research aircraft developed in the mid 1990s, with a wing span of 56.5m. At the 2005 Paris Air Show Grob announced another all new composite aircraft – the SPn Utility Jet, featuring a carbon fibre fuselage and wing.

The advances in composite structures have developed from series of major research programmes. As part of its Sixth Framework Programme the European Commission spearheaded the Euro 100 million ALCAS (Advanced Low Cost Aircraft Structures) project to help develop new low-cost, lightweight aircraft wing structures from advanced composite materials, such as carbon-fibre reinforced polymers. ALCAS is being managed by Airbus UK and Dassault Aviation; it runs from 2005 to 2009.

Meanwhile the fruits of another EU managed composite research programme, FUBACOMP (Full Barrel Composites), emerged in July 2005 when BAE Systems produced a 4:5 scale Dassault Falcon front fuselage section made entirely from carbon fibre. The section was manufactured using fibre-placement technology, where individual strips of carbon fibre are placed onto a mould, rather than the traditional method of carbon fibre plies being laid by hand. The FUBACOMP programme aims to develop European capability in fibre placement and project members include BAE Systems, Dassault Aviation, CEAT, Advanced Composites Group (ACG), Alenia, Eurocopter (France and Germany) and Brunel University.

One of the main barriers to increasing the percentage of composites to the overall weight of an aircraft has traditionally been cost, especially as production of composite structural parts has had to reply on many manual techniques in the past. New machine tools and more efficient autoclaves, plus manufacturing techniques which do not rely on first-generation carbon fibre manufacturing techniques have recently made available more cost-effective and complex carbon fibre structures. In particular, the development of CNC-controlled automated taper layers and fibre-placement systems has created tools that can meet the demand for volume production of complex contoured components and large composite structures.

The Airbus A350 will feature structures made up 52% of carbon composites, 17% Al-Li with the remainder made from, steel, aluminium and titanium. CFRP will be used extensively in wings, keel, floor beams and rear pressure bulkhead; Al-Li in fuselage; titanium for engine pylons.

But new, lighter structures can also be introduced into the assembly line of legacy aircraft, especially the moving surfaces of wings.

However, one of the major issues with the extensive use of carbon fibre is the challenge it poses at the end of the aircraft's life.

European Union (EU) states need to find new ways to reduce landfill and incineration waste disposal methods, particularly for carbon-fibre products. Landfill and incineration have traditionally accounted for over 90% of the disposal methods for carbon-fibre structures but an EU directive came into force at the end of 2004 in many EU states forbidding landfill disposal of composites. Sending composite materials to the incinerator is also becoming an unviable option, given the toxic by-products of the process.

Mechanical recycling, or regrinding, offers a third alternative to landfill and incineration. According to CompositesIQ, an information network for European composite structures' manufacturers, "Regrinding entails grinding up of the bulk composite scrap into smaller pieces. This method produces new composites reinforcement and filler materials. Currently this is the only commercially applied method.... To date, the regrinding process is the only commercially employed process that creates useful materials in the form of fillers and fibre reinforcement out of thermoset composite waste. Most operations have focused on the recycling of sheet (SMC) and bulk moulding compounds (BMC) because they comprise the largest fraction of the thermoset composite market. The organisation continues: "No satisfying recycling options, in terms of both technical and economical feasibility, are available yet."

There are a number of European research projects underway to look at the potential solutions to recycling composites. Probably the most significant of these is the recently-completed study by the INASMET-Tecnalia research centre in St Sebastian, Spain, which aims "to perfect a recycling technique that enables the obtaining of carbon fibre from waste components and the study and evaluation of the possibilities of its reuse as an element of reinforcement in new applications".

Three recycling techniques were examined: a chemical process based on nitric acid, in which the resin is dissolved and carbon fibre removed after washing; a thermal process called "pyrolysis", where argon is used to eliminate resin without damaging the carbon fibre; and a third involving incineration.

According to the research agency: "Although the three alternative ways studied for the recovery of carbon fibre are each technically viable, environmentally the only method that can be considered for the recovery of carbon fibre on a large scale is that of pyrolysis technique, and that the quality of the fibre obtained enables its use as reinforcement in applications that to date have not been considered, due to the high costs involved."

However further European research, sponsored mainly by the continent's automobile industry, is looking at potential markets for recycled composite materials. For example, the Dutch research institute KEMA is examining the potential to produce high-quality recyclates from reinforced plastics, to produce adhesives for the construction industry.  Other similar studies are under way in the UK's Brunel and Nottingham universities.

UK composite recycling company Milled Carbon has been working with Nottingham University to improve aerospace carbon recycling methods.  In April 2006 the company announced that by using the pyrolysis method it could "recycle cured parts up to 2 meters wide and 250 millimeters high to a current thickness of 25mm and uncured material in the form of manufacturing off-cuts or unused rolls of pre-impregnated material are processed in a similar fashion".

"We are also developing forms of the recycled fibres where, traditionally, virgin carbon fibres have been always been used," according to the company's managing director John Davidson. The company's work has been backed by Boeing as part of a new transatlantic aircraft recycling initiative running parallel to that of the PAMELA consortium.

The PAMELA (Process for Advanced Management of End-of-Life of Aircraft) project is a test-bed for a new Euro 2.4-million programme, part funded by the European Commission's LIFE (l'Instrument Financier pour l'Environnement) programme, to evaluate the costs and benefits of recycling up to 95% of the structures, materials and components of a generation of airliners which have reached the end of their operational life. The consortium of companies comprising waste management specialist SITA along with aerospace companies Airbus, EADS CCR, Sogerma Services and the Préfecture des Hautes-Pyrénées have set up the Tarbes Centre to develop new standards for recycling aging airliners. It will also develop a European information network on the technical and business implications of aircraft recycling. The Tarbes Centre should be fully operational by mid-2007 and aims to dispose of around 10 aircraft a year.

In June 2005 the Châteauroux-Déols facility in central France also opened, managed by metal recycling company Bartin. The facility is part of the Global Association For Aging Aircraft Value Improvement (AFRA) network, set up by a consortium of companies including Boeing, Volvo, Adherent Technologies (a carbon-fibre recycling company based in Albuquerque, NM) Milled Carbon and the Evergreen Air Center.

### 2.3.3 Towards the all-electric aircraft – improved aircraft systems

Replacing heavy hydraulic systems with lighter electric technologies is another area where substantial saving can be made. The goal of aircraft designers around the world is the "all-electric aircraft", using small electric motors instead of today's heavy, maintenance-intensive, hydraulic, pneumatic and mechanical systems.

Considerable research has taken place in this arena over the last few years. The European Union-backed research programme POA (Power Optimised Aircraft) has been evaluating the overall electrification of all the on-board systems – and in particular, all the systems related to the landing gear – for a number of years.

"Project MOET" (More Open Electrical Technologies), also backed by the EU and led by Airbus has been researching ways to develop the technologies required for more electric aircraft. According to team member Goodrich: "Benefits of an electric architecture include improvements in environmental impact and reliability as well as reduced maintenance costs." Additional technologies contributing to the evolution of the all-electric aircraft, according to Goodrich, include electric actuation for extension, retraction and steering of the landing gear system; electro-mechanical braking; the electrical power generation system/Variable Frequency Generators (VFG); and the ability to demonstrate electric engine start-up.

The consequences of all-electric systems run through the entire aircraft design. The engine produces thrust, pneumatic power, hydraulic power and electric power and will have be redesigned and optimised to produce thrust and predominantly electric power – but the benefits will be that an all-electric system aircraft will not require quite so much power from the engine.

By 2010/2013 it should be possible to replace all hydraulic controls by electric controls. Liebherr's Electro Hydrostatic Actuator (EHA) for the aileron control of the Airbus A321 is a product of the European Electrically Powered Integrated Control Actuation Programme, a fully electric-driven, self-contained hydraulic actuation package, requiring no external hydraulic supply.

EHAs are at the forefront of new, lightweight aircraft design. The F-35 Joint Strike Fighter features a Parker EHA. In the A380, the use of electric systems in the flight control architecture has meant a weight reduction of around 3,300 lb (1,500 kg) over conventional hydraulic networks. As well as EHAs, the aircraft also features Electric Back-up Hydraulic Actuators (EBHAs). Four EBHAs provide electrically- powered flight control actuation for the spoilers - the first time this technology has been used on a passenger aircraft.

Work by, among others, Hamilton Sundstrand on ElectroMechancial Actuators (EMAs) is leading a major redesign of the motor drive, with research by the US Air Force Research Laboratory and Hamilton Sundstrand suggesting new motor drives will be able to increase power density and convert electrical energy to mechanical energy with efficiency greater than 18%.

The A380 presented its designers with some tough weight-saving challenges. Because of the size, number and power demands on the aircraft's flight control surfaces, a conventional hydraulics system would have been extremely large and heavy to integrate into the aircraft's design. Instead the A380 uses a hybrid electric-hydraulic system based on electrohydrostatic actuators which use a small electric motor to power a hydraulic piston. The actuators are controlled electrically over a wire from the cockpit rather than through a hydraulic line; Airbus estimates that more-electric technology will reduce the A380's weight to the point that it will be 20% more fuel-efficient than its smaller rival, the Boeing 747.

In general there is a move away from numerous, separately-specified system components to integrated networks relying on solid-state power controllers and smart contactors. In a distributed, or integrated, architecture the long runs of individual power wires are replaced with secondary power feeders linked to multiplexed databus lines. The integrated network eliminates components and wires; reduces weight, installation and testing times and increases reliability.

According to some manufacturers' figures, by using distributed power systems, the number of electrical components can be cut by 35%; wire segments by 40%; weight can be reduced by 40%; installation time reduced by 60%; and reliability improved by 20%.

Hamilton Sundstrand sums the difference up as follows:

"In the typical centralised electric power management system, power is routed from the primary distribution network in the power centre to the loads through thermal circuit breakers for protection, then through relays for control. Each load has associated wires for power and control. Power application and removal is accomplished by crew operation of the circuit breakers.

"In the...distributed electrical power management system, the protection and control of individual loads are performed by a single Solid-State Power Controller (SSPC). Because they can be remotely controlled, the second power distribution assemblies containing the SSPCs can be strategically located throughout the aircraft to minimise total aircraft wiring." Electrical power systems are undergoing a dramatic change with the switch to variable frequency generators and electrohydraulic actuators replacing hydraulics. The benefits will be seen across a number of areas with estimated reductions in take-off weight (3%), life cycle-costs (4%) and maintenance (5%).

All internal aircraft systems are being reviewed for efficiency and weight improvements. Cabin air-conditioning systems in the future will have to rely on less power, have improved control equipment, lower noise levels, better constancy of temperature, lower maintenance costs and faster air-conditioning times.

Currently, environmental control systems (ECS) use air which is bled from the engine, which imposes increased power demands on the engine. In future aircraft systems (the Boeing 787 or the A350 XWB), aircraft designers are developing new ways to minimise the demand. In later generations of aircraft the ECS will not depend on engine-derived air at all, thus reducing further engine fuel burn.

The Rolls-Royce Trent 1000 engine for the Boeing 787 features an “IP Power Offtake” system, involving dual use starter-generators which act as both electrical starters on the ground, and power generators while airborne. “In flight, power is created by mechanically driving the generators using the engine’s intermediate pressure compressor, including power for the cabin Environmental Conditioning System (ECS) rather than taking conventional bleed air,” according to the company.

According to Philip McGoldrick, Technology Manager at Goodrich Control Systems Limited:

“In the1950s, jet engines were established as the main propulsion and electric generator power source, but shaft speed varies by ratio 2:1. Equipment (fuel and air pumps, electrical instruments) couldn’t take such a variation in input supply frequency. Therefore the speed of the mechanical to electrical power conversion was made constant using technology derived from Swedish sawmills. The IDG (Integrated Drive Generator) was invented. The IDG features:

- Poor Reliability
- Poor Maintainability
- Heaviness

- Difficult Installation
- Low Efficiency (400 parts).

The alternative – variable frequency generator offers:

- Better Reliability
- Better Maintainability
- Lighter weight
- Easy to Install
- More Efficient (120 parts)
- Lower life-cycle cost

"As well as efficiency, weight, cost to buy, running costs and installation, the biggest impact on aircraft is with reliability. If there is a technical fault with the typical passenger airliner that prevents it being available at the departure gate, 80% of such technical reliability problems are caused by the auxiliary equipment mounted on the engine.

"There is another, even more significant technology change in the offing: replacement of engine bleed air and engine hydraulic take-off by electrical power sources. These changes are bundled together and called the "more-electric aircraft" concept. In equipment and technology terms, bleed air replacement is the most significant. Engine bleed air has three uses as a power source on civil airliners: ECS (Environmental Control System, Pressurisation and Conditioning); icing protection (wing and nacelles); and engine start function.

"ECS is used mostly in flight; icing protection is used only at certain parts of the flight profile. Engine start rating is highest for ground starts, where the APU is the air source. Replacement of an aircraft hydraulic mains system driven by engine take-off with an electric power source is a potential weight-saver for the aircraft overall. Flight control surfaces and undercarriage will be hydraulically driven, but much of the weight of an aircraft hydraulic mains will be removed by local generation."

According to Airbus' Alain Garcia (April 2007), the A350 XWB will feature bleed off-takes in lower-pressure engine stages (benefiting specific fuel consumption) and the deletion of pre-coolers, thanks to lower-temperature flow (lower weight). "Roughly 30% reduction potential of the energy consumed by the ECS has been identified," he says.

An aircraft requires a number of separate power generation/storage systems: batteries, emergency power, tank and cargo bay inerting systems, APUs. Replacing these with new technology fuel cells will reduce engine off-take requirements by around 3% of fuel burn in the cruise – which equates to around 2,000 tonnes of kerosene (or 6,200 tonnes of $CO_2$ on a 20-year A320 operation) according to Garcia.

According to Boeing's "Frontiers" magazine, July 2004:

“On average, gas turbine APUs are 15 % efficient at converting jet fuel into electricity. In contrast, fuel cell APUs will be 60 % efficient, which will reduce by three quarters the amount of fuel an airplane uses to generate ground power. And because a fuel cell APU produces electricity electrochemically, not through combustion, its oxides of nitrogen and sulphur emissions will be negligible and its carbon dioxide emissions will be very low.

“The Boeing fuel cell APU concept envisions a hybrid system that combines a solid-oxide fuel cell with a compressor, turbine and other components. This turbo-machinery pressurises the fuel cell stack to maintain efficiency during high-altitude cruise. Because fuel cell APUs are so efficient, they may well see regular in-flight use. In contrast, turbine APUs are not used in flight except when backup power is required.

“The MEA concept --a significant change in how Boeing thinks about jetliner systems -- is another way the company is working to meet its commitments to good corporate citizenship and protecting the environment as stated in Vision 2016. Using fuel cell power, MEA-and its ultimate expression, the all-electric airplane-will yield efficiency gains across a broad range of fronts.

“Under this concept, the airplane's cabin pressurisation, environmental control system, lighting, cockpit instrumentation, wing anti-ice protection, and control-surface and landing gear actuation will someday all be electrically powered. In this airliner of the future, the fuel cell APU will also operate in flight as the full-time source of primary electrical power. Starter/generators fitted to the engines will provide engine starting and redundancy, but will not actually be called on to generate electricity in flight except to assist with high-load conditions such as landing gear actuation or initial powering of the galleys.

“This approach frees up the engines to devote all the power they generate to thrusting the airplane. Additional fuel is not burned to continuously generate electricity, and high-pressure air is not bled off the engines for cabin pressurisation. This fuel cell technology application could achieve 75 % efficiency in converting jet fuel into electrical power during cruise. The resultant fuel savings -- particularly in long-range flight operations -- create what engineers call a virtuous circle in design, in which the benefits compound each other to allow a fundamentally lighter and more efficient airplane.

“The first stage of MEA thinking is evident in the ultra-efficient 7E7 (now 787) which will feature electrically-powered cabin pressurisation. Unfortunately, fuel cells won't be ready in time for this all-new airplane's planned service debut in 2008, although the 7E7 will likely be easily upgradable once fuel cell APUs become available.”

It is not just in power systems where aircraft weight is coming down. Replacing steel brakes with new generation carbon brakes, augmented with new electronic management systems, can improve braking performance and decrease aircraft weight. An Airbus A300 with carbon, rather than steel brakes, is 600 kg lighter and as carbon maintains its properties at high temperatures it also has competitive operating advantages. All Airbus and Boeing aircraft feature carbon brakes options.

Brake manufacturers are introducing new and lighter materials such as the Messier-Bugatti SepCarb III which offers resistance to vibration and oxidation. On the Airbus A380 - which has required a greater braking performance at a lighter weight than ever before - Dunlop and Honeywell have developed wheels using a new metal-matrix composite material, lighter than previous materials.

**2.3.4 Aerodynamic improvements**

According to a March 2007 statement by the Airbus vice-president, environmental affairs, Philippe de Saint-Aulaire, Airbus is targeting a 50% reduction in aircraft fuel consumption by 2020: airframe improvements would provide about 25% of the reduction, engine improvements would deliver between 10 and 15% and improved air traffic management another 10%.

The 25% improvement is based on research by Airbus into drag reduction. According to a paper (http://www.dglr.de/veranstaltungen/extern/aerodays2006/sessions/A_Sessions/A5/A51.pdf
given by GézaSchrauf of Airbus at the Fifth Community Aeronautics Days conference held in Vienna in June 2006, Airbus has identified three major areas of drag-reduction potential: a 15% improvement in the area of viscous drag (through the introduction of laminar flow technology, turbulence and separation control technologies), a 7% improvement in lift-induced drag (through shape optimisation, adaptive wing devices, wing-tip devices and load -control technologies) and a 3% improvement in other drag areas such as wave drag and interference drag (through the development of new shock control technologies and novel configurations).

As was noted in the UK's Royal Aeronautical Society's technology sub-group's "Greener by Design" July 2005 study: "In both the medium and long term, reducing zero-lift drag is potentially the most powerful means available to reduce fuel burn. The options which offer the greatest possibilities are natural laminar flow control; hybrid laminar flow control; flying wing or blended wing-body configuration; all-over laminar flow control."

Research efforts into cruise drag reduction throughout the European Union (EU) have therefore been focused on three areas: natural laminar flow (shaping); hybrid laminar low (suction) and active flow control (wave cancellation). The research effort has come not from Airbus alone but through the collaborative work of European industry and research organisations working within the KATnet (Key Aerodynamic Technologies for Aircraft Performance Improvement) network, a consortium part funded by the European Commission as part of its Fifth Research and Technology Development Framework Programme. KATnet has provided a communication platform for European research organisations and companies

**Fuel conservation via weight or drag reduction – ATA**

:

- In removing seatback phones from its MD-80s and B737-400s, another airline shed 200lb per aircraft, translating into 3,400+ gallons saved annually
- One airline saved over 17 gallons/year per pound of weight per aircraft after shedding inflight phones, ovens, excess potable water, and some galley equipment on an older fleet
- Alaska Airlines indicated in March 2004 that removing just five magazines per aircraft could save $10,000 per year in fuel; also, the airline has reduced the weight of catering supplies
- JetBlue , US Airways and others have moved toward a paperless cockpit
- By removing six seats, JetBlue reduced A320 weight by approximately 904lb
- Airlines have been able to remove ovens, rubbish compactors, or even entire galleys, due to the elimination of hot meals on selected flights; others are using lighter seats; they have also removed magazine racks and replaced hard cabin dividers with curtains
- AirTran ordered carbon-fibre Recaro seats for its 737-700s to shave 19.4lb per row, resulting in estimated fuel savings of $2,000 per year per aircraft
- Alaska's new beverage cart, at 20lb lighter, could save $500,000 in annual fuel costs
- Pratt & Whitney estimates that its EcoPower engine-washing process saves Hawaiian 2.8lb (or $1 million) in fuel annually across the airline's 31 Boeing 767 engines
- Some airlines flush lavatories during extended ground delays to minimise takeoff weight.

to focus on a specific research programme within a co-ordinated, pan-European strategy.

The KATnet consortium has been lead by Airbus Germany (co-ordinator), Airbus UK, Airbus France, BAE Systems, Alenia Aeronautica, DLR, FOI, ONERA and QinetiQ. The objective has been to determine the technology status and development of long-term visions for the implementation of advanced aerodynamic technologies into future aircraft and to establish a network to co-ordinate work in the specialist areas. In terms of drag reduction the key areas of research for the KATnet organizations have been:

- Reducing lift-dependent drag
- The use of advanced materials and their installation to optimise elliptic lift distribution and minimise vortex drag
- Reducing design constraints using new materials

- The development of wing-tip devices and adaptive wing devices (including multi-functional control surfaces and min trailing edge devices)
- Improved load control
- Gust/maneuver load alleviation.

This work has been broken down further into the following projects, part funded by the European Commission and part funded by industry:

- Low-speed aerodynamics: EUROLIFT, HELIX, HiAer, EPISTLE
- High-speed aerodynamics: HiReTT, AEROSHAPE, M-DAW
- Flow-control technologies: ALTTA, AEROMEMS II, AWIATOR.

Some of the work packages have been extensive with clear near-term benefits. One of the most important of these has been the Euro 80-million AWIATOR (Aircraft Wing With Advanced Technology Operation) technology programme, due to be completed in the summer of 2007. Twenty-three partners (plus several subcontractors) under the leadership of Airbus have investigated new wing technologies and validate their improvement possibilities in flight. Two flight test campaigns (2003 and 2005/2006) with the Airbus A340 MSN 001 test aircraft have taken place to investigate the potential of new control surfaces for load control, spoilers for rapid descent and devices for reducing the wake vortex hazard. One important aspect of the programme has been to rate the technologies on a “total aircraft level”, so the integration of any new technology can be assessed on the overall performance of the aircraft. The programme has had four major objectives:

- Reduce wake vortex hazards, leading to a decreased separation distance behind a large aircraft of 1 nm
- Apply specific flight procedures using new devices, reducing noise by 2 EPNdB
- Increase high-speed cruise performance (and lower fuel burn by 2%), low-speed cruise performance through new devices and load control strategies
- Decrease the structural weight of new aircraft by 5% through applying new load-control strategies and by 10% using new devices.

Given the high degree of composite structures planned for the A350 XWB wing and the need to reduce current wake vortex separation minima for the A380, the relevance of these pre-competitive research areas is clear.

**Aerodynamic improvement projects in the European Commission's Sixth Framework research programme**

*ALCAS (Advanced Low Cost Aircraft Structures), a Euro 101.17-million programme to reduce the operating costs of relevant European aerospace products by 15%, through the cost effective application of carbon-fibre composites to aircraft primary structure

* NACRE (New Aircraft Concepts Research) Euro 30.34-million-project to investigate, from 2005 to 2009, the development of technologies required for novel aircraft concepts at aircraft component level

* REMFI (Rear Fuselage and Empennage Flow Investigation) a Euro 6.37-million project to examine the enhanced understanding of tail-flow physics, improved computational predictions for fuselage/tail design and analysis and improved experimental capabilities and measuring techniques for tail flows

* TELFONA (Testing for Laminar Flow on New Aircraft) a Euro 5.17- million project to develop the capability to predict the in-flight performance of a future laminar flow aircraft using a combination of wind tunnel tests and CFD calculations

* EUROLIFT II European High Lift Programme II (EUROLIFT II) a Euro 7.33-million investment in the development of simple, high-lift systems with reduced maintenance requirements.

**For a full breakdown of all engine and aerodynamic efficiency improvement programmes part-funded by the EC in the sixth framework package please see appendix two.**

### 2.3.5 Winglets

Winglets are wing-tip extensions which reduce lift-induced drag and provide some extra lift. The first big airliner to carry winglets was the MD-11; other Boeing aircraft flying with winglets are the 747-400, Boeing BBJ business jets, C-17 military transport and new generation Boeing 737s.

According to the "The Boeing 737 Technical Site"[11]

"Winglets have the potential to give the following benefits:

[11] Source: http://www.b737.org.uk

- Improved climb gradient. This will enable a higher RTOW from climb-limited airports (hot, high or noise abatement) or obstacle limited runways
- Reduced climb thrust. A winglet-equipped aircraft can typically take a 3% derate over the non-winglet equivalent aircraft. This can extend engine life and reduce maintenance costs
- Environmentally friendly: the derate, if taken, will reduce the noise footprint by 6.5% and NOx emissions by 5%. This could give savings on airport noise quotas or fines
- Reduced cruise thrust. Cruise fuel flow is reduced by up to 6% giving savings in fuel costs and increasing range
- Improved cruise performance. Winglets can allow aircraft to reach higher levels sooner. Air Berlin notes, "Previously, we'd step-climb from 35,000 to 41,000 feet. With blended winglets, we can now climb direct to 41,000 feet where traffic congestion is much less and we can take advantage of direct routings and shortcuts which we could not otherwise consider."

Nearly 95% of all new Boeing 737s are now built with winglets - but Airbus aircraft tend to either have "wing fences" or no winglets at all. Their development was pioneered in the late 1970s by, among others Dr Richard Whitcomb at the NASA Langley Research Center, who predicted that transport-size aircraft with winglets would realise improved cruising efficiencies of between 6% and 9%. According to NASA: "A winglet flight test programme at the NASA Dryden Flight Research Center in 1979-80 validated Whitcomb's research when the test aircraft - a military version of the Boeing 707 jetliner -- recorded an increased fuel mileage rate of 6.5%."

So why are not all transport aircraft equipped with them? Acording to the Boeing 737 Technical Site: "Winglets cost about $725,000 and take about one week to install which costs an extra $25,000-$80,000. Once fitted, they add 170-235kg (375-518lb) to the weight of the aircraft, depending upon whether they were installed at production or as a retrofit. The fuel cost of carrying this extra weight will take some flying time each sector to recover, although this is offset by the need to carry less fuel because of the increased range. In simple terms, if your average sector length is short (less than one hour) you won't get much the benefit from winglets - unless you need any of the other benefits such as reduced noise or you regularly operate from obstacle limited runways."

Airbus is talking to Aviation Partners[12] about developing a winglet package as part of the A320 "enhanced" package, which will see the development of an A320 over the next few years with a 5% improvement in fuel burn.

The current fuel crisis in the aviation industry has provided a new impetus in winglet research and new business for companies involved in their development, especially as retrofitable devices. The potential for fuel savings are substantial; new designs such as "spiroid" winglets severely cut back

[12] Flight International, 30 January-5 February 2007

concentrated wingtip vortices, which account for nearly half of the induced drag generated during cruise. In 2001, winglet manufacturer Aviation Partners tested spiroid winglets on a Gulf stream II and reduced cruise fuel consumption by more than 10%, according to the company.

By using Aviation Partners winglets, business jet operators will save 110 million gallons of fuel in 2006[13] and 150 million gallons in 2007. "Assuming the company delivers 400 blended winglet ship-sets during 2005-10…the overall fuel savings in this decade could reach about 1.2 billion gallons."

### 2.3.6 More esoteric designs – lifting bodies

The advent of the Sixth Framework Programme (2000-2006) delivered an aerospace research programme worth Euro 1.07 billion and some further advanced aerodynamic research programmes, specifically investing increasing amounts of research effort into blended and advanced-swept wing designs. One of the most significant of these has been the VELA project, which targets fuel consumption improvements up to 30% over current aircraft designs. Led by Airbus, with a team of 17 partners, the programme has investigated the benefits, potential and problems of a flying wing transport aircraft. Two configurations have been built for wind-tunnel testing by the Institute of Aerodynamics and Flow Technology, DLR, Germany.

However, as the operational deployment of such a radical concept is unlikely before 2018-2020 this potential major emission-improvement design lies outside the scope of this study.

[13] *Aviation International News.*

**Table 9. Potential reduction in greenhouse gas emissions from aerodynamic improvements to current generation aircraft**

| **Emission improvements through adding winglets and "cleaning-up" airframe to improve fuel consumption** | **Rationale for improvements** | **Total CO2 saved** |
|---|---|---|
| Adding winglets to improve fuel consumption | According to Boeing (see table 11), a 1% improvement in fuel burn performance for a single-aisle aircraft equates to average annual savings of 146 tonnes in CO2 emissions, per aircraft, per year. Winglets improve Boeing 737 NG performance by -2.6% in fuel burn for 500nm missions and -3.6% improvements for 1,000nm[14]. An average fuel burn improvement of 3% is estimated (though Ryanair, a short-haul carrier, estimates fuel improvements of 4% following the addition of winglets). The backlog order for the A320 and Boeing 737 families currently reaches more than 3,500 in May 2007, with 1,500 Boeing 737s to be delivered and 2,000 A320s to be | 1,095,000 tonnes of CO2 could be saved between 2008-2010 through the fitting and retrofitting of winglets, equating to 365,000 tonnes of CO2 a year – a rate which will increase after 2010 with the growing use of winglets on both Airbus and Boeing types. However, this figure does not take into account fitting of winglets to larger and smaller (regional and business jets) types, which is growing. Larger types will benefit more from winglets than smaller. A further, conservative, estimated saving of 80,000 tonnes of CO2 a year from fitting current-generation widebody types (Boeing 767, Airbus A330-A340) with retrofit packages and large business jets/regional jets with winglets should be factored in. |

[14] http://www.icao.int/icao/en/ro/nacc/acilac/19_goetz_boeing_aviaenvir.pdf

| | | |
|---|---|---|
| | delivered. Of these, a realistic assessment would put A320E (see below) and winglet-equipped A320s at 1,000 of these aircraft ordered. | |
| A320 enhanced – available from 2009, offering a 5% fuel efficiency improvement | The A320 enhanced aircraft should be available from 2009. At current delivery and forecast delivery rates this would equate to 480 new aircraft a year – but of these aerodynamic improvements would make up just 2% of the better fuel-burn performance. | 140,160 tonnes of CO2 emissions will be saved on an annual basis with the introduction of the enhanced A320, based on annual delivery rates of 280 aircraft and a 1% improvement in fuel performance delivering 146 tonnes less in CO2 emissions. |

### 2.4 The potential of new fuels

#### 2.4.1 Introduction

The potential replacement of traditional jet-burning fuels with synthetic fuels has been a consideration for many years. During the last months of the Second World War around 85% of Germany's air force operations were conducted using synthetic fuels.

According to the aviation industry environment group ATAG:

"While the dependency of the aviation sector on fossil fuels is expected to continue for the foreseeable future, concerns about rising fuel costs, energy supply, security and aviation emissions have called for a fresh look at the use of alternative fuels.

The potential for alternative fuel use in aviation is not a new concept. Early jet engines were developed using hydrogen, but the very strict technical requirements for aircraft to use a fuel with high energy content per weight and volume led to the adoption of kerosene as the standard aviation fuel. In the late 1970s, synthetic aviation fuels were developed for military use from shale oil, tar sands and coal liquids but programmes to further develop these fuels were abandoned as synthetic fuels were not cost-effective.

"In the early 1980s, Brazil developed PROSENE, an alternative combustible lipofuel (vegetable oil) used as an alternative to aviation kerosene. However, this programme was also stopped in favour of national biodiesel and biokerosene.

"The embargo to end apartheid in South Africa led to the adoption of semi-synthetic aviation fuel, SASOL, a blend of petroleum-derived and synthetic kerosene. A blend of 50% synthetic fuel and 50% crude oil fuel has been tested and approved for aviation. This semi-synthetic fuel is used by South African Airways and is fully satisfactory. Use of fully synthetic jet fuel is being tested and approval deemed imminent."

An October 2006 report on alternative fuels produced by Boeing, NASA, and MTU Aero Engines ("Alternative Fuels and Their Potential Impact on Aviation") concluded: "The only currently known drop-in alternative jet fuel was found to be a synthetic manufactured fuel. Alternative aviation fuels synthesised by using a Fischer-Tropsch-type process, are ideally suited to supplement, and even replace, conventional kerosene fuels. Although this fuel, and its manufacturing process, does not help address global warming issues, it was found to be the most easily implemented approach.

"Another possible alternative, bio-fuel, could be blended in small quantities (i.e., 5% to 20 %) with current jet fuel. This bio-jet-fuel blend can be derived from sustainable plant products, which makes it attractive as a step toward a "carbon neutral" fuel that will help address global warming issues. However, because of aviation's high-performance fuel specification needs, direct bio-fuels would need to go through an additional, possibly costly, fuel processing step. Reduced particulate emissions have been one of the benefits observed in diesel engines and smaller gas turbine engines, but they have not been substantiated in new-technology, large turbine engine tests. Therefore, as aircraft use a small proportion of fossil fuels, and unless some other beneficial properties are found, it appears that biofuel will be easier to use and will offer more global warming benefits when used in ground transportation vehicles. Because of the limited availability of arable land, bio-fuels will be able to supply only a small percentage of most countries' energy needs.

"Other alternative fuels result in airplane performance penalties. For example, liquid hydrogen (LH2) not only presents very substantial airport infrastructure and airplane design issues, but because of the need for heavy fuel tanks, a short-range airplane would experience a 28% decrease in energy efficiency while on a 500-nautical-mile (nmi) mission. However, because airplanes need to carry much more fuel for a long range flight, and liquid hydrogen (LH2) fuel is quite lightweight the lighter takeoff weight of the airplane results in an energy efficiency loss of only 2% while on a 3,000-nm mission.

"Ethanol takes up 64 % more room and weighs 60% more compared with Jet-A fuel. This type of alternative-fuelled airplane would experience a 15% decrease in fuel efficiency on a 500-nmi mission and a 26% efficiency decrease on a 3,000-nmi mission compared with a Jet-A fuelled airplane."

There are therefore a number of important challenges to be overcome before a fully acceptable replacement to traditional fossil fuels can be realised, not all of them scientific.

“Throughout the airline industry tests are being made to run engines on bio-fuel. One of the problems is that there is currently no tax on standard Jet A fuel. Thus tax concessions cannot be made to encourage alternative fuels in the same way they were used to boost development in the auto industry,” according to Volvo Aero.

But the technical challenges to developing new fuel alternatives are tough. According to Airbus’ Alan Garcia:

“Standard Bio fuels do not emit CO2, but they cannot be used for aircraft because of:

- Chemical compatibility (low thermal stability, high temperature freezing point…)
- Efficiency (calorific power of biodiesel is 10% lower than kerosene)
- Affordability (currently around $130/150 a barrel).

“Bio-fuels may become standard complement to oil kerosene. Use of biokerosene is the only viable solution, but:

- Their transformation emits up to 4 kg of CO2 per kg.
- Cost and availability of feedstock remain open questions.”

Below are listed the key synthetic fuel programmes.

**Alternative fuel options**

ATAG has prepared the following analysis of alternative fuel options.

**Synthetic liquid fuels**: Synthetic fuel or synfuel is any liquid fuel obtained from coal, natural gas or biomass. It can sometimes refer to fuels derived from other solids such as oil shale, tar sand, waste plastics or from the fermentation of biomatter. The leading company in the commercialisation of synthetic fuel is Sasol, a company based in South Africa. Sasol currently operates the world's only commercial coal-to-liquids facility at Secunda, with a capacity of 150,000 barrels a day. Other companies that have developed coal- or gas-to-liquids processes (at the pilot plant or commercial stage) include Sasol, Shell, Exxon, Statoil, Rentech, and Syntroleum.

**Bio-jet fuel:** jet fuels made from converted agricultural oil crops such as soya.

**Ethanol fuel**: can be combined with gasoline in any concentration up to pure ethanol (E100). Ethanol is, by far, mostly used to power cars, but it may be used to power other vehicles such as farm tractors and, perhaps in the future, aircraft.

**Hydrogen**: The use of hydrogen in aviation is expected to start with fuel cell applications for the replacement of auxiliary power units (APUs), ram air turbine (RAT) and distributed power units. These applications will generate large fuel savings on the ground, lower noise and lower NOx.

**Benefits of alternative fuels**

A limited oil supply could make synthetic or biofuel essential in the long-term. Synthetic liquid fuel is nearly identical to kerosene. It is limited in use today, but could be environmentally promising. Immediate benefits will include a very "clean" burn, meaning less coking up of the engine and reduced maintenance costs. They have no sulphur and no or limited aromatic components. Such fuels are also expected to produce less particulate matter. However, they produce equivalent levels of $CO_2$ to petroleum kerosene, and possibly more depending on the energy which is used for their production. In addition, the new fuels are chemically compatible with all fuel system materials, such as seals and joints and aircraft airframes. They can also make use of existing distribution systems.

Biojet-fuel appears as a mid-term option, but may be affected by limited production capacity. However, it will require considerable land resources, which may generate other environmental and social costs. The synthetic or biojet-fuels of the future will have to behave like jet fuel and meet all current specifications, allowing engine architecture to develop along established lines.

Ethanol is not a good option for long-haul aircraft (ethanol-fuelled aircraft will require much larger wings and engines reducing its fuel efficiency) but may be relevant to regional short-haul and general aviation. Hydrogen may be a very long-term option for aircraft engines, depending on technological developments and potentially prohibitive infrastructure investment (e.g. airports will have to be converted).

Since air transport is a relatively "compact" industry, it would be logical for the air -transport industry to be one of the first sectors within the transport industry to take the lead by using alternative fuels. However, the challenge is that aviation's demand may not be sufficient to justify the important investments required. Hence the idea to consider the role of airports in supplying alternative fuels not only to aircraft and ground airport activities, but also to the local communities around airports.

Source: ATAG

### 2.4.2 The USAF synthetic fuel-blend trials

The United States Air Force (USAF) has begun trials with a Boeing B-52 powered by mixture of synthetic fuel and JP-8 in all eight engines. The synthetic fuel is made from a 50-50 blend of traditional crude oil-based fuel and a Fischer-Tropsch fuel derived from natural gas. In January 2007 the B-

52 underwent cold-weather testing, the last step in the testing and certification process for the fuel. The first B-52 flight using Fischer-Tropsch (FT) fuel occurred September 19, 2006, at Edwards AFB, California, since when the aircraft has been tested extensively -- up to the point of flying with synthetic fuel in all eight engines. The cold-weather data will be analysed along with the data from Edwards AFB, and a complete test report is scheduled to be issued in June.

The FT process produces a much cleaner fuel from coal, gas and biomass feedstock – but the Syntroleoum plant in Tulsa, Oklahoma, which produced the fuel has since been mothballed[15].

### 2.4.3 Volvo Aero, SAS, Swedish Civil Aviation Authority and Oroboros (funded by Vinnova) alternative fuel study

Programme participants are looking for alternative fuels as similar as possible to traditional Jet A fuel. According to Volvo Aero: "The project is examining whether it is possible to extract gas from wood chips or other organic material, and then convert the gas into a liquid fuel cost-efficiently. The team has tested synthetic fuels in the combustion lab at Lund University in conditions that correspond to a modern aircraft engine. The tests show that there are no major differences in combustion properties between synthetic fuel and Jet A. But the most positive result is that emissions are much cleaner, compared with fossil fuels…The project has shown it is possible to produce eco-adapted aircraft fuel. One key area remains to be tackled – making the price competitive."

### 2.4.4. Virgin Fuels

The Virgin Group is investing between $300 million to $400 million over the next two to three years in research into cellulosic-ethanol based fuels – mainly for land-based transport modes such as automobiles, trains and trucks. But if this fuel source does emerge as a viable alternative to kerosene "that effectively leaves aircraft to burn petroleum-based fuel," according to Virgin's Sir Richard Branson.

Meanwhile in April 2007, Boeing and Virgin Atlantic announced an environmental partnership, which includes "a joint bio-fuel demonstration aimed at developing sustainable fuel sources suitable for commercial jet engines and the aviation industry." Boeing, Virgin Fuels and GE Aviation plan to conduct a joint bio-fuel demonstration on a Virgin Atlantic Boeing 747-400 in 2008, probably using a bio-fuel derived from soya or rapeseed.

Meanwhile Boeing and Virgin are also examining the potential of using CO2-absorbing algae. According to *Flight International*: "The US Department of Energy's Office of Fuels Development funded a programme for almost two decades until 1996 to develop renewable transportation fuels from algae. The main focus of the programme, know as the "Aquatic Species Program" was

[15] *Flight International*, 16-22 January 2007

the production of bio-diesel from high lipid-content algae grown in ponds in the Arizona desert, feeding on waste CO2 from coal-fired power plants…Development was interrupted when oil prices fell, however, and the commercial need to develop an alternative was substantially reduced. Some countries, including New Zealand, have continued to work on the production of fuel from algae, and have made significant progress."
.
Algae ponds covering an aggregated 34,000sq km located in a warm climate could reduce the carbon dioxide footprint generated by global aviation to zero, according to Boeing's alternative fuel expert Dave Daggett, quoted in *Flight Global* (26 April 2007).

Bio-fuels have their champions. "They can meet Jet A1 standards and are environmentally very efficient," according to Francis Couillard[16], "They reduce carbon dioxide emissions by 80-90%."

### 2.4.5. All-Electric Aircraft Propulsion – NASA Glenn

A multidisciplinary effort is underway at the NASA Glenn Research Center to develop and evaluate concepts for non-traditional fuel cell power and propulsion systems for aircraft applications. As part of this effort, system studies are being conducted to identify concepts with high payoff potential and associated technology areas for further development.

"To support this effort," according to NASA, "a suite of component models was developed to estimate the mass, volume, and performance for a given system architecture. These models include a hydrogen-air PEM fuel cell; an SOFC; balance-of-plant components (compressor, humidifier, separator, and heat exchangers); compressed gas, cryogenic, and liquid fuel storage tanks; and gas turbine/generator models for hybrid system applications.

"First-order feasibility studies were completed for an all-electric personal air vehicle utilising a fuel-cell-powered propulsion system. A representative aircraft with an internal combustion engine was chosen as a baseline to provide key parameters to the study, including engine power and subsystem mass, fuel storage volume and mass, and aircraft range. The engine, fuel tank, and associated ancillaries were then replaced with a fuel cell subsystem. Various configurations were considered including a PEM fuel cell with liquid hydrogen storage, a direct methanol PEM fuel cell, and a direct internal reforming SOFC/turbine hybrid system using liquid methane fuel. Each configuration was compared with the baseline case on a mass and range basis. A comparison of the study results is shown in the bar chart. On the basis of the study methodology, the SOFC-hybrid system appeared to offer the most potential in terms of achieving an acceptable takeoff weight and range. This was due to a number of factors, including the use of a hydrocarbon fuel, which is more volumetrically efficient than liquid hydrogen storage; direct internal reforming of the fuel, thus eliminating the need for an

[16] Quoted in *Airlines International,* October/November 2006

external fuel processor; and the ability to extract energy from the hot fuel cell exhaust streams by expanding the gas in a turbine."

Work is underway between Boeing, NASA and a number of European universities including the Technical University of Munich, fuel cell manufacturers and the automotive industry to develop an electrically-powered demonstrator aircraft. - adapting a single-engined aircraft with fuel cells and an electric motor turning a conventional propeller.

A fuel-cell/battery-powered Diamond Dimona motor glider is due to take to the air in 2007, with lithium ion batteries for take-off and landing and hydrogen-fuelled proton exchange membrane (PEM) fuel cell for cruise. It is part of a Boeing Madrid research centre programme, which also entails using solid-oxide fuel cells for APUs within 15 years.

### 2.4.6 Other fuel trials – hydrogen and liquefied natural gas

According to the NASA report (see above) hydrogen fuel (H2), publicised as the most environmentally-benign alternative to petroleum, has its own drawbacks and is not a source of energy in itself. H2 production needs "an abundantly available source of energy, such as electrical power, produced from nuclear fusion and a large source of clean water". However, that has not stopped Russian aircraft designers from experimenting with cryogenically-stored hydrogen fuels. The Tupolev design bureau has tested such an aircraft "without any serious incidents" according to the company. This experimental TU-155 was later converted to "use not only liquid hydrogen but also to use Liquefied Natural Gas (LNG)…Remarkable properties of liquid hydrogen as aviation fuel and first of all its high ecological cleanliness, high heat of combustion and high cooling capacity attracted attention of aviation specialists to this type of fuel. Liquid hydrogen allows us to improve aircraft performance significantly….Its (natural gas) high energy capacity and huge cooling capacity make it possible to build aircraft with significantly high performance in comparison with aircraft using kerosene. Fuel efficiency of flight using LNG can make 10 g/pass, km.

"When using LNG, potential emission of toxic agents will be decreased as follows: carbon monoxide: 1 – 10 times, hydrocarbons: 2.5 – 3 times, nitrogen oxides:1.5 – 2 times, polycyclic aromatic hydrocarbons including benzapyrene:10 times….To use cryogenic fuel , the airframe and some standard systems were modified, and cryogenic fuel charging, storage and feeding systems were installed that ensured fire/explosion safety, and data acquisition and recording system as well."

On 15 April, 1988 the aircraft performed its maiden flight using liquid hydrogen and on 18 January, 1989 the aircraft performed its first flight on liquefied natural gas.

### 2.4.7 Conclusions

According to the NASA/Boeing/MTU study: "Synthetic fuels derived from non-renewable energy sources, such as coal or natural gas, are not considered sustainable. However, this process may be able to use vast untapped energy resources, such as coal, stranded natural gas, and methane hydrates, which could provide energy for many decades to come. Global warming issues with synthetic fuel would ultimately also make it unsustainable. Biofuels are derived from plants and may be considered sustainable if a sufficient quantity of crops can be grown to support the demand for fuel. Unfortunately, many countries would be unable to grow sufficient fuel feedstock to produce enough biofuel to supply the country's energy needs."

Given the conclusions above, the land-use issues involved in developing biofuels, the potential loss in engine performance as a result of their use this report concludes that, for the moment at least, synthetic fuels do not offer a short-term alternative to jet fuel use and, thereby, emissions improvements which can be easily quantified.

## 2.5 Airlines: new operating concepts to lower emissions/noise using current infrastructure

### 2.5.1 Introduction

Since 2001, airline fuel efficiency of US airlines within the Air Transport Association of America (ATA) has improved 34 %, on average, from 37.4 revenue passenger miles (RPMs) per gallon to 50.1 RPMs per gallon. Part of that gain is driven by higher passenger load factors. In terms of seating capacity per gallon ATA records a 26.6 % increase over that same period, from 49.2 available seat miles (ASMs) per gallon to 62.3 ASMs per gallon; ATA airlines consumed 400 million fewer gallons of fuel in 2005 than in 2000, while carrying more passengers and more cargo.

**Table 10. Fuel consumption improvements by US airlines**

| Year | RPMs per gallon | ASMs per gallon |
|---|---|---|
| 1971 | 15.0 | 29.9 |
| 1981 | 24.9 | 42.6 |
| 1991 | 31.9 | 50.7 |
| 2001 | 37.4 | 49.2 |
| 3Q06 | 50.1 | 62.3 |

Source: ATA

Viewed over a longer period, U.S. airlines have more than tripled RPMs per gallon since 1971, according to ATA.

The IATA Environment Committee is in the process of updating the existing IATA fuel efficiency goal of a 10% improvement per RTK (revenue-tonne-kilometres) between 2000 and 2010, as this goal was achieved last year. The revised goal, to be submitted soon to the Board of Governors, seeks at least 25% further improvement by 2020. The original target was to reduce the total release of $CO_2$ emissions into the atmosphere by almost 350 million tonnes compared to a scenario in which year 2000 efficiency levels would be "frozen".

While many potential fuel-saving remedies are not in the hands of airlines (airspace redesign, ATM procedures, airport aeronautical facilities) many are.

Hubbing strategies, aircraft procurement policies, successful ticket sales strategies all impact the environmental performance of individual airlines.

Despite increasing demands for their services many of the world's airlines have been able to cut their emissions of greenhouse gases, thanks to a number of tightly targeted initiatives. For example, ANA set the goal of reducing FY 2007 $CO_2$ emissions per available seat km to 12% of FY1990 levels. "In FY2005, we achieved a 10.6% reduction; we continue to approach our goal by adopting the very latest aircraft and through optimal engine maintenance," according to the airline. "ANA's $CO_2$ emissions from aviation activities were approximately 1.80 million tons (equivalent in carbon, approx. 6.61 million tons in $CO_2$ equivalent) in FY2005; this was 0.3% lower than in FY2004. The reduction was achieved by retiring old aircraft and replacing them with the latest aircraft, as well as by implementing measures to reduce fuel…although the number of seats in service increased significantly from FY1990, the $CO_2$ emissions per ASK decreased."

ANA's Efficient Fuel Program (EFP), one of the most successful across the industry, has several elements:

- Creating fuel-efficient flight plans having optimal altitude and speed, while considering weather conditions and air traffic control information
- Taxiing with some engines shut down
- Recovering engine performance by washing the compressor
- Prioritised use of ground-power GPU
- Operation with RNAV (Area Navigation)
- Saving fuel through simulators
- Cabin weight reduction programmes.

"We monitor the amount of fuel saved each month; in FY2005 we saved 18,000 kiloliters of fuel over the previous year. This represents the amount of fuel required by a B777-200 to make 1,250 round trips between Tokyo and Osaka."

JAL's major policies aimed at preventing global warming comprise buying new, more fuel-efficient aircraft, achieve annual reduction of 1% in annual thermal and electric energy consumption by Japan Airlines International and Japan Airlines Domestic and actively use mobile GPUs.

British Airways is targeting a 30% improvement in aircraft fuel efficiency between 1990 and 2010.

The larger the airline and route structure, the bigger the potential savings. But even smaller airlines have been able to achieve substantial fuel improvements through using current technology equipment in different ways.

“Special flying routes are used to lower the noise level in the case of applying procedures to lower the aircraft engine power levels at take-off wherever it is possible to do so, thus extending the useful life of the engine while at the same time saving fuel and reducing CO2 emissions up to 25%”, according to Croatia Airlines. “The effect achieved is considerable, since such procedures are followed in 95% of take-offs within the company flight network. Operating procedures lowering the level of noise at landing, which also result in fuel savings and CO2 emission reductions, are followed in most domestic and foreign airports, i.e. wherever it is possible to do so. “

Low-fare airlines argue their point-to-point route structures and no-frills approach offer potential greater efficiency improvements than their full-fare competitors.

“Ryanair has minimised and continues to reduce fuel burn and CO2 emissions per passenger kilometre,” according to the company. “This has been achieved through the combination of: numerous fuel-saving measures (including the use of the latest aircraft and engine technology, eg winglets); and commercial measures aimed at maximising passenger numbers per flight in order to spread the fuel use and CO2 emissions over the greatest number of passengers (efficient seat configuration and high load factors).

“Other characteristics of Ryanair's low-cost business model include, for example the use of secondary airports and point-to-point services, which help to increase fuel efficiency and limit emissions. Ryanair avoids long taxiing times and holding patterns at congested primary airports, and delivers passengers to their destination directly on one flight ("point-to-point"), as opposed to forcing passengers onto connecting flights through congested main hub airports, which require two take-offs and two landings.

“The combination of these operations and commercial initiatives and Ryanair's substantial investment in new aircraft has led to an overall reduction in fuel consumption and emissions of almost 52% between 1998 and 2006… Ryanair's fuel burn per 100 revenue passenger kilometres (RPKs) is currently in the range of 3.8 litres and is expected to decrease further due to fuel-saving measures currently being implemented. For example, the fleet-wide installation of winglets on all Ryanair's aircraft will itself further reduce fuel burn and CO2 emissions by up to 4%.”

**Fuel conservation through operational means - ATA**

Since 2002, the Air Transport Association of America has been monitoring airline fuel efficiency improvement programmes through operational and weight-reduction programmes. Some results are outlined below:

- En route, airlines optimise speed, flight path, and altitude to reduce airborne consumption, accommodate air traffic bottlenecks, and avoid consuming extra fuel while awaiting a gate
- Alaska, American, Southwest, and others have added life vests on certain domestic routes to enable pilots to fly over water, in cases where over-water routings are more efficient. Examples include LAX-CUN, DFW-MIA, MIA-NYC and AUS-TPA
- American redistributed cargo in the airplane's belly to minimise fuel consumption
- American and Delta use super tugs on the ground to reposition aircraft where feasible
- AirTran, Continental, Southwest, and others have installed winglets to reduce drag
- Airlines estimate fuel savings of 3-4% per Boeing 737-700 flight
- Several airlines taxi in on one engine when conditions permit; American Airlines saves $10-$12 million/year with this procedure
- American, Southwest, and others are using ground power to provide electricity and ground-conditioned air, rather than the plane's auxiliary power unit (APU)
- Delta has deployed a decision support tool to provide pilots with co-ordinated speed adjustments, allowing more evenly-spaced landings and less airspace congestion at Atlanta
- Most airlines have reduced excess fuel on international flights with FAA approval thanks to more precise navigation allowed by GPS and better wind forecasts
- New "end-around" taxiway at ATL will save airlines $26-$30 million per year; DFW is next.

Low-cost carriers argue that by sticking (for the moment at least) to relatively short, point-to-point services, using new aircraft and filling them up the are more environmentally successful than the traditional full-fare airlines.

"Our simple, automated pricing model means we attract more people to fly with us. Because we attract more passengers per aircraft, our traditional rivals flying the same route with the same type of plane use 27% more fuel than easyJet," according to easyJet (see appendix one). "easyJet does not fly to congested hub airports, such as London Heathrow or Frankfurt Main. These types of busy hubs tend to require aircraft to fly longer holding patterns and take more time to taxi to and from the runway, which naturally uses more fuel."

Offsetting is another new initiative which man airlines are now adopting. According to Delta Airlines:

“We pledge to zero out the air travel carbon footprint of every worldwide Delta customer who flies. To celebrate our commitment to our hardworking men and women, we’ll also plant a tree for every worldwide Delta employee. As a result of this single step, nearly 200 acres of native forests will be restored across the nation—with a focus on the Gulf Coast region, an area that has lost more than 20 million acres of beautiful forestland in the last century. Delta's Force for Global Good will offer our employees and customers annual opportunities to get involved in sponsored tree plantings.

“And, beginning June 1, 2007, we will be inviting our delta.com customers to participate in Go Zero$^{SM}$ by offsetting the carbon footprint associated with their flight.”

According to SAS:

“We now offer all customers the possibility to offset carbon dioxide emissions. On the website…you can enter your journey and a calculator computes the distance and CO2 contribution. The amount you can pay in compensation is invested in projects for renewable energy in other countries. This amount also corresponds to a reduction in the CO2 emissions caused by your flight or air transport. A common feature of all of these projects is that they have generated a documented reduction in carbon-dioxide emissions and that such reductions been verified by an independent auditor.”

Most IATA airlines have been successful in reaching these targets. “Fuel productivity of SIA fleet as measured by load-tonne-km per US gallon (LTK/AG) in 2005-06 increased by 1.9% over the previous year to 9.52 LTK/AG,” said Singapore Airlines. “This improvement could be attributed to fuel conservation measures and network efficiency. Correspondingly, our CO2 emission per unit of LTK also improved in equal ratio.”

Thus some airlines believe their investments in fuel efficiency improvements have started to decouple their rate of traffic growth from the rate of commensurate fuel emission increases:

“Since 1991, the companies within the Lufthansa Group have been able to continuously decouple their transport performance from environmental effects,” according to the airline. “While transport performance increased by more than 218 %, kerosene consumption rose by 116 %. Half of the airline’s growth was therefore realised without additional burdens on the environment…Lufthansa still has its sights firmly set on further efficiency goals: the passenger fleets’ specific fuel consumption is to be reduced by 33 % from 1991 to 2008, and by 38 % from 1991 to 2012. Associated with this goal is a simultaneous reduction in the specific emissions of carbon dioxide. In 2005, Lufthansa’s passenger fleets achieved a reduction by 29.2 percentage points. The specific emissions of carbon monoxide (CO) per 100 passenger kilometres measured in 2005 were the lowest values ever recorded at the airline. The previous year's low emissions level for unburned hydrocarbons (UHCs) was maintained in 2005. While specific emissions of nitric oxide (NOx) increased, they were still significantly below the levels customary until 2002."

However, although the "high-level" target of 1% improvements in fuel efficiencies set by airline groups has been achieved, it is extremely difficult to quantify where the real savings have been and where they have been offset by weight increases and operational inefficiencies in other areas. The following sections analyse the fuel efficiency initiatives in more detail.

### 2.5.2 Re-equipping with new aircraft

A new aircraft entering the fleet incorporates at least a 15% improvement in direct operating costs and fuel efficiency over the legacy fleet, otherwise it will not be a viable product. Below, table 15 outlines the environmental consequences of introducing new technology aircraft to the current fleet – but these just show the potential improvements over current generation aircraft and do not take into account the benefits currently being derived from replacing legacy aircraft with new generations of Airbus and Boeing aircraft.

Some airlines expect more than 15% improvements in their new aircraft. "Reducing CO2 emissions boils down to reducing fuel consumption," according to ANA (see appendix one). "The most effective methods are: introducing fuel-efficient engines with the latest technologies; reducing air resistance through improved wing designs; and reducing fuselage weight through the use of composite materials. The Boeing 787 employs all of these methods, and ANA was its first customer in July 2004, ordering 50 of them. The B787 is expected to reduce fuel consumption by 20% compared with the current B767-300."

Unfortunately, few of these improvements are retofittable.

ANA's CO2 emissions from aviation activities were approximately 1.80 million tons (equivalent in carbon, approx. 6.61 million tons in CO2 equivalent) in FY2005; this was 0.3% lower than in FY2004. The reduction was achieved by retiring old aircraft and replacing them with the latest aircraft, as well as by implementing measures to reduce fuel.

By buying new aircraft "Continental is nearly 35% more fuel efficient for every mile a passenger flies than in 1997," according to the company.

"The Boeing 737-800 Next Generation aircraft has a vastly superior fuel burn to passenger kilometre ratio than that of the 737-200 aircraft," according to Ryanair. "The move from these older aircraft to new 737-800 Next Generation aircraft alone has reduced Ryanair's fuel consumption and CO2 emissions per passenger kilometre by 45%."

Aircraft programmes which stay in production for more than 20 years (such as the Boeing 737) often undergo several programme updates to improve their environmental and efficiency performance. For example, Boeing's New Generation 737 line (737-600, 737-700, 737-800, 737-900) feature a new and larger wing, higher cruise speed, more range and improvements in noise, fuel burn and thrust. A 737-800 equipped with the new winglet design burns up to 5% less fuel than former types, according to the company. Raked wing tips installed on the latest generation 777-300ER (extended range) aircraft achieve an estimated 2% fuel efficiency improvement. "This equates to a savings of 1.3 million lb of fuel per year per airplane, and 3.9lb million less of global warming carbon dioxide (CO2) being emitted into the environment," according to Boeing.

Boeing's new 747-8 "will provide nearly equivalent trip costs and 10 % lower seat-mile costs than the 747-400, plus 28 % greater cargo volume," says Boeing. "Operating economics will offer a significant improvement over the A380. The 747-8 is more than 11 % lighter per seat than the A380 and will consume 10% less fuel per passenger than the 555-seat airplane.".

**Table 11: new airliners of 100 seats and more, entry dates and their potential to improve greenhouse gas emission performance**

| | **New generation aircraft** | **Legacy aircraft** | **Improvement in greenhouse gas emission performance** |
|---|---|---|---|
| 2018* | Airbus A320/Boeing 737 replacement | Boeing 737 NG/A320 family | 15-20% over current single-aisle aircraft |
| 2014 | Airbus A350 XWB | Airbus A300, A310, A330 Boeing 757, 767 | 30%. Airbus seeking a 5% improvement over Boeing 787 |
| 2010 | Boeing 747-8 Intercontinental | Boeing 747-400 | 15% |
| 2009 | Boeing 787 | Airbus A300, A310, A330 Boeing 757, 767 | 25% |
| | Boeing 747-8 F | Boeing 747 freight versions | 15% |
| | A320 continuous improvement programme | A320 | 5% |
| 2007 | A380 | Boeing 747-400 | 20% |

*** Current forecast for new generation narrowbody aircraft, depending on development of "breakthrough" engine technology.**

In 2006 Airbus flight-tested (see section above) a new "continuous improvement programme" A320 featuring:

- A redesign of the surge-tank inlet
- New shared engine pylon
- A redesigned upper belly fairing
- “Enhanced” cabin interior
- Upgraded CFM “Tech Insertion” package and IAE “V25000Select”.

The company is aiming at 5% fuel efficiency improvements with this package

Meanwhile, according to the 2007 Bombardier annual market forecast for 20-149 seat airliners, from 2007 to 2026, around 11,200 aircraft will be delivered – no fundamental change over the 2006 estimates. Bombardier sees the 100- to 149-seat segment as the largest growth area, with 5,900 deliveries - to 8,400 aircraft by 2026. For the 60- to 99-seat segment, 4,300 aircraft are to be added and 1,000 for the 20- to 59-seaters. The outlook is broadly similar to the forecast of Embraer.

**Table 12: Global airline fleet by aircraft type**

| **Aircraft type** | **Global fleet** |
|---|---|
| Regional jets | 2710 |
| Single aisle aircraft | 10580 |
| Twin aisle | 3070 |
| Boeing 747 | 970 |
| Total | 17330 |

Source: Boeing - http://www.boeing.com/commercial/cmo/pdf/CMO_06.pdf

**Table 13. Emission improvements through re-equipping airline fleets with new aircraft**

| Emission improvements through replacing end-of-life aircraft with new types | Rationale for improvements | Total CO2 saved |
|---|---|---|
| | Around 3.3% to 3.5% of the global airliner fleet is replaced every year, with new aircraft on average 15% more fuel efficient than those they replace; the fleet is renewed more or less every 25 years. The total civil jet operational transport fleet was 17,330 aircraft at the start of 2006 and emitted 610 million tonnes of CO2 in 2006[17]. According to Boeing a single-aisle aircraft emits, on average, 14,600 tonnes of CO2 a year. But the *average* annual emission rate as measured by the high-level estimate of global CO2 emissions (610 million tonnes) divided by the known world fleet (17,330) would produce an average aircraft emission rate of 31,190 tonnes of CO2. Which means either the Boeing estimate is too low or the CO2 emissions by widebody aircraft are of a scale much greater than would commonly be estimated. Annual aircraft replacement numbers of the 17,330 fleet are 572 aircraft. If these are 15% more fuel efficient than the aircraft they replace then the annual CO2 emissions would fall by 2,676,102 tonnes. However, this figure relies on IPCC and AEA data – ironically, if aviation industry data is used (and it would probably be more | A maximum of 2,676,102 tonnes – but more likely to be nearer 1,240,00 tonnes. |

[17] Source: Aviation Environment Federation.

| | | |
|---|---|---|
| | precise, if smaller) potential $CO_2$ savings would be slightly less than half this figure. | |

### 2.5.3 Painting, cleaning and more efficient MRO

Keeping aircraft, engines and systems "clean" improves efficiency and allows the aircraft to fly as close as possible to their original operating cost parameters.

If aircraft are not washed regularly they build up "excrescence drag", additional drag due to the sum of all deviations from a smooth, sealed, external surface. This can account for as much as 4% of overall drag – adding up to 400,000 gallons of fuel (1.5 million litres) a year to the amount used by a Boeing 747.

And during time in the air, pollutants and minute particles of dust build up inside an aircraft engine. This build-up begins to impede the engine's compressors, decreasing efficiency. To counteract such problems, Korean Air has instituted the regular washing of engines with water to maintain the efficiency of compressors and the power of engine outputs. The result has been an elevation in fuel efficiencies by 0.5% and fuel cost savings of approximately KRW3.9 billion, while cutting down on the $CO_2$ emissions.

According to ANA: "The more an engine is used, the more dust particles stick to its compressor and degrade performance. ANA has been regularly washing compressors to maintain high engine performance and to reduce fuel consumption since FY2003. This effort has been extended to most of our aircraft. The amount of fuel saved from this washing in FY2005 was around 6,000 kiloliters - equal to 420 round trips between Tokyo and Osaka on a B777-200. Aiming for an even greater effect in FY2006, we plan to increase the frequency of washing by five times over the previous year."

Meanwhile, Air Canada calculates that by having less paint on the aircraft they could save about US$21,000 a year per aircraft. And Boeing announced in July that the livery of the 787 models would be amended around the engine nacelle inlets. By choosing grey, not only does this reduce the thickness of the paint but also avoids small elements of drag by using a single colour and avoiding paint edges. They estimate this micro change reduces an aircraft's fuel consumption by as much as 30,000 gallons (113,000 litres) a year.

**Table 14. Potential reduction in greenhouse gas emissions from optimised MRO practice, including engine models**

| **Emission improvement potential by cleaning engines regular** | **Rationale for improvements** | **Total CO2 saved** |
|---|---|---|
| | Using a single airline source and then developing this into a fleet-wide generalisation is not an ideal approach to the bottom-up rationale. However, Korean Airlines' experience in regularly washing engine interiors suggest substantial fuel improvements could be possible – especially when other MRO techniques such as improved monitoring of equipment to reduce failures and delays are included. The 0.5% fuel-efficiency improvements noted by KAL following optimised engine maintenance practices is used as baseline to include all MRO improvements. The total CO2 savings are calculating using the Boeing single-aisle 146 tonne CO2 measure for emission improvement rates from a 1% fuel saving, across the | 1,265,090 fewer tonnes of CO2, potentially possible across the fleet. However the timescale for introducing these new measures is unfixed. |

| | | |
|---|---|---|
| | fleet. | |

### 2.5.4 Better flight planning

According to an ATA study, better flight planning allows airlines to more closely match predicted fuel burn with the routes planned – thus cutting the need for carrying large quantities of spare fuel. ATA estimates 200,000 tonnes of extra fuel were carried by US airlines in 2005 as a result of delays in the airport/ATM infrastructure.

However, a new generation of electronic flight briefing systems has been developed in the last few years which has radically changed the way aircraft are prepared for flight.

Chief among these is the development of the Electronic Flight Bag (EFB) which has started to replace the bundle of navigation charts, logbooks, and manuals carried by pilots.

**Improvements in flight and fuel planning**

- Reducing flight time by one minute on each flight can equate to savings of more than US$2 billion annually
- As a rule of thumb, every extra pound of weight burns approximately 3% more fuel per hour of flight time
- By using ideal-trim tools and loading aircraft to the optimised centre of gravity, airlines can potentially reduce fuel costs by .03 % to .05 %.
- For an airline spending US$100 million in fuel, a 0.5 % improvement in fuel costs is worth US$500,000. When considering that most fuel conservation programmes can be improved and tuned to produce well over 2 % improvement in fuel, this is worth US$2 million in annual savings.

Source: Sabre Airline Solutions

The EFB integrates all the paperwork above with a weight-and-balance calculator that allows pilots to calculate the ideal speeds and engine setting for an aircraft instantly, in any weather, on any runway, with any payload. According to some estimates [18] savings associated with digitising and integrating this information are as much as 9,000 kg for a single Boeing 777 operation.

[18] Source http://www.asiatraveltips.com/travelnews03/1610Boeing777.shtml

Estimates for the new Class III EFB put annual fuel savings of 308,000 lb for a Boeing 777 on trans-Atlantic operations[19]. Without the EFB, a single 777-200ER flight requires 77 lb of paper.

Efficency savings come from these key areas[20]:

- En-route convective reroute reduction – fuel and block time
- Fuel savings from elimination of flight bag weight
- Communications savings from transactional-based data reduction
- Elimination of paper distribution
- Savings in maintenance of electronic updates vs. manual loading.

Further, EFBs allows for the more precise optimal control of the aircraft's centre of gravity (4% aft for less drag) According to ANA: "In general, the fuel saving of about 0.05% can be expected once the centre of gravity moves backward by 1%."

By integrating the EFB within an aircraft's flight management system, a new way of dynamically plotting the safest and most environmentally-friendly routings will soon become available. For example, parcels carrier UPS plans to integrate an automatic dependent surveillance-broadcast (ADS-B) system (see next section) that incorporates a "merging and spacing" tool into its FMS/EFB architecture. When two aircraft are on the approach path to an airport it will allow the following to determine the lead aircraft's speed changes and automatically calculate the appropriate speed changes for the pilot in the trailing aircraft. This means better speed management and fuel efficiency. UPS is working with ACSS of Phoenix, Ariz., to develop the "SafeRoute™" concept.

Using manual charts means that take-off and landing calculations have to be conservative, often based on early dispatch weight and balance information which adds delay and cost to each flight. A current-technology airliner burns around 3-4% of the weight of additional fuel carried per hour of flight; on a seven-hour transatlantic flight, an aircraft boarding 5,000kg of extra fuel will burn 1,300kg of that fuel simply to carry it. "That costly situation is exacerbated still further on longer flights, with the same aircraft flying a 14-hour leg burning more than half the additional fuel merely to carry the fuel weight," according to SITA.

The benefits of optimising engine settings for environmental improvement are considerable. According to Croatia Airlines: "Procedures are used to lower the aircraft engine power levels at take-off wherever it is possible to do so, thus extending the useful life of the engine while at the same time saving fuel and

[19] Source: www.globalepoint.com

[20] Source: http://spacecom.grc.nasa.gov/icnsconf/docs/2004/13_session_c5/C5-05-Burns.pdf

reducing CO2 emissions up to 25%. The effect achieved is considerable, since such procedures are followed in 95% of take-offs within the company flight network. Operating procedures lowering the level of noise at landing, which also result in fuel savings and CO2 emission reductions, are followed in most domestic and foreign airports, i.e. wherever it is possible to do so."

The EFB allows for far faster and more accurate calculations of weight, routings and balance, resulting in lower thrust ratings. The latest generations of EFBs integrate aircraft positioning data with airport traffic maps, which improves situational awareness. It will mean new environmental improvement software – such as "brake to vacate" [21] concepts – can be integrated automatically into aircraft systems.

For the moment the key is to determine the optimum fuel load to take account of dynamic weather patterns and safety minima performance levels.

"But determining the optimum route that minimises fuel consumption, en-route charges and time related costs – while maximising operational efficiency and passenger service – entails an almost impossibly convoluted set of considerations and calculations which could soon also include potential penalties linked to excessive emissions….Sophisticated new flight-planning systems capable of juggling this ever-changing range of variables – least-cost routing, aircraft performance characteristics, weather and navigation data, fuel tankering, overflight charges, the cost of delays, ATC flow restrictions and much more – can help significantly decrease the total cost associated with each route flown," according to SITA, which recently conducted a comparison study to demonstrate the benefits of optimisation. "Comparing just eight fixed daily short-haul sectors against full optimisation on route choice, flight level and speed, SITA's flight planning software generated fuel savings of some US$ 500,000 per year."

ANA developed a new contingency fuel method (load 5% fuel instead of 8.5% reserves) and saved sometimes 3,000lb of fuel on a single international flight. [22]

As a way to calculate the most efficient fuel-loads on any given route – and to match that with the economics of fuel prices and overflight charges - Fuel Cost Index software is also now available which describes the ratio of the cost

[21] The Brake-to-Vacate concept from Airbus is aimed at reducing the amount of time an aircraft remains on the runway and ensuring that energy-heavy operations such as reverse thrust can be optimised. The software enables pilots to select a runway exit while the aircraft is making its landing approach and uses the auto-flight, flight controls, and auto-brake systems to regulate deceleration after touchdown. This allows the aircraft to reach a specified exit at the correct speed under optimum conditions. The system will be offered as an option on all A380s by 2007, according to Airbus and will be followed by retrofits available on all of other Airbus aircraft.

[22] Source: http://www.ana.co.jp/eng/aboutana/anaenvironment/2_3_tousya_2.html

of time (flight crews, aircraft, time-based maintenance and so on) over the cost of fuel.

SITA's Cost Index software dynamically calculates lateral and vertical profile optimisation against weather characteristics at each waypoint. "Comparing a B747-400 long-range cruise flight plan with an equivalent Cost Index-based plan over an 11-hour 45-minute Heathrow-to-Kuala Lumpur sector, total savings (time and fuel) were shown to be US$ 425. Calculate that saving over four sectors per day (including return leg), spread over a one-year period, and total savings amount to US$ 650,000."

The calculations are complex because fuel price varies from location to location; the software calculates the most cost-effective aircraft management solution and this may involve taking on board extra fuel from a location where the price is cheaper – which may sometimes add to the environmental burden, not decrease it. At the same time, greater accuracies can result in major fuel savings: "As an example, on a long-range flight where 100 tonnes of fuel is consumed, a 1% error in planned fuel burn can mean carrying one tonne of unnecessary fuel," says SITA.

### 2.5.5. Optimised aircraft and crew management

Other software tools developed to closely match aircraft schedules to aircraft types also produce secondary benefits of an environmental natures. By integrating operations, management, schedules and rostering within a single software system fleet assignment models (FAM) can limit the number of fleet types serving each airport in the schedule. As yet, however, there has been little work to quantify the savings in fuel use by the application of these tools.

**Table 15. Potential reduction in greenhouse gas emissions from optimised fuel-planning and more accurate flight briefings**

| **Emission improvement potential by the use of more accurate and lighter flight planning tools** | **Rationale for improvements** | **Total CO2 saved** |
|---|---|---|
| | EFB use is slowing growing throughout the world's airline fleet. Current equipage rates are at around 1,000 aircraft a year (new and retrofits), mainly in the long-haul sectors where fuel savings and route optimisation benefits offer the clearest cost-benefits. Using the Boeing 777 as the benchmark (140 tonnes saved annually on a transatlantic operation) this would generate potential savings of 140,000 tonnes of weight, equating to 441,000 tonnes of savings in CO2 emissions a year. However, the Boeing 777 is, on average, slightly larger than the mean twin-aisle types and the claims for savings are likely to be in the upper end of the performance envelope. A reduction in potential benefits has therefore been made. | 350, 000 tonnes of CO2 a year |

### 2.5.6 Flying at optimum altitudes and more slowly

Flying aircraft at speeds and heights optimised for environmental efficiencies will require a judgement of balance. There may be alternatives to the current cruise flight levels; flying higher increases the potential for water vapour emissions and contrail formation. Flying lower may reduced NOx impact but increase fuel burn and CO2 emissions up to 6%; but this could be compensated by a reduction in aircraft speed.

The optimum flight altitude is determined by the aircraft's weight, but many flights cannot fly at the "best" altitude due to air traffic restrictions. However, with the airspace distance set at every 1,000 feet instead of the former 2,000 feet, with the introduction of reduced vertical separation minima (see next section) the possibility of aircraft flying at the best altitude has increased greatly. RVSM has already been applied to flights over the Pacific Ocean and the South China Sea, and plans are being made to expand the application to flights over Japan, Korea and Russia in the near future. [23]

However, other en-route operations are also being researched for fuel efficiencies.

According to the Science and Technology Sub-Group of the UK's Royal Aeronautical Society, in its 2005 "Greener by Design Study":

"If migrating geese and swans fly in V formation to reduce fuel burn, why shouldn't transport aircraft do likewise? The NASA Autonomous Flight Formation project, which is addressing this question at the Dryden Flight Research Center, has demonstrated automatic close formation flying of two F-18 combat aircraft using GPS to provide positional information. Early results suggested savings in fuel burn of up to 10% might be achievable by formation flying.

"The benefit from formation flying comes from the following aircraft flying in the upwash generated by the outer half of the wingtip vortex from the aircraft ahead. NASA has pointed out that, as proved in Munk's theorem of 1923, aircraft do not have to be in tight formation to exploit this effect, although in practice the follower needs to be not more than a few wingspans behind the leader to avoid the vortices, as they age, becoming unstable and breaking into loops.

"The Sub-Group does not see the need for a programme in Europe to duplicate the work at NASA but an independent aerodynamic and environmental assessment of the potential gains from formation flying by current swept-winged configurations should be considered. As with air-to-air refuelling there are serious questions in handling safely the interaction between aircraft. If we look far enough into the future, however, there is clearly the potential to overcome these by automatic flight control using spatial positional information from GPS. The formations need not be regimented, but simply a co-operative activity of companions joining up along the way, not necessarily from the same starting point or with the same destination; instead of striving to keep aircraft well apart, the ATM problem could be reduced by dealing with formations rather than single aircraft. If air travel is to increase

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[23] http://www.jal.com/en/environment/report/2003/pdf/s3_1.pdf

threefold over the coming years, such an arrangement might become a way of making the skies less, rather than more, hazardous.”

For the moment, the study authors suggest more work will be required on altitude/speed operations before quantifiable improvements in $CO_2$ burn can be established.

### 2.5.7 Reducing weight in the cabin

In 2004 Alaskan Airlines found that  removing just five magazines per aircraft could save US$ 10,000 a year in fuel costs. However, for airlines – who compete fiercely on in-flight comfort and safety – the benefits of lightening the load of passenger service and comfort equipment has to be carefully balanced with requirement to fill empty seats in the first place.

Refitting aircraft interiors with lighter, but stronger, structures, equipment and materials can generate substantial fuel improvements. According to IATA, for every kilogram of weight that is removed from a single-aisle plane, approximately US$372/year is saved in fuel costs.

Over the last few years there have been substantial improvements in the development of new ranges of stronger but lighter composite materials for aircraft interiors. In particular, technical laminates and honeycomb panels have become extremely important for the aircraft industry as weight reduction increases efficiency and reduces operating costs.

According to Dale Brosius of Brosius Management Consulting (Brighton, Mich.) the current total annual prepreg (or composite) usage for aircraft interiors, new and aftermarket combined, stands at about 13 million lb (6,000 metric tonnes). Modern interior composites are becoming lighter – and as airlines can often refit interior cabins at least once in an aircraft’s 20 (plus)-year life these can often be an important opportunity to save weight. For example, GE Plastics’ latest Ultem** PEI flame-retardant resin, for example, features moulded-in-colour which helps reduce the approximately 5 kg of paint in cabins, while reducing part weight by 5%-15 % via thinner walls, according to the company.

Traditionally, interior moulded structures are made from Nomex honeycomb core approximately 0.5-inch/13mm thick, with a 0.12-inch/3 mm cell size, or “crush core” as used mainly by Boeing and Airbus and their main tier one interiors suppliers. But manufacturers and aircraft operators are putting increasing pressure on interior suppliers to develop lighter alternatives. For example, the Airbus A380 features an“ultra-lightweight” baggage stow bin for the Airbus A380 from AIM Group made from tubular-cored thermoplastic panels. Suppliers are experimenting with replacing interior parts still made from aluminum - seat rails and brackets – with composite structures.

The M.C. Gill Corporation – a major supplier of aircraft interior floors – has recently introduced its next-generation structural core - GillcoreTHK Kevlar©

reinforced phenolic honeycomb. According to Irv Freund, vice-president sales and marketing, the new materials have “typical weight savings of 20-45% as compared to Nomex and other core materials.”

And Lonseal’s new range of aviation non-textile flooring (NTF) “Loncoin II Featherweight” is more than 30% lighter than the original Loncoin II NTF, says the company.

Apart from structures, the interiors market encompasses: panels, galleys, toilets, seats, luggage bins, in-flight entertainment and communications systems.

Lighter seating has lead to some dramatic increases in efficiencies. For example, by fitting new Recaro “Slimline” seats on its A320s, Finnair will increase its capacity on European and domestic routes by 5% while cutting the overall weight of the A320 by 850kg, lowering CO2 emissions by nearly 10%. Virgin Atlantic is introducing a composite seat-back to its current Contour/Reynard Aviation seats.

“Introducing a composite seat-back enabled us to make the seat much lighter, and although we’ve added leather to it, on an entire shipset we’ve managed to make a 70kg saving,” reckons Paul Edwards, senior design manager at Virgin Atlantic. “We’ve also managed to reduce the number of seat components by about 25%.” All aircraft flying out of London/Heathrow will be reconfigured by the end of 2007, with aircraft operating out of London/Gatwick finished in early-2008.

According to ANA: “Since October 2005, we have been introducing in domestic economy class new lighter-weight seats made of carbon-fibre reinforced plastic instead of the conventional aluminium alloy, resulting in an annual saving of 200 fuel drums per B777-200 And in October 2006, we introduced 200 new containers made mainly of Kevlar©, some 28% lighter than conventional types, mainly on the Tokyo-San Francisco route. Using these lighter containers saves approximately 2.5 fuel drums each way on this route.”

All major seat manufacturers are looking at weight reduction programmes for their next generation of aircraft seats – or offering lighter updates to existing models. For example, Sicma Aero Seat now offers an upgrade package to its Silverwing II range which features a reduced weight and integrated IFE module. Sicma’s new business-class seat, SKYnest, offers a full range of motion but is driven by only one actuator.

Not just structures, but the weight of seat coverings can be reduced. E-Leather Ltd’s new leather/ textile fibre “is around 33% lighter than normal leather; typically 500g/m2 compared to leather upholstery at 850g/m2,” says the company. “For an aircraft with 165 seats, a typical loading reduction of 181kg can be achieved.”

New galley technology is also driving down aircraft weight: B/E's induction oven cuts previous heating times of 20 minutes in half, preparing meals in just 8 to 10 minutes. "This enables the airline to reduce the number of ovens required on board by about 40%, while maintaining the same onboard efficiency, saving cost, weight and valuable galley space," said the company.

And new aircraft will feature increasingly smart IFE systems – though they are unlikely to go wireless until after 2010. ANA' Panasonic's eX2 IFE system for its first Boeing 787 is smaller and lighter than Panasonic's current System 3000i, offering up to a 30% reduction in weight.

**Table 16: Reducing cabin interior weights**

| **Emission improvement potential by fitting lighter seats, less galley equipment and using lighter materials** | **Rationale for improvements** | **Total CO2 saved** |
|---|---|---|
| | Finnair's experience of fitting new lightweight seats has demonstrated a 5% increase in capacity while cutting the overall weight of the A320 by 850kg, while lowering CO2 emissions by nearly 10%. If this were replicated across the entire single aisle world fleet it would save a potential 850,000 tonnes in weight and lead to a cut in CO2 emissions of 14,600,000 tonnes. This does not take into account further weight savings possible from using lighter materials, or adapting this to widebody fleets, or factoring in the frequency of interior updates to exploit new lightweight | 5,840,000 tonnes of CO2 saved a year. |

| | | |
|---|---|---|
| | interior products and materials. The Finnair experience is likely to be at the upper end of what is possible – but this is an area where airlines can make substantial weight savings, though at a high investment cost. The CO2 savings have been based on calculations of fitting 800 aircraft a year – of all sizes - with interiors 425 kg lighter than currently in operation, producing a 5% improvement in CO2 emissions. | |

## 2.6 Airports – managing emissions during taxiing and operations in and around the airport

### 2.6.1 Introduction

The airport environmental footprint has three major sources:

- Aircraft operating into, out of and within the airport area
- Airport ramp, car park and terminal operations
- Vehicles transporting people and freight into the airport area.

This report is focused on the impact of aircraft emissions on the build-up of greenhouse gases in the atmosphere and therefore focuses on the issue of limiting aircraft emissions, via the main engines and APU, on the ground. Take-off and landing emissions are covered in the next section.

In general, when aircraft are idling and taxiing, the emissions footprint will be dominated by CO and HC; during the take-off phase and climbing, the emissions are dominated by NOx. However, again in general, the greenhouse gas emissions of aircraft tend to be overshadowed at large airports by other ground traffic. A study at Munich Airport showed that air pollution for the residential areas in the vicinity of the airport (30 x 30 km) differed greatly in relation to road (motorway) and air traffic (as well as being dependent upon location and weather conditions). While the air pollution in the vicinity of a motorway junction is almost exclusively caused by road traffic, other locations are influenced to a much greater extent by aircraft exhaust gases. Aircraft emissions were dominant at some locations, during the prevailing wind, even though the mean value of aircraft emissions was lower than that for motor vehicles in the area. Meanwhile, a recent study at London/Heathrow airport showed that aircraft contributed between 16% and 35% of ground level NOx concentrations

"Aviation contributes to local air pollution in many ways: aircraft account for the largest proportion of emissions from internal airport sources; although this is exceeded by emissions from road transport when airport and background levels are included together," according to the Aviation Environment Federation.

Despite the increasing concentration of aircraft at busy hubs, airports and airlines can take a number of measures to mitigate the impact of aircraft greenhouse gas emissions.

According to Continental Airlines (see appendix one):

"At our Houston hub, we have been using electric ground equipment since 2002 and we will have reduced our emissions from ground equipment approximately 75 % by the end of 2007. We have begun a cold-weather test of this electric ground equipment at our New York/Newark hub. We are also testing the use of alternative fuel and fuel additives for ground service equipment."

### 2.6.2 Taxiing alternatives

Moving the aircraft from the gate to the runway, from the runway to the gate or to service areas, consumes considerable amounts of fuel. Manoeuvring an aircraft around a large airport they may constitute, *in extremis*, 20-33% of the time of an average airline flight[24]

Airlines have for some years been trialling one-engine taxiing. The practice is in use today, particularly in the US, but could be more widespread. Pilots will need additional training.

According to ANA (see appendix one): "To help save fuel, ANA has been stopping some engines while taxiing on runways since 1994. The decision of whether or not to shut down engines is made by the captain and based on the airport, weather, taxiway and aircraft conditions, and instructions from the control tower. Fuel thus saved in FY2005 is estimated to be around 1,800 kilolitres, which equals the amount of fuel required for a B777-200 to make 125 round trips between Tokyo and Osaka."

New ways of using aircraft tugs (preferably electrically- or biofuel-powered) to move aircraft around the ramp, rather than under the aircraft's own power, are

[24] Source: Delos Aerospace

undergoing evaluation. FMG, the Munich airport operating company, will be switching more than a third of its apron ground services fleet over to biodiesel.

In December 2006 Virgin began testing a “starting grid” concept, a holding area, close to a runway, consisting of several parking bays for aircraft. It means that aircraft can be towed closer to a runway before take-off, substantially reducing the time that engines need to be running. An aircraft would only need to start its engines once on the grid, about 10 minutes before take-off. The test trials, at both London's Heathrow and Gatwick airports, took place throughout December on a series of Virgin Atlantic Boeing 747-400 departures. Virgin Atlantic is working alongside BAA and NATS during the trials, which are aimed at validating the operational procedures needed for starting grids so that they can become commonplace. A longer, more detailed trial is then expected to take place in 2007. Teams from Virgin Atlantic are also holding talks with the international airports in San Francisco and Los Angeles, as well as JFK in New York, about the timing of similar trials.

Other possible new technologies include wheel-mounted electric motors for taxiing that eliminate the need for jet engine-powered manoeuvres around the airport aprons and taxiways. For example, in March 2007 Delos Aerospace launched an in-wheel electric motor/generator concept “capable of producing sufficient power density to effectively manoeuvre aircraft of any weight on the ground…a total systems integration of a fully-electric landing gear and manoeuvring system wherein axial flux disk motor/generators replace the old friction disk technology, providing increased braking and manoeuvring capability to the aircraft wherein there are many engineering benefits to eliminating the heat generated within friction based braking systems.

“This…method allows for higher levels of effective braking and manoeuvering capability and reduces the required fuel weight by 1200lb for average airline flight times of 60-90 minutes and over 4,000lb for larger airliners that might fly out of LaGuardia Airport,” says the company.

Meanwhile, Delta Airlines is partnering with Chorus Motors to build a production electric wheel drive for ground-manoeuvring, for the airline’s Boeing 737s. Regulatory approval is being sought in 2009. Chorus is reported [25] as saying the target weight for the unit is between 90kg-110kg.

The development of a new generation of towbarless, high-speed aircraft tugs – some of them powered by batteries – has opened the potential for developing these operations further. Long-range tugs will still have to rely on diesel/LPG/petrol engines – though perhaps adapted to take synthetic fuels. Electric tugs can be more usefully used for push-back operations; Stockholm Arlanda 2 is the world’s first all-electric ramp handling airport terminal. But using these methods will require a radical change to the way airports operate, giving airlines much less control over their ramp operations, slowing down aircraft movements on the ground, with a commensurate loss of flexibility and capacity.

[25] *Flight International*, 10-16 April 2007

Quantifying the potential benefits of improved taxiing operations is complex , as airport operations differ widely in size and scope. In relatively congested airfields the operation of high-speed tugs could cut down capacity as the time need to hook and unhook the aircraft from the tug, plus resources required for the safe management of the operation, could add to the environmental burden, rather than decrease it, as it would incur new delays. The use of electric motors to power the aircraft on the airport apron could only be viable if their size and weight can be clearly seen to be less than the fuel burn required to carry them.

However, the potential for these technologies at appropriate locations – and the current single-engine taxiing operations – offer some major potential savings in CO2 emissions which will need further research.

**Table 17. Potential reduction in greenhouse gas emissions from more efficient taxiing operations**

| Emission improvement potential by improving taxiing operations | Rationale for improvements | Total CO2 saved |
|---|---|---|
| Taxiing with fewer engines than used for flight, using new, electric taxiing motors located on the aircraft's under-carriage, using high-speed tugs. | According to Delos using electric motors located on the undercarriage reduce the required fuel weight by 1200lb (540 kg) for average airline flight times of 60-90 minutes and over 4,000lb (2025 kg) for larger airliners. However, these figures seem at the outer limit of expectations for such technology – as the weight of the units has yet to be clearly defined and airport ramps differ widely in size. If the "bottom-up" analysis approach is taken, airlines can be estimated as expending around 5% of their fuel use on airport taxiing operations. This | Potential new benefit of up to 62,050,000 fewer tonnes of CO2 emissions a year – at an annual delivery rate of 6,205,000 tonnes of fewer CO2 emissions per year (2007-2016). |

| | | |
|---|---|---|
| | equates to the production of 7300 tonnes of $CO_2$ per single aisle aircraft (using the Boeing 737 emission baseline) a year. Alternate taxiing operations could cut this by half, resulting in a potential average saving of 3650 tonnes of $CO_2$ per aircraft, per year. Multiplied to the world fleet, this would equate to a potential saving of over 62,050,000 tonnes of $CO_2$ a year. | |

### 2.6.3 APU alternatives

One major source of greenhouse gas emissions at airports is the aircraft's auxiliary power unit (APU), which powers the aircraft's electrical systems on the ground, when the aircraft's engines are turned off.

There are alternatives to APUs – diesel or LPG- powered ground power units (GPUs), mobile generators which attach the aircraft at the terminal gate – and frequency converters which convert main electrical supplies to the aircraft's 400Hz frequency.

According to ANA: "As an environmental preservation measure, ANA has been attempting to prioritise the use of GPUs and curb the use of APUs since 1990. An APU is a small on-board generator that provides electricity as well as pneumatic pressure for engine ignition and cabin air conditioning. APUs are less energy efficient than GPUs as they burn onboard fuel; we thus decided to use GPUs to a greater extent. In comparing the two, we found that by not using APUs we saved 33,000 kilolitres, or 160,000 barrels of fuel, in FY2005. This equals the amount of fuel needed for 2,300 round trips between Tokyo and Osaka by a B777-200."

Using an APU gives the pilot more control over ground operations than having to rely on ground-handling companies. But there is a cost to this – most notably in the amount of fuel used to power the APU. According to a much-quoted Aviation Systems Inc study, based on the operation for one year of a

Boeing 747-200 with one turnround per day of 1.5 hours duration, the cost of powering a GPU is considerably less than that of an APU.

**Table 18. APU v GPU fuel consumption comparisons**

| | |
|---|---|
| All APU Operation | Consumption 69,992 US gals |
| GPU | Consumption 3,888 US gals |
| (plus GPU diesel fuel 2,500 US gals) | |

*Source: Aviation Systems Inc*

Extensive use of the APU also means the unit is subject to the rigours of the aircraft maintenance regime, which is necessarily more severe than the regime for ground support equipment.

Frequency converters can be fixed or mobile and are usually solid state and require input from the mains electrical supply either in the hangar, on the ramp or beneath the passenger boarding bridge at the terminal gate. Although the frequency converter offers the most environmentally "clean" supply of electrical power at an airport apron, its use has not been as widespread as at once predicted, mainly as a result of low-cost airline operations; low-cost carriers tend to avoid expensive boarding-bridge equipped terminals and the onus on a fast turn-around, requiring flexibility of movement, underlines the convenience of the on-board system.

A further study by Aviation Systems Inc at Amsterdam/Schiphol involved 322 aircraft turnrounds over a 24-hour period, measuring the continuous use of the APU compared against other power sources. When other power sources were used, the APU was turned on just five minutes before the main engines were started.

**Table 19. APU emission rates**

| Emissions | Full APU operation | Restricted APU operation |
|---|---|---|
| Hydrocarbons lb/pa | 52,010 | 2,104 |
| Nitrogen Oxide lb/pa | 474,244 | 18,516 |
| Carbon Monoxide lb/pa | 928,908 | 37,233 |

Source: Aviation Systems Inc

The conclusions of the study were that unrestricted APU operations generate a total of around 650 tonnes of greenhouse gases and particulate matter each year - or about 10% of the total emissions from main engines of the same fleet, according to some estimates.

However, not all airports and handling agents currently supply sufficiently reliable and flexible power source alternatives to APUs.

**Table 20. Potential reduction in greenhouse gas emissions through minimising APU use**

| **Emission improvement potential by minimising APU use** | **Rationale for improvements** | **Total CO2 saved** |
|---|---|---|
| Using GPUs and frequency converters at airports, rather than the aircraft's APU. | Up to 10% of an airlines' fuel bill can be saved through this measures, according to Aviation Systems Inc. However, this figure is highly dependent on the airline fleet operation and the availability of fixed and mobile ground power units at airports. A more realistic figure based on an airline's (ANA) own reports suggest potential savings of 1% to 2% on the annual airline fuel bill are possible. | Potential savings of 6.1-million CO2 emissions over 10 years possible – or 610,000 tonnes of CO2 saved a year. |

## 2.7 Air traffic management – providing more environmentally friendly routings

### 2.7.1 Introduction

With no major new "green" technology breakthrough, which could be widely and cheaply disseminated, expected within the next five years, the aviation industry is going to have to rely on using the current generation of aircraft and engines in a more efficient way. This is putting the spotlight on air traffic management systems to provide more direct routings, or more flexible routings, to save time, fuel burn and CO2 emissions in the air.

In 2006, IATA's fuel-saving "Go-Teams" completed 42 visits and identified a total fuel saving potential of $83 billion among IATA member airlines through route and TMA, infrastructure and operational efficiency improvements.

According to the study *Recommendations to the Nation on Reducing U.S. Oil Dependence* (December 2006) (http://www.secureenergy.org/reports/ESLC_Oil_Report.pdf) published by the Energy Security Leadership Council , 0.4 million barrels of oil a day could be saved by requiring the Federal Aviation Administration (FAA) to implement improvements to commercial air traffic routings to increase safety and decrease fuel consumption.

"Airlines invest enormous amounts of money for avionics and on-board systems designed to integrate with the air traffic system," according to IATA's CEO Giovanni Bisignani, speaking in April 2007. "On a single aircraft, this could be up to US$5 million. But we are not making full use of their capabilities because air traffic management is a patchwork of different plans, strategies, capabilities and technologies. So when we fly from one provider to another we are forced to operate at the lowest common denominator with maximum spacing between aircraft. Letting aircraft operate more independently of ground infrastructure is safe, efficient and cost effective…The UN estimates that there is a 12% inefficiency in air traffic management. That means 73 million tonnes of unnecessary CO2 emissions. What needs to be done? The list is long: make a Single European Sky a reality, fix the Pearl River Delta, upgrade the overloaded US ATM system or simply eliminate delays wherever they exist. And solutions are possible. *Last year alone IATA's work on over 300 routes resulted in up to 15 million tonnes of CO2 savings.* But there is much more that needs to be done."

(Editor's italics)

So the potential for near-term savings are enormous.

This was recognised by the IPCC Special Report on Aviation and Global Atmosphere (1999), which concluded: "As the aviation industry grows more and more rapidly, the impact of air traffic operations on the global atmosphere becomes increasingly important. Efforts to control or reduce the environmental impact of air traffic have identified a range of options that might reduce the impact of aviation emissions. In particular, it is expected that improvements in air traffic management (ATM) and other enhanced operational procedures for air traffic systems could help reduce aviation fuel burn, and thereby reduce the levels of aviation emissions."

Unfortunately, decisions on improving the current network of routes are shared between governments, international agencies and national air navigation service providers (ANSPs) and agreement is difficult given the complexities of national sovereignty and defence interests which have to be taken into account. In areas of fairly low population density such as Australasia and the Pacific, route networks have been realigned to provide more flexible airway operations. But in the core traffic-intensive areas of Western Europe, providing a more flexible airways system so aircraft can plot their own routes based purely on optimal environmental and fuel-efficient operations remains a frustrating challenge.

According to the Eurocontrol Performance Review Commission (PRC) report on calendar year 2006 (PRR 2006), European ATC service providers could be able to save an estimated 2.3 million tonnes of $CO_2$ emissions between 2007 and 2010 by introducing more efficient routings - the equivalent of 5,500 flights around the earth or around 5.9% of the average European trip distance.

According to the report every flight travels nearly 50km further through the air than it needs to reach its destination, the PRC reports. ATC-caused delay has risen for the third successive year, says Eurocontrol; en-route delay is running at 1.1min per flight and when delays to air traffic flow management (ATFM) caused by aircraft management on the ground at airports is added into the equation, the PRC reports, the total ATM-caused delay is 1.9min.

ATM improvements come in a number of different areas:

- Airspace redesign – a mainly State responsibility to reconfigure airspace to increase capacity, improve safety, integrate military traffic and lessen environmental impact. The Single European Sky (see later) involves the complete redesign of European airspace architecture around function airspace blocks (to match sector sizes with traffic levels) rather than national boundaries. IATA's work in this area (see above) to shorten routes or make it possible for aircraft to fly their own optimised profiles is currently delivering 15 million tonnes of $CO_2$ savings, according to IATA's CEO (see above).
- Development of more accurate systems and procedures (in the realms of communications, navigation and surveillance) to more accurately manage traffic, increasing capacity, safety and environmental responsiveness.

### 2.7.2 Redesigning airspace to optimise aircraft efficiencies

The potential for aircraft efficiency improvements through the introduction of new ATM procedures and equipment has been demonstrated by the introduction of reduced vertical separation minima (RVSM) in Europe, North America and elsewhere.

This has effectively led to doubling the number of usable altitudes between 29,000 and 41,000 feet. In the US, Domestic Reduced Vertical Separation Minima (DRVSM) procedures implemented in 2005 are believed to have saved 500 million gallons of jet fuel in their first year alone, equivalent to nearly 12 million barrels…That is over 2% of all the jet fuel consumed by US commercial carriers.

RVSM was introduced in January 2002 within Europe. According to a recent Eurocontrol study on the environmental impact of RVSM:

"Six months later, with RVSM firmly bedded in, the decreases in fuel burnt and directly proportional emissions were in the range 1.6-2.3%. The reduction in nitrogen oxide was in the range 0.7-1%. Average fuel savings per flight are estimated at 17-37kg, representing potential fuel savings of 310,000 tonnes annually. These results can be compared to shutting down all intra-European air traffic for four days (100,000 flights), or removing 5,600 transatlantic flights from the annual schedules. In RVSM airspace, savings were even greater, at 5% for fuel and associated emissions (water vapour, CO2 and sulphur dioxide), and up to 4.5% for NOx. As a side effect, fuel burnt below the RVSM altitudes, i.e. between FL200 and FL270, has also decreased, indicating that RVSM has also improved flight efficiency in the lower airspace."

The report concluded: "The average fuel and emissions reductions achieved through RVSM are greater than first estimated, go a long way towards meeting the objective of a 6-12% reduction first proposed by the IPCC and demonstrate that ATM can contribute significantly to minimising aviation's climate change impact."

RVSM gives pilots greater opportunity to fly fuel-optimised routes by offering a greater number of alternative altitudes. Allowing aircraft to dynamically alter their altitude and course in response to prevailing weather conditions are key attributes of the strategic Single European Sky ATM Research programme (SESAR) and US Next Generation Air Transportation System (NGATS) airspace improvement programmes.

SESAR envisages:
* A three-fold capacity increase to reduce delays on the ground and in the air
* A 10-fold improvement in safety performance
* A 10% reduction in the environmental impact of flights
* A 50% reduction in the cost of ATM services to airspace users.

But these are targeted for 2020.

The recent decision by Indonesia to trial an ADS-B surveillance system based on regional, rather than national, procedures is a significant example of how the future trans-national ATM system might work. The trial will demonstrate the effectiveness of enhancing surveillance across international Flight Information Region boundaries, aiming to reduce delays and increase capacity. Once flights are managed on a regional, rather than a national, basis then the effectiveness of the environmental protection elements in programmes such as shared civil/military airspace, collaborative decision making between ANSPs and their aircraft operator customers, integration of airports into the overall traffic management programmes rises exponentially.

According to the Civil Air Navigation Services Organisation (CANSO), the trade association of air navigation service providers (ANSPs):

"The opening of new polar routes into Russian airspace has allowed aircraft to fly routes that are much shorter and more fuel efficient than previously; a New York to Hong Kong flight routed over the artic will save five hours of flight time

"Airservices Australia's 'flextracks' programme enables aircraft to use the prevailing jet-stream conditions to fly more efficient routes; one airline calculated it had saved 8408 kg of fuel and 43 minutes of flying on a single service between the Middle East and Australia by diverting from the straight path to hitch a ride on the high-speed jet-streams.

“Even quite small changes to airspace design can have substantial environmental benefits. In the North Atlantic Track (NAT) Random Route Westbound initiative the FAA is participating with NavCanada in a new procedure that allows aircraft to transition off the NAT structure and onto a customer preferred flight path. As a result aircraft will save an estimated three to five minutes of flight time per flight.

“On 24 November 2005 Sweden’s LFV introduced a double flight route over the Baltic Sea for traffic between Europe and Asia. The flight route for Far East traffic means flight paths will be about 10-15 km shorter compared than previously; over a year this equates to about 390 000 km, saving airlines about SEK 40 million annually in fuel bills.”

### 2.7.3 The next major ATM efficiency improvement programmes

**RNAV and RNP – more accurate navigation**

The next big fuel saving programmes in ATM centre around concepts such RNAV (Area Navigation) and RNP procedures into airports. RNAV (Area Navigation) is a procedure for aircraft to navigate the designated flight route by radio-guidance facilities such as DME (Distance Measuring Equipment) and satellites. It allows aircraft to improve the efficiency of climbs, descents, and other movements by supplementing ground navigation information with GPS data and computer analysis, will also yield substantial efficiencies upon full implementation.

According to ANA: “Not only does RNAV enable faster and shorter flights while reducing fuel consumption and engine exhaust, it also reduces noise around airports during the night. RNAV was employed for the arrival route to Hakodate, Itami, Takamatsu, Fukuoka, and Kagoshima airports. The amount of fuel saved from the shortened path to those five airports is 1,700 kilolitres annually. This equals the amount of fuel needed for 120 round trips between Tokyo and Osaka by a B777-200. ANA will make further efforts to expand the use of RNAV in Japan and abroad.”

RNAV is just one concept in a new generation of improving ATM procedures to optimise the aircraft’s own highly accurate on-board navigation and communications systems to calculate and fly the safest most fuel-efficient routes possible. These means adapting the aircraft’s flight profile to the accuracy of the systems on board. There are three elements to this: required navigation performance (RNP); required surveillance performance (RSP); and required communications performance (RCP).

Together, they will allow ATM system operators to deliver more direct routings while increasing the number of aircraft in each sector, cutting delays and unnecessary fuel burn.

RNP allows for precise lateral and vertical navigation, under autopilot control, to keep the aircraft within very tightly defined paths. ICAO defines RNP as “a statement of the navigation performance accuracy necessary for operation within a defined airspace.” RSP and RCP requirements will mean developing standards to exploit advanced on-board equipment, such as Automatic Dependent Surveillance Broadcast, Mode S, Traffic Collision Avoidance System and, possibly, merging and spacing and similar self-separation tools.

ICAO is currently working to standardise criteria for RNP airspace.

These new procedures will build on current programmes such as basic area navigation (see above) (B-RNAV) which links the aircraft’s highly accurate on-board navigation systems to the controller’s computer. The mandatory implementation of B-RNAV in 1998 enabled European Civil Aviation Conference (ECAC) states to increase en route capacity by 20% to 30% through the provision of more direct routes. Accuracy is defined in terms of the maximum distance in nautical miles from its indicated position that an aircraft was likely to be at least 95 % of the time. So an airway requiring RNP-5, the value used for the ECAC B-RNAV mandate, demands a navigation system able to keep within five nautical miles of the centre line with a 95 % probability.

The US has introduced RNAV-based standard instrument departures and arrival routes (SIDs and STARs), cruise routes and approaches.

Using RNAV approaches, rather than radar vectors, on descent to touchdown saves around 30% in fuel burn over radar vectors.[26]

In the US, 20 new north-south routes have been implemented above FL 180 on the US west coast for suitably equipped aircraft to provide an alternative to crowded conventional routes for qualified traffic. Aircraft must be capable of track-keeping accuracy of plus or minus two nautical miles for 95% of total flight time, and tracks are at least eight nautical miles apart.

By more accurately knowing where the aircraft is within the system, controllers can cut separation distances in the air and on the ground, cutting departure separation times and the average taxi-out time at peak periods, which have fallen by up to five minutes per operation in recent trials in the US.

At the start of May 2007 Southwest, American and Delta announced they had decided to make major investments to retrofit their aircraft for RNP operations. Southwest has decided to upgrade its entire fleet of Boeing 737s to be RNP-capable.

One noticeable difference between these new ATM procedures and former ATC models is the emphasis on allowing aircraft with highly-accurate navigation and position reporting systems to choose their own optimum routes, rather then making them fly prescribed paths.

[26] Source: http://www.dglr.de/veranstaltungen/archiv/focusing-technology/2004-05-11_Elliff.pdf

According to Air Traffic Control Association (ATCA) president Neil Planzer[27] "UPS has gained some degree of control over the production line by implementing its own systems…UPS has been working on a number of aircraft-centric tactical solutions to improve hub operations at its major airport centres. These include a surface management system to manage and space the 100 aircraft try to depart its Louisville hub in two hours; continuous descent approaches and merging and spacing procedures, including Cockpit Display of Traffic Information (CDTI) operations, which could save up to 8,500 flight hours a year. The new procedures are being implemented not through the retrofitting of expensive individual avionics systems, according to Robert Walker, Division Manager, United Parcel Services, but via bundling the software together in the aircraft's electronic flight bags (EFBs) which connect directly to the aircraft's flight management system."

**CPDLC –better communications**

Controller pilot data-link communications (CPDLC) is one of the key enabling technologies for opening up new airspace and airport capacity – replacing voice communications between pilot and controllers with a digital data-link from the flight management system to the controller's computer. According to SITA "European trials reveal that CPDLC can cut voice channel communications load between aircraft and air traffic control centres by close to 50%."

The Eurocontrol Link2000+ programme, based at the Maastricht Upper Airspace Centre, has pioneered CPDLC services in Europe and around 300 aircraft are scheduled to be equipped with CPDLC/ATN avionics - including Aeroflot, Air Berlin, Air Europa, Alitalia, Federal Express, Finnair, LTU, Lufthansa, Malev and SAS. DFS (Germany), Skyguide (Switzerland) and ENAV (Italy), with NAV EP (Portugal), DSNA (France), AENA (Spain) and the UK's NATS are expected to start CPDLC services around 2011-2012, according to SITA. The FAA's programme to implement CPDLC across all 20 US en-route centres is pending completion of the ERAM ATC Center Modernization programme, expected to be finalised around 2010.

**Automatic Dependent Surveillance – better surveillance**

Automatic Dependant Surveillance allows the aircraft to alert the controller of its position – rather than relying on an aircraft response to a ground-based radar interrogation signal. As ADS-B (Broadcast) messages can be relayed across digital ground stations and satellites this effectively expands the range of airspace monitoring tools to vast new areas, well beyond the range of traditional radars.

**CNS/ATM – the incoming ATM technologies**

[27] Source: http://www.canso.org/NR/rdonlyres/C34E050C-8695-4D35-B42A-8DCDE24E40C4/0/ATMnews_ATCA3.pdf

All these new technologies and procedures are collectively known as CNS/ATM systems. As part of the ICAO Special Implementation Project (SIP) workshop on the development of business cases for the implementation of CNS/ATM systems (Cairo, 6 – 9 September 2004) a new study "Environmental benefits of communications, navigation, surveillance/air traffic management (CNS/ATM) systems" was published.

According to the report, under the aegis of CAEP, a modelling capability was developed to quantify the impact of CNS/ATM systems on global emissions. This capability was the first step toward a common methodology that could be used globally to evaluate the impact CNS/ATM systems might have on reducing fuel consumption and related emissions. "The initial U.S. study done in 1998 had shown potential annual savings of over 10 billion lb of fuel (6%), over 200 million lb of both NOx (10%) and CO (12%), and 60 million lb of HC (18%) compared to what would have resulted without the CNS/ATM improvements. "

The study reached further conclusions.

"Within the timeframe under consideration (1999-2015) at the time of the study, global air traffic was expected to increase by around 61% (these are pre-9/11 forecasts from ICAO). In the same time period, fuel consumption and CO2 emissions were projected to increase by just 37%. Fuel burn and CO2 emissions are growing less quickly than traffic because of the introduction of more efficient engine technology coming into the fleet due to aircraft retirement and fleet expansion." The preliminary results of this study show that by 2015, there would be a 5% reduction in total fuel burn and CO2 emissions in the regions studied even with forecast growth factored in. The table below shows a summary of the annual fuel and CO2 savings for 2015 from CNS/ATM improvements for both the United States (CONUS) and Europe (ECAC). The results are displayed by flight segment.

**Table 21: Percentage annual fuel & CO2 Savings by 2015 due to CNS/ATM**

| | **Continental US** | **European area** |
|---|---|---|
| Above 3000' | 5 % | 4 % |
| Below 3000' | 5 % | 7 % |
| Surface | 11 % | 3 % |
| Whole flight | 5 % | 5 % |

Source: ICAO

Preliminary results show savings of a similar order of magnitude for NOx, HC and CO, but this extrapolation would be subject to further analysis, verification and validation.

The study concludes:

"Initial studies show that the implementation of CNS/ATM systems will provide an environmental benefit in the form of decreased fuel usage and the related reductions in gaseous emissions. In a period when the aviation industry is being asked to do more to reduce the emissions related to aviation activities, it is important to fully utilise efficiency improvements available from CNS/ATM implementation – and to measure the inherent environmental benefits."

In the US, NextGen and in Europe, the Single European Sky ATM Research programme (SESAR), both using digital, satellite-based technologies to provide the capacity and efficiency necessary to keep pace with growing demand in air traffic services, will lead to further improvements. According to ICAO: "NGATS (now renamed NextGen) might yield oil savings of as much as 0.4 million barrels a day by 2030…"

The Single European Sky programme, in contrast, aims to deliver a reduction of CO2 per production unit of up to l2% over current levels, by delivering more efficient routes and fewer delays, though some proponents of the programme suggest even greater savings will be possible.

### 2.7.4 Continuous descent approaches into airports

A new type of "green approach" called a continuous descent approach (CDA), allows aircraft to "glide" along a steady descent path rather than power and up and down the conventional stepped approaches into most busy hubs, cutting emissions by up to 6% over conventional approaches.

With better-planned approaches an airline can save between 100 and 300 kilos of fuel per flight, according to Sweden's LFV, and have been operationally in use at Stockholm/Arlanda since 16 March, 2006 by SAS and Falcon Air. SAS has 19 Boeing 737s equipped to carry out this type of approach. Most of these aircraft have the FMS version installed which can send unique information directly to the ATC centre-based system. It works by allowing the pilot during the final approach to plan the sink profile as optimally as possible. Air traffic control centre equipment communicates with the aircraft's FMS during green approaches; approximately 40 minutes before landing the CIES assesses the landing time which is then sent to the airport's database.

The use of continuous descent approaches into its main Louisville hub have resulted in 880,000 lb of fuel savings for parcels carrier UPS – a figure which will soon rise to over a million gallons. UPS has measured that its Boeing 757 aircraft are each saving around 250 gallons of fuel per flight and its widebody aircraft up to 465 gallons on every landing, using the CDA operation.

**ATM fuel-saving programmes in the USA**

ATA is quantifying real and potential ATM improvements in the following areas:

- The introduction of Domestic Reduced Vertical Separation Minima (DRVSM) has doubled the number of usable altitudes between 29,000 and 41,000 feet, allowing greater access to fuel-efficient routes previously unavailable due to increase separation requirements. FAA estimates savings to airlines at more than $5 billion through 2016
- Area Navigation (RNAV) procedures promote reduced fuel usage through more efficient climb and descent gradients; shorter, more predictable, and more repeatable ground tracks and reduced delays. Annual benefits estimated at tens of millions of dollars at ATL and DFW
- Required Navigation Performance (RNP) uses on-board technology that allows pilots to fly more direct point-to-point routes reliably and accurately; gives pilots lateral guidance and vertical precision; allows more efficient airspace management and reduces fuel burn
- Per FAA, Florida airspace optimisation has reduced: 1) flight distances on standard arrival and preferential routes into south Florida airports; 2) re-routes into adjoining foreign airspace, which cause additional foreign over-flight fees; and 3) departure delays from BOS/NYC/WAS metropolitan airports to south Florida. FAA estimates annual airline savings at $20 million
- Advanced Technologies & Oceanic Procedures (ATOP) reduces current separation minima from 100 nautical miles to 50 nautical miles (or 30 miles for equipped aircraft). ATOP permits more aircraft to access more fuel-efficient trajectories because routes can be spaced more closely together, and aircraft can operate more closely in trail. These more efficient trajectories allow aircraft to operate on better time tracks, with less excess fuel reserves, consequently allowing them to carry extra payload
- The new oceanic ATC system is estimated to save airlines about 6.5 million pounds of fuel (or about $8 million a year) on oceanic flights from the US to the Caribbean and South America (Source: Lockheed Martin)
- User Request Evaluation Tool (URET) permits controllers to predict potential aircraft-to-aircraft and aircraft-to-airspace conflicts earlier, allowing them to construct alternative flight paths or cancel climb or descent restrictions. URET addresses conflicts strategically rather than tactically, with fewer deviations to the route or altitude and less restrictive climb or descent profiles. Estimated FY05 savings = 25 million aircraft miles and $175 million in operating expenses.

According to CANSO, tailored arrivals trials at San Francisco - like previous ones in Australia and the Netherlands during the past two years –" show fuel savings from 400lb (180 kilograms or approximately 60 gallons) to 800lb (360 kilograms or approximately 120 gallons) per flight," according to Boeing ATM. "The implication of these studies is that, when fully implemented, tailored arrivals could save airlines $100,000 per year in fuel costs per aircraft for flights into major airports," says Mead, lead engineer for advanced ATM air/ground communications at Boeing Phantom Works.

"In Australia, green approaches introduced in November 2001 in Oceanic and Continental airspace have been responsible for an estimated 10,800 tonnes annual reduction in carbon dioxide emissions on the Brisbane Oceanic routes alone.

"These are small, national initiatives which are already starting to deliver considerable savings in fuel burn. The imminent introduction of new air traffic management systems based on trans-national, rather than national, traffic flows should see these national best-practice efforts rolled into regional then global operating environments."

However, there are differences within the ATM world as to whether all airports will be able to introduce (CDAs), as the airspace complexity around the airport can at some hub clusters make these approaches on all runways unviable. But researchers are currently assessing the potential benefits. Airbus is working with AVTECH Sweden on a set of computer simulation tools for designing new operational procedures that can increase runway capacity and reduce fuel burn and resulting emissions similar to those achieved at Stockholm Arlanda. These connect remotely the aircraft's FMS (flight management system) to air traffic control computers via datalink, to strategically accomplish four-dimensional, continuous-descent arrivals. The current target is to reduce negative environmental effects by 10% for each individual flight.

According to Croatia Airlines:

"Special flying routes are used to lower the noise level. Procedures are used to lower the aircraft engine power levels at take-off wherever it is possible to do so, thus extending the useful life of the engine while at the same time saving fuel and reducing CO2 emissions up to 25%. The effect achieved is considerable, since such procedures are followed in 95% of take-offs within the company flight network. Operating procedures lowering the level of noise at landing, which also result in fuel savings and CO2 emission reductions, are followed in most domestic and foreign airports, i.e. wherever it is possible to do so."

**New Swedish approaches suggest 200 kg of fuel savings per landing are possible**

Airlines can save up to 200 kilos of fuel per landing by using "green approaches" according to Volvo Aero. Fully implemented, the system can save airlines almost one billion Swedish krona per year. "Green Approach gives air traffic controllers the same information as the pilot, which is a completely new concept. It allows controllers to line up incoming aircraft well in advance thereby avoiding queue problems at the airport," explains Fredrik Lindblom, project manager at the Swedish Civil Aviation Administration (LFV).

LFV and the airline SAS started testing a new system to avoid queue problems in mid-March 2006. The project is appropriately named Green Approach and is part of the NUP2+ EU project. Traditional air traffic control is based on the controllers using their own systems to make their own estimates. But the pilots have access to more detailed information than the controllers via their flight management systems (FMS) computer. The FMS gathers and analyses data about velocity, position, weather and wind and can compute precisely when the plane will land. With the Green Approach system, this information is then transmitted from the aircraft's flight path computer to a computer at LFV which in turn transmits the information to air traffic controllers, among others. Since air traffic control has access to the same information as the pilot, they can give the aircraft information so it can land without waiting. Less fuel is required since the aircraft maintains an even speed throughout the flight and does not have to circle. Noise levels are reduced as well since the aircraft glides the last distance with the engine in neutral.

*Source: Volvo Aero*

**Table 22: Potential and actual reduction in greenhouse gas emissions from ATM efficiency improvements**

| Emission improvement potential from ATM efficiency improvements | Rationale | CO2 saved |
|---|---|---|
| Airspace redesign | The UN estimates that there is a12% inefficiency in air traffic management. That means 73 million tonnes of unnecessary CO2 emissions. IATA's work on over 300 routes in 2006 resulted in up to 6 million tonnes of CO2 savings. | Currently running at 6 million tonnes of CO2 a year (according to IATA), but will increase once as CNS/ATM concepts are delivered in the short term and SES/NextGen programmes are delivered |
| Introduction of CNS/ATM concepts – RNAV, CPDLC, ADS-B etc | An initial 1998 US study has shown over 10 billion lb of fuel (6%), over 200 million lb of both NOx (10%) and CO (12%), and 60 million lb of HC (18%) will be saved by introducing CNS/ATM improvements. ICAO is modelling savings in aircraft fuel burn/emissions as a result of more direct routings at around 0.5% a year | Savings equate to 3.05 million tonnes of CO2 emissions a year. |
| Continuous descent approaches | Trials show of 200 kg of savings potentially possible per aircraft, per landing. ACI's Global Traffic Forecast 2006-2025 shows 67.9 million aircraft movements (landings and takeoffs) at the | Potential savings of at least 2.1 million tonnes of CO2 emissions over 10 years. |

| | | |
|---|---|---|
| | world's airports. The FAA's aircraft movement figure at commercial airline airports for 2006 is 25.2 million (or 12.6 million landings and 12.6 million take-offs). If CDA operations were introduced at one third of airports over 10 years that would result in (2006 base-line figures), 33.95 million approaches saving 200 kg of fuel – or 6.79 million tonnes, resulting in 21.3 million tonnes of CO2 emissions. | |

## 3. Estimates of current and future environmental impact

### 3.1 Introduction

This section presents a review of all the major studies undertaken by academic, NGO, government and inter-governmental bodies with conclusions about the current nature of aviation's impact on the environment, with a special reference to the emissions of greenhouse gases.

The studies examined in this report represent three main types; proposals for the introduction of financial and other mechanisms designed to control the growth of aviation, arguments against the implementation of enforced mechanisms and financial burdens to limit the rise in emissions produced by aviation and finally an examination into whether the implementation of taxes on aviation fuel for domestic flights contravenes the 1944 Chicago Convention.

The studies covered include:

1. The EU Communication- 'Reducing the Climate Change Impact of Aviation'
2. The International Civil Aviation Organisation (ICAO): Working paper: 35th Assembly session – 'Aviation and Climate Change' presented by IATA
3. The Intergovernmental Panel on Climate Change (IPCC) – 'Aviation and the Global Atmosphere'
4. The Massachusetts Institute of Technology (MIT) – 'Aviation and the Environment'
5. The Royal Commission on Environmental Pollution (RCEP) - 'Special Study: The Environmental Effects of Civil Aircraft in Flight'
6. The Stern Review
7. The Stockholm Environment Institute - 'Aviation and Sustainability'
8. Dr E Pache 'The possibility of introducing a kerosene tax on domestic flights in Germany'

The object of this section is to highlight and précis the key findings of each of these significant studies. This analysis is a subjective review by the report authors, aimed at featuring climate-change emission responsibilities, and should not be regarded as a definitive and all-encompassing description of the entire report findings.

In broad terms, organisations which sponsor/commission reports on the effect of aviation on the environment tend to fall into the following categories:

- Governments and international organisations
- The environmental lobby
- Commercial aviation interests
- Research institutes.

Each of these separate groups has their own reasons for commissioning reports but in essence they seek either to propose the imposition of enforced financial mechanisms to limit aviation growth or to counter the arguments used to champion reductions in aircraft traffic. Government-backed studies may also be commissioned on the basis of a partial recognition of the opportunity to expand the scope of revenue-collection opportunities via taxation on fuel, tickets and infrastructure usage.

Proponents of the imposition of aviation fuel tax and other financial schemes frequently start their argument with suppositions that aviation is not covered by the Kyoto Protocol and all aviation fuel is protected from taxation. Domestic aviation is covered by the Kyoto Protocol and the Chicago Convention of 1944 only protects fuel for international flights in transit. International flights were not included in the Kyoto Protocol, but were subject to a 'special memo' calling for their inclusion once an acceptable process for their inclusion had been developed. The Chicago Convention exempts fuel on international flights in transit not only to promote aviation as a social benefit to mankind but also to avoid unfair practices, which could in effect lead to double taxation.

Efforts are underway by many countries to renegotiate bi-lateral air service agreements (ASAs) to make it possible to introduce aviation fuel taxes and in 2003 the EU passed a directive (2003/96 EC) allowing its Member States to tax domestic flights.

Those studies calling for a reduction in aviation growth tend not to spend a great deal of time examining in detail the expected outcomes of programmes designed to reduce aviation's negative effects on the environment. For example, the studies do not examine the effect of the introduction of new, more environmentally-friendly aircraft into airline fleets, in any detail. Nor do they highlight individual development programmes for 'cleaner/greener' engines, such as the Component validator for environmentally-friendly aero-engine (CLEAN) project and the Advanced near-term low emissions (ANTLE) project as part of the Efficient and environmentally friendly aero-engine (EEFAE) programme (see previous sections). Efforts undertaken by the ATM community to reduce fuel burn through increased efficiency and revised procedures (Reduced Vertical Separation Minima - RVSM, Dynamic Management of the European Air Network - DMEAN, the Single European Sky - SES, Continuous Descent Approaches - CDA) are also often largely ignored. Furthermore, few of the studies mention the funding, by the European Union (EU), of successive Framework Programmes, which have promoted the development of environmentally-friendly aviation platforms, procedures, equipment and operations such as the 'Clean Sky' Joint Technical Initiative (JTI) proposed under the Seventh Framework Programme (FP7).

The studies commissioned to counter the arguments for reducing air traffic growth tend not to discuss in detail the progress in the development of the science of monitoring and understanding changes caused by human activity on the atmosphere. Rather, they highlight the uncertainties which still exist about the accuracy and efficacy of the methods used to measure the effects of emissions on the environment such as Radiative Forcing (RF) or Global Warming Potential (GWP). They also tend to gloss over the progress in the understanding of the effects of contrails and the effect of aviation emissions on cirrus clouds.

The two reports which have the most comprehensive and scientifically-based explanation of the effects of aviation on the atmosphere and the likely consequences of this are the IPCC "Aviation and the Global Atmosphere" and the Stern Review. The other reports over this in varying degrees of detail but essentially defer to the IPCC report.

The IPCC report, 'Aviation and the Global Atmosphere' set the benchmark for the description of what the negative impact actually is and how it is induced. The report gives a detailed breakdown of all of the emissions which are deemed to have a harmful effect on the environment and induce global warming – carbon dioxide (CO2), water ($H_2O$), nitric oxide (NO) nitrogen dioxide ($NO_2$) (collectively known as NOx), sulphur oxides ($SO_xO$) and soot. All of the subsequent studies agree that these are the harmful agents which lead to global warming due to the effects they have on ozone ($O_3$), methane ($CH_4$), UV radiation and clouds.

The IPCC study takes pains to highlight the fact that there are difficulties in trying to predict the effects that emissions will have on global warming for many reasons. One of the report's great successes is that it has energised governments to accelerate efforts to mitigate the harmful effects of aviation. The European Union, for example, has spent more than Euro1 billion on projects designed to reduce the environmental impact of aircraft NOX and CO2 emissions alone since 1992 (see EU Communication: Reducing the Climate Change Impact of Aviation) as part of an overall effort including over 350 separate projects with funding of Euro 4 billion. The EU has also set down its own goals for the reduction of aircraft emissions as per the Advisory Council for Aeronautical Research in Europe (ACARE) Strategic Research Agenda (SRA), which calls for the reduction of fuel consumption and $CO_2$ emissions by 50% and of NOx by 80% by 2020. The Massachusetts Institute of Technology (MIT) 'Aviation and the Environment' recognises the predominance of the IPCC report and calls for the US to commission its own in-depth study on aviation and the environment.

Although it is relatively straightforward to estimate how much of each of the harmful emissions has already been produced, it becomes more difficult to predict how much will be produced in the future. Various factors need to be accounted for, such as development of more efficient ATM procedures, the use of 'greener' engines, the rate of introduction of new aircraft into airline fleets (according to IATA's Working Paper on environmental protection, over US$1 trillion will be spent on new aircraft over the 20 years covered by ICAO's CAEP forecast) and the possibility of the introduction of cleaner fuels (hydrogen and/or biofuels). In addition to this, there are also uncertainties about the effects of contrails and the effect of aircraft emissions on cirrus clouds. The issue is compounded further by attempts to account for aviation emissions being more harmful than emissions produced at ground-level. The IPCC study does this by converting the figures using the Radiative Forcing (RF) metric. This metric has advantages and limitations. One of the limitations of the RF metric is that it is prone to change. When the IPCC calculated aviation RF values, it converted the figures using an RF factor of 2.7; as already mentioned, this has since been recalculated by the TRADEOFF project to 1.9. It remains to be seen whether it will be reduced further.

The Stern Review takes a slightly different approach to the environmental issue of climate change and sees climate change as the "greatest and widest-ranging market failure ever seen". It concedes that nobody can predict the effects of climate change with complete accuracy but that taking action immediately should be viewed as an investment in the future -- in other words, "a cost incurred now and in the coming few decades to avoid the risks of very severe consequences in the future". The review goes on to say, "evidence gathered by the Review leads to a simple conclusion: the benefits of strong early action considerably outweigh the costs."

The Review concentrates on the amount of global warming likely to take place and predicts what outcomes can be expected as the temperature rises. Its key metrics are therefore the rise in temperature in degrees Celsius and amounts of greenhouse gases in the atmosphere. Current stocks of greenhouses gases in the atmosphere are stated as equivalent to 430 parts per million (ppm) of CO2 compared to 280 ppm before the Industrial Revolution (circa 1750). According to the review this has already led to an increase in global warming of ½ a degree Celsius and will lead to a further ½ degree increase in the next few decades. If the increase in the stock of greenhouse gas emissions does not exceed current rates, by 2050 the stock will have doubled to 550 ppm. However, the rate of increase is accelerating and this figure (550 ppm) is expected to be achieved by 2035. With it will come a 77 to 99% chance of an increase in global temperature of between 2 - 5ºC with the most extreme forecasts for temperature change in the review are 10ºC. Stern refers to the IPCC 2001 study, which asserts that human activity is responsible for the most of the warming experienced over the past 50 years.

The Review concedes, however, that there is a significant amount of dissent within the scientific community about the trends in the rise of the earth's temperature and the reasons for it and highlights the "Hockey Stick" debate, which says that the reason graphs depicting the temperature rise resemble a hockey stick – ie they have a long lead followed by a sharp curve at the other end – is because the data is questionable due to the fact that accurate data can only be accessed for the past 150 years. Data going back further than that has to be interpreted from 'proxy' sources like tree rings, historical records, ice cores, lake sediments and corals.

### 3.1.1 The Communication from the EU Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions - 'Reducing the Climate Change Impact of Aviation'

The communication was published on 27th September 2005. It was intended as a basis for discussion among other EU institutions for bringing aviation into the EU Emissions Trading Scheme (EU ETS) as well as to provide a background for discussion for the EU ETS review in June 2006. In short, the EU wants to ensure that aviation does not undermine the progress made by other industries in reaching or exceeding Kyoto Protocol goals. The communication recommends that aviation should be incorporated in the EU ETS on the basis of the recommendations of the July 2005 CE Delft report "Giving wings to emissions trading".

The study recommends:

- Inclusion of aviation into the EU Emissions Trading Scheme (ETS)
- More priority to be given to reducing aviations negative effects through research programmes and FP7
- Timely progress to be made on the introduction of the Single European Sky (SES)
- Removing all legal obstacles to allow for aviation fuel taxation.

### 3.1.2 Intergovernmental Panel on Climate Change (IPCC) 'Aviation and the Global Atmosphere'

The Intergovernmental Panel on Climate Change (IPCC) was requested by the International Civil Aviation Organisation (ICAO) and the parties to the Montreal Protocol on 'Substances that deplete the ozone layer' to undertake a comprehensive fact-based and scientifically-backed study on the effects that aviation has on the environment. Once approved in 1999, the study became the baseline for the majority of studies carried since its publication. It is one of the most widely-quoted studies in the aviation field and is used as a major reason for why aviation growth should be controlled. Its key authors come from a mixture of academic and national research organisations in the UK and the US (Joyce E Penner: University of Michigan, David Lister: DERA (now QienetiQ), David J Griggs: UK Meteorological Office, Mack MacFarland: DuPont Flouroproducts).

The report concludes with a summary of actions which could be used to limit aviation's impact on the environment by controlling its growth. Among the options are additional levies and charges as well as voluntary agreements between countries, in particular an emissions trading scheme.

The report was updated in May 2007 (http://www.ipcc.ch/SPM040507.pdf), with broadly similar conclusions to the impact of aviation on climate changes as those outlined in the 1999 study.

The Intergovernmental Panel on Climate Change (IPCC) – 'Aviation and the Global Atmosphere' mentions possible options to be considered rather than calling for the following to be implemented:

- Pass all environmental costs onto the aviation industry (internalise external costs)
- Use of emissions trading
- Voluntary measures such as emission levies
- Increased use of rail transport.

**3.1.3 Royal Commission on Environmental Pollution (RCEP) 'Special Study: The Environmental Effects of Civil Aircraft in Flight'**
This report was published in November 2002 to contribute background information for the British Government's upcoming White Paper on Air Transport as the RCEP assumed that the White Paper would not include enough detail on the negative effects of aviation. The report builds on previous reports notably its 18$^{th}$ (1994) Transport and the Environment report, which called for regulatory action to curb the growth in aviation and its 22$^{nd}$ (2000) report Energy – The Changing Climate, which called for the imposition of tax on aviation fuel.

The Report promotes among other things the restriction of aviation growth, a shift to other modes of transport - in particular rail - and the development of rail networks around airport hubs, rather than the proliferation of regional feeder airports. It specifically promotes the technological development of the Blended Wing-Body (BWB) concept and warns against the development of supersonic or near-supersonic aircraft due to the altitude these types of aircraft fly at and the increase in the Radiative Forcing (RF) they produce.

Significantly, the report suggests that the use of hydrogen fuels will probably not be less harmful in terms of global warming due to the amount of water emitted by hydrogen-powered engines.

The Royal Commission on Environmental Pollution (RCEP) - 'Special Study: The Environmental Effects of Civil Aircraft in Flight' makes the following recommendations:

- Impose climate protection charges for aircraft taking off and landing at EU airports
- Restrict airport development
- Encourage modal shift to rail
- Support progress on technological and operational improvements
- Include international aviation in the emissions trading scheme envisaged as one of the Kyoto Protocol implementing mechanisms.

### 3.1.4 The Stern Review
**'The Economics of Climate Change'**

The most recent study into the economic effects arising from the increase in global temperature, the Stern Review, was published in October 2006 following a request by the United Kingdom's then Chancellor of the Exchequer, Gordon Brown. It examines all sources of emissions production, agriculture, industry, transport waste, land use, buildings and power. The report identifies increases in emissions production and suggests a set of key actions which should be immediately adopted in order to stabilise the amount of carbon in the atmosphere. Most significant amongst these are emissions trading, a curb on deforestation and technological advances to lower carbon emissions.

The Stern Review makes the following recommendations:

- Put an appropriate price on carbon through policy measures including taxation and emissions trading
- Technology co-operation to assist with development of low-carbon technologies
- Reduction in deforestation
- Adaptation: Rich countries should assist poor countries in understanding the risks of climate change and adopting development strategies to mitigate against it as well as research into new crop varieties which are resistant to flood and drought.

### 3.1.5 Stockholm Environment Institute
**'Aviation and Sustainability – A Policy Paper'**

The report, published in July 2004, promotes sustainable development policies, which would curb the growth of aviation and introduce additional charges to the industry on the basis of the "Polluter Pays" principle. The self-funded report states that the growth in aviation is at odds with the principles and objectives of sustainable development as follows: "Sustainable development requires careful thought and prudence about environmental capacity, climate change and equity and the growth in demand for aviation is threatening efforts in all these areas of policy development."

The report is intended to promote the urgent need for demand management in aviation, the introduction of emission charges and a modal shift from aircraft to train.

The Stockholm Environment Institute - 'Aviation and Sustainability' makes the following recommendations:

- Establish wide-ranging dialogue (Governments, NGOs, industry, regulators, citizens)
- Pass all environmental costs onto the aviation industry (internalise external costs)
- Adopt World Health Organisation (WHO) recommended values on noise thresholds
- Shift traffic to non-car modes for access to and exit from airports

- Adoption of "environmental bubble" concept around airports for a small set of pollutants
- Ban on night-time flights
- Air tickets subject to VAT in Europe and equivalent in non-EU states
- Modal shift from air to rail
- Include emissions in national and international reduction strategies and improve monitoring capabilities.

**3.1.6 International Civil Aviation Organisation: Assembly 35th Session Working Paper: Agenda Item 15 - 'Environmental Protection'**

The Working Paper was presented at ICAO's 35th Assembly on 2nd August 2004 by representatives of the International Air Transport Association (IATA). Its main aim is to highlight IATA's support for ICAO's role in developing mechanisms to mitigate environmental pollution from aircraft emissions. It seeks to promote improvements in ATM, operational procedures, technology developments and voluntary initiatives as against imposed mechanisms such as regional or local taxes and charges, which could undermine ICAO's efforts to bring about its own solution to control aircraft emissions.

The Working Paper gives qualified support to an Emissions Trading Scheme but with several provisos. The Working Paper is an attempt to bolster ICAO's influence within the environmental protection fraternity particularly as ICAO warns against the use of taxes and charges and suggests that voluntary schemes are the way forward. The paper is also a lobbying vehicle for ICAO to amend its draft Consolidated Statement of Continuing ICAO Policies and Practices Related to Environmental Protection.

The International Civil Aviation Organisation (ICAO): Working paper: 35th Assembly session – 'Aviation and Climate Change' recommends:

- Continue to work for the reduction in aviation's effect on the environment whilst protecting its right to grow
- Ensure that ICAO represents aviation's interests in UN debates to maintain a flexible approach
- Refrain from local, national or regional measures including, taxes and charges, which may impede the implementation of a voluntary solution
- Continue to support the development of aviation as a critical element in a sustainable global society.

**3.1.7 Massachusetts Institute of Technology MIT**
**'Aviation and the Environment'**

The report makes proposals to address aviation's negative effects, including noise, local air quality and climate change. It suggests that environmental issues may impose the fundamental limit on the growth of the US air transportation system in the 21st Century. It makes the distinction that European concerns regarding the negative effects of aviation tend to focus on climate change, whereas US concerns target noise and local air quality. The report states that continuation of ongoing technology research is expected to reduce fuel consumption at the rate of 1% per year for the next 15 to 20 years (with more opportunities relating to the airframe rather than engines). It also concedes that air traffic growth is set to grow at a rate of 3% – 5% per year. The report therefore states that low emissions technology and operations must therefore make up the difference to avoid increased pollutant emissions from aircraft.

The report concedes that there are no major US research projects to research the unique climate impacts of aviation. This, it warns, may put the US at a disadvantage when negotiating appropriate regulations and standards with other nations. It goes on to warn that another risk is that the US may become reliant on data put forth by others who may favour curtailing aviation activity to mitigate environmental impacts, despite its significant contribution to the economy.

The Massachusetts Institute of Technology (MIT) – 'Aviation and the Environment' makes the following recommendations:

- Establish a federal interagency group to co-ordinate aviation mitigation activity
- Develop more effective metrics and tools
- Adopt a balanced approach including operational, technological and policy options.

### 3.1.8 'The possibility of introducing a kerosene tax on domestic flights in Germany'. Dr E Pache - legal opinion commissioned by the Federal Republic of Germany's Environment Agency

The report was published on 18th January 2005 by Dr E Pache, a German lawyer specialising in international and national law, as a legal opinion commissioned by the Federal Republic of Germany's Environment Agency. It examines whether introducing a tax on domestic flights in Germany for aviation kerosene contravenes the 1944 Chicago Convention. The report concludes that the Chicago Convention does not preclude the imposition of a tax on aviation fuel for domestic flights, as it only covers aircraft in international transit.

The report explains that after the EU passed its directive 2003/96/EC in October 2003 Member States were freed up to impose excise duties on kerosene should they deem it worthwhile.

Dr E Pache's study considers that a tax could be applied to domestic flights using one of three options:

- Tax based on the removal of aviation kerosene from a tax warehouse in the Federal Republic of Germany
- Tax on the consumption of fuel whilst flying over the Federal Republic of Germany via a reporting-based scheme
- Tax on the consumption of fuel whilst flying over the Federal Republic of Germany via an estimating-based scheme .

### 3.2 Forecasts given within the reports analysed

It is generally accepted that aviation has recovered from the slump brought about by the September 11 bombings and the subsequent SARS alert and is now back on a growth rate of between 3% to 5% per year for the foreseeable future. The most frequently-quoted forecasters – Airbus, Boeing and Rolls-Royce -- have all produced forecasts which predict similar trends in aviation growth. In short, growth rates in Europe and the US are stable at about 3% per year, whereas the rise in air traffic in the developing nations is predicted to be much steeper, with growth rates in China forecast at about 8% per year and the Middle East seeing a rise of 5%. Predictions published in the studies, for the growth in aviation, are within the generally accepted norms.

Predictions within the studies for the growth in emissions from aircraft are more divergent. The IPCC study 'Aviation and the Global Atmosphere' is seen by most other studies (global, national or regional) as the 'Bible' and as a result is frequently quoted. The IPCC study predicts that CO2 emissions will increase by 2050 by a factor of between 1.6 to 10 times the levels seen in 1992. The wide range in the prediction results from the fact that the IPCC uses six different scenarios to base its forecasts on. The study clarifies this point and states that the more extreme scenarios, based on low or high rates of growth and, which could include a fleet consisting of over 1,000 supersonic passenger jets, are not very likely. It is important therefore to assess whether the IPCC's more extreme scenarios are being quoted rather than its 'mean' or 'average' forecasts.

Much of the data used in the IPCC study is taken from earlier studies, some ranging back as far as 1992 and advances in scientific understanding in what is a relatively new field have progressed significantly since the IPCC report was published. For example, the EU communication 'Reducing the Climate Change impact of Aviation' says, "The IPCC estimate that aviation's impact may be 2 – 4 times greater than its CO2 emissions alone is restated in this document as being closer to 2 times greater rather than possibly 4 times greater."

This highlights two factors. Firstly, that the EU communication is quoting the extreme ranges within the IPCC study and secondly, the advances in scientific understanding are evolving continuously. A mean/average factor of 2.7 is stated for aircraft Radiative Forcing (RF) in the IPCC report. This has since been recalculated by the TRADEOFF project, funded under the EU 5$^{th}$ Framework Programme, to be closer to 1.9. The Stockholm Environment Institute (SEI) quotes the IPCC study in a similar way when predicting the amount of emissions aviation is likely to be responsible for in 2050. "Aviation emissions accounting for man's contribution for global warming could grow from today's 3.5% to between 4% and 15% by 2050. A closer prediction is given in the Stern Review of 5%.

The Stern Review focuses on the likely costs to global economies of a warmer earth, which will give rise to more extreme weather patterns and events including widespread flooding on the one hand and drought on the other.

Coverage of aviation falls within the section on 'Transport'. The Review is able to put the current situation regarding aviation's emissions contribution into context and explains that, "Transport accounts for 14% of global greenhouse gas emissions, making it the third largest source of emissions jointly with agriculture and industry. Three quarters of these emissions (75%) are from road transport, while aviation accounts for around one eighth (12.5%) and rail and shipping make up the remainder (12.5%). The report begins to lose specificity and goes on to say that even though it is difficult to predict the future, total CO2 emissions from transport are expected to more than double in the period to 2050 making it the second fastest-growing sector after power."

The Review goes on to explain that it is possible that CO2 emissions from aviation could account for as much as 5% of the warming effect if the Radiative Forcing (RF) is taken into account. "CO2 emissions from aviation are expected to grow by over three-fold in the period to 2050, making it among the fastest-growing sectors. After taking account of the additional global warming effects of aviation emissions, aviation is expected to account for 5% of the total warming effect (radiative forcing) in 2050." The level of uncertainty in this prediction highlights the difficulty in predicting with authority what aviation's impact will actually be.

The use of kerosene is set to rise according to the IPCC report by 3% per year in the period 1990 to 2015, representing a compound increase of over 55%. This figure is supported by Dr Pache's use of the TÜV Rheinland prediction that the use of kerosene will have doubled over the period 1995 to 2020 based on an annual increase of circa 3%.

The studies covered in this report, which propose the imposition of taxes, charges, levies and trading schemes, concentrate on the actions required to make it possible to impose them and the various options which should be considered, and not the amount of money that would need to be raised in order for the required outcomes to be achieved. IATA's Working Paper 'Environmental Protection' delivered at the 35$^{Th}$ ICAO assembly does however, put a figure on how much money it would take to meet targets set by ICAO to reduce emissions. Accordingly, it would take as much as US$47 billion to US$245 billion in taxes and charges each year to attain a reduction in air traffic which would be consistent with ICAO targets. Similarly the Working Paper estimates that the costs involved in setting up an emissions trading scheme to achieve the ICAO targets would be in the region of US$17 billion to US$60 billion.

### 3.3 Forecasts and recommendations of studies proposing the introduction of financial mechanisms to restrict aviation growth

The EU Communication forecasts:

- If aviation growth continues unabated emissions from international flights from EU airports will have increased by 2012 by 150% since 1990. This would offset more than a quarter of the reductions required by the EU's target under the Kyoto Protocol

- The IPCC estimate that aviation's impact may be 2 – 4 times greater than its $CO_2$ emissions alone is restated in this document as being closer to 2 times greater rather than possibly 4 times greater.

IPCC forecasts:

- Increase in $CO_2$ emissions by 2050 of between 1.6 to 10 times the levels existing in 1992
- In period 1990 – 2015 fuel use is predicted to increase at a rate of 3% pa and passenger-km by 5% pa
- In 2050 aircraft $CO_2$ emissions are predicted to be in range of 0.23 to 1.45 Gt C/year (Billion ($10^9$) tonnes of carbon per year)
- The report concludes that the increase in emissions due to traffic growth may not be fully offset by the reduction in emissions resulting from technological advances in the period following 2015 if certain conditions are not met.

RCEP forecasts:

- UK airport to be serving 1 billion passengers per year by 2050.

Stern Review forecasts:

- Current stocks of greenhouse gases in the earth's atmosphere (equivalent to 430 ppm $CO_2$) will lead to another half a degree Celsius warming in the next few decades
- Even if the annual flow of emissions did not increase beyond today's rate, the stock of greenhouse gases in the atmosphere would reach double pre-industrial levels by 2050 (550 ppm $CO_2e$)
- The level of 550 ppm $CO_2e$ could be reached by 2035 due to increased growth in developing countries. Leading to a 77 or 99% chance of a 2º Celsius global rise in temperature
- Under a business as usual (BAU) scenario, the stock of greenhouse gases could more than treble by the end of the century, giving at least a 50% chance of a 5º Celsius rise in temperature
- Total $CO_2$ emissions from transport are expected to more than double in the period to 2050 making it the second fastest growing sector after power
- $CO_2$ emissions from aviation are expected to grow by over three-fold in the period to 2050, making it among the fastest growing sectors.

The Stockholm Environment Institute forecasts:

- Global aviation growth to be in the range of 3% – 7% for the next 20 years (up to 2025).
- Number of aircraft to double over next 20 years (Boeing 2003)
- Number of km flown is set to triple over next 20 years (2025)
- Freight growth is expected to rise by 5% – 6% pa for the next 20 years (IATA 2003)

- Global fuel use projected to increase by over 3% per year to 300m tonnes pa by 2015 and over 400m tonnes pa by 2050 (IPCC)
- Aviation emissions accounting for man's contribution to global warming could grow from today's 3.5% to between 4% and 15% by 2050 (IPCC 1999)
- UK air travel to triple over the next 30 years from 180 to 500 million passengers per year
- UK aviation growth will require an increase in airport capacity equivalent to one Heathrow airport every 5 years.

**3.4 Recommendations of studies arguing against the introduction of financial mechanisms to restrict aviation growth**

ICAO/IATA forecasts/recommendations:

- Over the 20 years covered by the ICAO's Council Committee on Aviation Environmental Protection (CAEP) forecast, airlines are expected to invest over $US1 trillion in new aircraft
- For the reduction targets assumed in the ICAO analysis, costs of CO2-related taxes or charges would range from approximately US$47 billion to US$245 billion per annum. (see CAEP/5)
- For the reduction targets assumed in the ICAO analysis for an emissions trading scheme, costs would range from approximately US$17 billion to US$ 60 billion per annum.

MIT forecasts/recommendations:

- The MIT report refers to predictions for the growth of carbon emissions made by the IPCC 1999 report Aviation and the Global Atmosphere. Specifically aviation may be responsible for between 3% and 15% of anthropogenic forcing of climate change by 2050.
- US air traffic to grow at a rate of between 4.7% (international markets) and 3.5 % (domestic market) over the next 12 years (ie 2004 – 2015).

**3.5 Recommendations from the examinations of how to apply financial mechanisms to aviation**

Dr E Pache:

- Annual increase in passenger air transport between 2003 and 2022 of 5% -measured in passenger kilometres (Airbus)
- Annual increase in passenger air transport between 2003 and 2022 of 5.1% - measured in passenger kilometres (Boeing)
- Committee on Aviation and Environmental Protection (CAEP) predicts a global growth in air traffic volume in period 2000 to 2020 of 4.3% (measured in passenger kilometres)
- More precisely CAEP is forecasting a growth in domestic air travel in period 2000 – 2020 of 3.5% and a growth in international air traffic of 4.9%.

- Air cargo transport to triple up to 2022. (DLR Luftverkehrsbericht 2004)
- By 2020 kerosene consumption is expected to have approximately doubled compared with the baseline year of 1995. (TÜV Rheinland)

# 4. Regulatory and other initiatives to curb greenhouse gas emissions from aviation

## 4.1 Introduction

This section offers a review of the regulatory measures and other, non-aviation industry, initiatives to curb the impact of aviation on climate-change, especially in relation to the formation of greenhouse gases. As highlighted in the previous section, while our knowledge of aviation's contribution to the formation and impact of greenhouse gases such as carbon dioxide has been considerably refined over the last three to four years, there are still many areas of outstanding ignorance.

According to the Massachusetts Institute of Technology:

"Our ability to simulate the entire aviation system and its environmental impacts provides us with a unique opportunity to identify fundamental research problems. As an example, while aircraft contribute only 0.01 percent to the US national particulate matter (PM) inventory, PM has a relatively high health impact (health costs are around $60,000/metric tonne, versus $2000/metric tonne for NOx and $5-$125/metric tonne for CO2). Our assessments show that the health and welfare impacts of aviation PM are similar to those of NOx. However, while much is known about aircraft NOx emissions, little is known about PM emissions and their relationship to engine design and operating conditions. Emissions from fossil fuel combustion typically contain not only hard particles (soot), but also minor fractions (parts per million and parts per billion) of gases such as $SO_3$. $SO_3$ reacts with water to form $H_2SO_4$ and then condenses — forming very small volatile particles (these particles range in size from several nanometers to tens of nanometers in diameter)."

There is very little agreement between the world's governments as to what should be done to curb greenhouse gas emissions from aviation. Actions vary from none to extensive; Switzerland and Sweden have adopted similar measures to control pollution by charging increased landing fees based on NOx and hydrocarbon emissions. Norway and the UK have developed "offset" policies for government employees, where the government buys quotas for the emissions caused by the trip. The UK has been capturing emissions by government and ministerial air travel since April 2006 and is spending up to GBP3 million pounds ($5.9 million) to buy 255,000 tonnes of carbon credits for 2007-09.

National aviation regulators often find themselves with seemingly contradictory remits – on the one hand to promote the interests of the domestic aviation industry while curbing the excesses of unrestrained growth. Governments, too, face conflicting pressures – on the one hand to liberalise air traffic agreements between states and regions to increase aviation competition and bring down prices, while on the other hand to curtail man-made emissions of greenhouse gases. The recently signed EU-US liberalised transatlantic agreement could create 72,000 jobs across the US and the

European Union and result in an additional 200,000 tonnes of freight traveling between the two continents, according to recent study by consultancy Booz-Allen Hamilton. Passenger traffic between the USA and the EU could rise by 26 million passengers over five years and could generate as much as EUR12 billion ($16 billion) in economic benefits on both sides of the Atlantic.

One approach by governments in Europe has been to advocate the growth of "responsible flying" where individuals can offset their aviation carbon emissions. Germany's Federal Environment Ministry, in association with Germanwatch and the Forum Anders Reisen, has the "Atmosfair" initiative directed at people who cannot, or do not want to avoid flying, but, who are concerned about the effects of flying on climate. Passengers will be able to calculate how much greenhouse gas emissions their flight will cause and pay a voluntary contribution to ensure that equivalent emissions are saved elsewhere. The money raised goes towards climate protection projects in developing countries and passengers can pay the contribution either at the time they book their ticket or directly on the "atmosfair" website.

At the start of 2007 there is still a great deal of measurement and monitoring activity being carried out by national agencies. For example, the FAA is engaged in an extensive research activity to develop a comprehensive framework of aviation environmental analytical tools and methodologies to assess interdependencies between noise and emissions and analyse the cost/benefit of proposed actions to mitigate these impacts.

According to the agency: "This framework of tools will allow optimising activities to reduce aviation's environmental impact, including greenhouse gases. They include:

1. Environmental Design Space (EDS), which will provide integrated analysis of noise and emissions at the aircraft level
2. Aviation Environmental Design Tool (AEDT), which is comprised of EDS integrated with existing or new aviation noise and emissions analytical modules to provide an integrated capability of assessing interrelationships between noise and emissions and amongst emissions at the local and global levels
3. Aviation Environmental Portfolio Management Tool (APMT), which interacts with AEDT, EDS and economic modules to provide the common, transparent cost/benefit methodology, needed to optimise aviation policy in harmony with environmental policy."

The FAA, NASA and Transport Canada are also jointly sponsoring research through the Partnership for Air Transportation Noise and Emissions Reduction (PARTNER) Center of Excellence to reduce uncertainties associated with the impact of non-CO2 (e.g., contrails, oxides of nitrogen, and particulates that induce cirrus clouds) aviation emissions on climate. The goal is to reduce uncertainties to levels that enable appropriate action. PARTNER's members include aerospace manufacturers, airlines, airports, national, state and local government, professional and trade associations, non-governmental organisations and community groups, united in the desire to foster collaboration and consensus among some of the best minds in aviation. PARTNER pursues technological, operational, policy, and workforce advances to address aviation and environmental challenges.

In fewer than three years of operation, PARTNER has conducted research and activities including:

- Producing *Aviation and the Environment*, the report to the US Congress, which proposes a national vision statement, and recommended actions;
- Successfully testing alternate landing profiles as a no/low-cost means to reduce aircraft noise, fuel consumption, and pollutant emissions;
- Participating in three significant measurement campaigns at US airports to assess and understand the formation of particulate matter from aircraft;
- Collaborating with NASA and industry to study the acceptability of low impact sonic boom noise to enable supersonic flight over land;
- Examining land use, noise, and local development dynamics related to airport encroachment;
- Assessing human health and welfare risks of aviation noise, local air quality, and climate change impacts;
- Developing aircraft and air transportation system simulations to assess policies, technologies, and operational options for jointly addressing air transportation and environmental goals; and developing online resources to better inform the public about aircraft noise issues.

The FAA also leads US participation in CAEP and is working with its counterpart authorities through ICAO to explore the use of voluntary agreements to deal with this issue. FAA was also instrumental in the development of ICAO guidance in the area of best operational practice to reduce fuel usage.

Recent mounting evidence, such as the release of the February 2007 IPCC report, on the speed with which climate change is occurring and man's contribution to the process, is increasing pressure on governments to take action. US Energy Secretary Samuel Bodman said that his country supports the findings of the most recent IPCC report: "We agree with it, and the science behind it is something that our country has played a very important role in," he said. "We estimate that the US has invested more in climate-change science than the rest of the world combined," he added, claiming that the US had spent $29 billion since 2001 in climate-related science and technology programmes.

The European Commission on 10 January 2007 announced an "An energy policy for Europe" (see http://eurlex.europa.eu/LexUriServ/site/en/com/2007/com2007_0001en01.pdf) proposing a 20% cut in greenhouse gases by 2020, with the intention of raising that to 30% if other industrialised nations follow suit.

Meanwhile, airlines, airports, manufacturers and ANSPs are developing strategies to protect themselves, where they can, from government moves to tax their operations on an environmental basis. The development of “codes of conduct” and voluntary taxation measures are being developed as part of a series of self-regulatory measures.

For example in early February 2007 Lufthansa said it was studying plans to collect a voluntary climate protection fee from passengers, to contribute to the work against global warming. The voluntary supplements – as yet unknown as this report went to press - would be handed over directly to climate protection projects in developing and emerging countries.

### 4.2 Pressures on governments to restrict aviation growth

Global passenger growth among IATA airlines grew 5.9% in 2006 over 2005. While the cargo growth rate increased from 3.2% in 2005 to 4.6% in 2006, it remains below the historical growth trend of 5.6%. Average passenger load factors in 2006 rose to a record high of 76.0%, up from 75.1% in 2005.

According to IATA:

“The Middle East was the fastest-growing region for both passenger and cargo recording full-year growth of 15.4% and 16.1% respectively. Although the cargo growth rate improved marginally to 4.6%, the key markets of Europe and Asia were relatively subdued at 1.7% and 4.7% respectively. High fuel costs and strong competition from other transport modes (particularly in Europe) constrained growth in 2006. North America was the most improved market as freight growth increased from 0.4% to 6.0% as airlines switched capacity towards cargo.

“All regions except the Middle East saw a decline in passenger traffic growth rates compared to 2005. The largest decline was in Latin America where 11.4% growth turned to a 2.4% contraction in 2006, primarily due to restructuring of the industry in the region. North America saw the second largest decline—from 8.9% to 5.7%—as carriers withdrew unprofitable capacity.”

Ever since its inception the air transport industry has enjoyed, on average, year-on-year growth rates of more than 4%. However, the first signs are now appearing that unrestricted travel growth may no longer be possible. The first problem is airport capacity.

“If demand keeps growing at 4.3% a year airports will be severely constraining traffic growth in 2025,” according to Victor Aguado, director general of EUROCONTROL, speaking in January 2006. “Demand will have increased by a factor of 2.5 and despite a 60% capacity increase of the airport network on twice the volume of 2003, traffic will be accommodated. Demand corresponding to 3.7 million flights year cannot take place…. The top 20 airports will be saturated at least 8 to10 hours a day.”

For airports, the main issue is runway capacity. It takes between 10 and 15 years in Europe generally to plan for and build a new runway and the continent is running out of time and space to create enough runway capacity to handle annual growth rates in aircraft movements of 4% to 5%.

For the next few years there appears enough capacity – by using more regional airports for example – to forestall an imminent crisis. London/Heathrow with two runways processes nearly 69 million passengers a year, while Amsterdam Schiphol, with six runways, just 44 million.

But even with the development of new runways it is unlikely that enough airport capacity will be created to meet the eventual demand; airport operations will be constrained by new environmental limits. Although the European Commission has ruled out unilateral restriction on air traffic volumes, the Commission is considering moves to replace short-haul airline services with high-speed rail services, when viable alternatives exist.

According to a 2005 consultation paper on airport capacity, efficiency and safety in Europe (http://europa.eu.int/comm/transport/air/safety/consultation_en.htm), the European Commission has suggested: "[it] … should explore transferring air services onto rail alternatives …so as to restrict traffic rights for certain short-haul flights when an efficient rail link alternative already exists. This could be accompanied by a provision in a directive on airport charges…to allow airport operators to apply higher charges to short-haul flights, when competitive rail link alternatives exist."

However, distorting competition in favour of rail travel over air travel is not a fair position for a strategic transport regulator to take, according to the European Regions Airline Association (ERA), which represents the continent's smaller, regional carriers.

"Air transport provides the only fully comprehensive public transport links to Europe's regions that lie more than 200 kilometres from major center, " believes the ERA. "Many passengers traveling between major cities and regional towns or cities are not traveling between the two city centres. Thus, even on those routes that are served by high-speed rail (which generally only serves city centres), air travel remains a more attractive option for many passengers. Putting the consumer first requires a regulatory framework that allows air and rail businesses to compete for customers on an equal footing, taking into account infrastructure and environmental costs."

But this is just the first of several new proposed regulatory constraints which would effectively act as a brake on the growth of the air transport industry in Europe. At the end of February 2006, the then French President President Jacques Chirac announced his government would start levying a new tax on passengers from July 2006 to finance development in poorer parts of the world. The new tax will range from Euro1 (for intra-EU coach class fares) to Euro 40 for first-class intercontinental business fares. Europe's airlines and airport responded with anger - "The French propose to impose a nominal one-euro levy on short-haul leisure journeys, a figure which will go nowhere towards meeting the needs of the developing world. AEA asks whether it would even cover the cost of collecting it," according to the Association of European Airlines (AEA). But this not an aviation tax in isolation; Brazil, Chile, Congo, Cyprus, France, Ivory Coast, Jordan, Luxembourg, Madagascar, Mauritius, Nicaragua, Norway and the UK have all agreed to impose new aviation taxes to help developing countries fight a range of diseases.

**Table 23. IATA airlines traffic growth 2006-2005**

| Jan-Dec 2006 over Jan-Dec 2005 | RPK Growth | ASK Growth | PLF | FTK Growth | ATK Growth |
|---|---|---|---|---|---|
| **Africa** | 8.6% | 8.7% | 68.3 | 5.9% | 6.2% |
| **Asia/Pacific** | 5.3% | 2.8% | 74.6 | 4.7% | 3.4% |
| **Europe** | 5.3% | 4.5% | 77.0 | 1.7% | 3.8% |
| **Latin America** | -2.4% | -2.9% | 73.0 | -2.6% | -2.5% |
| **Middle East** | 15.4% | 15.6% | 73.4 | 16.1% | 16.8% |
| **North America** | 5.7% | 4.8% | 80.2 | 6.0% | 7.2% |
| **Industry** | 5.9% | 4.6% | 76.0 | 4.6% | 5.2% |

Proposals to put a ceiling on aircraft movements at European airports has been a feature of regulatory responses to airport development plans for many years.

In February 2007, Zurich's cantonal parliament rejected a proposal to cap flight movements Zurich airport which would involve a maximum of 250,000 flights a year. The parliament adopted measures that are likely to limit traffic to 320,000 flights.

According to local press reports:

"An Aircraft Noise Pollution Index will measure the number of people directly disturbed by air traffic. Flights could be stopped once a threshold reached roughly 47,000 people affected, which equates to around 320,000 flights."

**4.3 The EU's emissions trading scheme (ETS)**

Under the Kyoto Protocol, the EU is required to cut its emissions by 8% from 1990 levels by 2012. Developed nations who have signed the protocol have committed to reduce six greenhouse gases ($CO_2$, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride) by 5.2% below 1990 levels during 2008-2012. The EU emissions' trading scheme is the main method agreed by EU states to meet the Kyoto target.

Emissions trading in the EU has already impacted the aircraft manufacturing sector and is about to impact the aircraft operating community.

The Europe's Emissions Trading Scheme (ETS) was introduced to the 25 states of the EU at the start of 2005, mainly to target major CO2 emitters such as energy-generating, iron and steel works, glass and cement facilities**.** Around 12,000 energy-emitting plants have been able to buy and sell permits that allow them to emit CO2 into the atmosphere. Organisations exceeding their individual limit are able to buy unused permits from companies that have cut their emissions. They will be fined Euro 40 ($51) for every one tonne of $CO_2$ over the allocated limit in the initial phase (2005-2008), rising to Euro 100 in the second phase (2008 to 2012).The ETS covers about 40% of the EU's total CO2 emissions.

Each nation agrees a National Allocation Plan (NAP) with the European Commission. The NAPs allocate individual limits for the plants covered by the scheme.

By setting the total number of permits below the current level of emissions, the ETS should lead to a reduction in the amount of CO2 being emitted – depending, of course, on the number of permits issued by each member state. And this has proved something of an Achilles heel. States have tended to issue more permits to emit CO2 than required.

For the first phase (2005-2007) annual C02 emissions cap, country by country, see;
http://ec.europa.eu/environment/climat/pdf/nap_2_guidance_en.pdf).

At the same time, 15 members of the EU have committed to reduce overall emissions of six greenhouse gases to 8% below the 1990 level by 2012. Each EU state has an individual target set under a "burden-sharing" agreement. Apart from Cyprus and Malta - which have no targets - the other 10 EU states have individual reduction targets of 6% or 8%. The levels are somewhat tougher than the Kyoto agreement, which came into force in the EU during the middle of February 2005.

In developing its post-2012 policy the Commission is now trying to encourage the formation of a forum of the world's seven largest emitters - EU, US, Canada, Russia, Japan, China and India - to develop a common approach to the issue, and issued a strategy paper to this effect on 9 February 2005 (http://europa.eu.int/rapid/pressReleasesAction.do?reference=IP/05/155&format=HTML&aged=0&language=EN&guiLanguage=en).

Bringing airlines, along with maritime transport and forestry, into the emissions trading scheme was one of the Commission's main objectives for post-2012 action. Including internal EU flights within the trading scheme would cover 80% of emissions from aviation within the 25-member bloc, estimates the Commission. In deciding to take unilateral action on this issue it concluded, in September 2005, that bringing aviation into the EU's ETS would be the most cost-effective way of reducing the climate change impact of aviation.

The EU's Environment Council on 20 February 2007 agreed to cut greenhouse-gas emissions by 20% by 2020 to reduce global warming. The agreement included the addition of aviation in the EU's Emissions Trading Scheme (ETS). German airlines said that they would join the emissions-trading scheme from 2011.

The core agreement (see: http://www.consilium.europa.eu/ueDocs/cms_Data/docs/pressData/en/envir/92864.pdf) outlines the following key points:

"Accordingly, the Council: REITERATES that absolute emission reduction commitments are the backbone of a global carbon market and that developed countries should continue to take the lead by committing to collectively reducing their emissions of greenhouse gases in the order of 30% by 2020, compared to 1990 with a view to collectively reducing their emissions by 60 to 80% by 2050 compared to 1990;

"…In this context, IS WILLING to commit to a reduction of 30% of greenhouse gas emissions by 2020 compared to 1990 as its contribution to a global and comprehensive agreement for the period beyond 2012, provided that other developed countries commit themselves to comparable emission reductions and economically more advanced developing countries adequately contribute according to their responsibilities and respective capabilities;

"…INVITES those countries to come forward with proposals regarding their contributions to a global and comprehensive post-2012 agreement;

"…DECIDES that, until a global and comprehensive post-2012 agreement is concluded, and without prejudice to its position in international negotiations, the EU makes a firm independent commitment to achieve at least a 20% reduction of greenhouse gas emissions by 2020 compared to 1990;

"….DECIDES that a differentiated approach to the contributions of the Member States is needed reflecting fairness and transparency and taking into account national circumstances and the relevant base years for the first commitment period of the Kyoto Protocol;

"….RECOGNISES that the implementation of these targets will be based on Community policies and on an agreed internal burden-sharing;

"…INVITES the Commission to start immediately, in close co-operation with the Member States, a technical analysis of criteria, including socio-economic parameters and other relevant and comparable parameters to form the basis for further in-depth discussion;

"…UNDERLINES that these commitments should be implemented through national and Community climate policies, action in the context of the EU's energy policy, limiting transport emissions, reducing greenhouse gas emissions in residential and commercial buildings, strengthening the European Union Emissions Trading Scheme (EU ETS), including extending the global carbon market and using project-based mechanisms (JI andCDM), tackling emissions from non-CO2 gases, and enhancing natural sinks linked with biodiversity protection;

"…TAKES THE VIEW THAT this approach will allow the EU to reduce its energy consumption, improve Europe's competitiveness, reduce dependence on external sources of energy supply, demonstrate international leadership on climate issues, guide the implementation of the EU ETS beyond 2012, and encourage investment in emission reduction technologies and low-carbon alternatives;

"…WELCOMES the Commission's proposal for a Directive of the European Parliament and of the Council amending Directive 2003/87/EC so as to include aviation activities in the scheme for greenhouse gas emission allowance trading within the Community;

"…EMPHASISES that a global and comprehensive post-2012 agreement should further determine an outline for future commitments and contributions leading up to 2050, providing continuity to the carbon market within that timeframe."

While the move generally received broad support from member states, most insisted that all routes – intra-EU and international – should be covered by the scheme. This means foreign airlines will have to comply with EU aviation emissions rules. US carriers have argued this would be illegal and that the EU must wait for a global agreement to be reached in ICAO.

According to FAA Administrator (at the start of 2007) Marion Blakey. "Many countries around the world, including the US, view this unilateral approach as unworkable and unsustainable under international law." She adds that the approach "is directly counter to everything ICAO stands for" and that "trying to impose a one-size-fits-all solution on a complex issue in a global industry is a recipe for failure".

The US laid out its objections to the move in November 2005 when the FAA's assistant administrator for policy planning Sharon Pinkerton met with European Commission (EC) officials. "There are some differences in the context that we are all working in, in the States , versus the context in Europe. One of those differences certainly is that in the States we see aviation as a very small contributor, as opposed to other modes, to the greenhouse gas issue. In addition to that, our industry isn't really growing at the same pace. In fact, we are growing at a third the rate that the industry is growing in Europe. Perhaps, most important, is that we try to expand capacity in the States. In the obstacles to increasing capacity and expansion of our airport community, the greenhouse gas issue really doesn't come up.It is more of an issue of noise still being on the front burner, as well as local air quality issues. Out of our top 50 airports, about 90 percent of them are not in compliance (with clean air/local air quality standards) - they are in what we call non-attainment zones…

"I think we should continue to work through the ICAO [International Civil Aviation Organisation] … and in October 2004, we had our last Assembly meeting, at which the Assembly decided that, yes, emissions trading schemes are probably more cost-effective than charges. But the decision was taken that we really need to come up with guidance on how to move forward with emissions trading schemes. So that, in fact, is what the working group - we have a kind of committee on environmental protection -- it's called CAEP [Committee on Aviation Environmental Protection] -- which is formed from certain ICAO members. CAEP has working groups and one of the specific working groups is working on emissions trading schemes, both voluntary schemes and mandatory schemes to try to come up with guidance for the 2007 Assembly. My message was urging that we use that forum to try to work through these issues."

When the details of the proposal were made public the Air Transport Association of America (ATA) in December 2006 issued the following statement in response to the decision by the European Commission (EC) to include aviation in its emissions trading scheme:

"ATA is disappointed that the European Commission remains intent on unilaterally covering the flights of non-European Union carriers in its emissions trading scheme. This misguided decision clearly violates international laws and bilateral air service agreements, and deferring its implementation by one year does not change that outcome.

"The International Civil Aviation Organisation (ICAO) is working on appropriate multi-lateral solutions to address greenhouse gas emissions of international aviation, including emissions trading guidance. The EU is alone in its efforts to bypass that ongoing work. We urge the EU to join with the rest of the world in working through ICAO to find constructive solutions to this issue." But many in Europe see ICAO as a mechanism for slowing down and watering down agreements. The Danish Environment Minister Connie Hedegaard said on the ETS issue: "We cannot wait for ICAO and we cannot allow our competitiveness to be harmed…All flights must be included from day one."

The system will work by imposing a cap on CO2 emissions for all aircraft arriving or departing from EU airports, while allowing airlines to buy and sell 'pollution credits' within the EU ETS (see /http://europa.eu.int/eurlex/pri/en/oj/dat/2003/l_275/l_27520031025en00320046.pdf).

On 20 February 2007, in a first debate on the issue, environment ministers backed the Commission strategy but there were disagreement as to timing, ambition and geographical scope of the proposal.

The Commission has already undertaken extensive research into the cost of bringing airlines into the ETS. It estimates that the cost impact of adding aviation into the ETS for flights departing EU airports should not add more than 9 euros to the price of a return ticket (for a download of the principal consultant's report to the commission on the issue please see appendix xx: http://www.ce.nl/eng/index.html ).

An expert group (http://www.europa.eu.int/comm/environment/climat/pdf/eccp_aviation.pdf) was also set up by the Commission from all sides of the aviation industry to develop a report on the technical aspects of integrating aviation in the EU's ETS. The group has looked at a number of issues, including whether intercontinental flights should be included in the scheme and whether other greenhouse gases - including nitrogen oxides (NOx) and water vapour – will be included.

**Features of the EU's ETS**

- Intra-EU flights come under the scheme in 2011. Flights in and out of the EU will be exempted until 2012;
- The scheme is also to cover Norway, Iceland and Liechtenstein - the three members of the European Economic Area (EEA);
- Pollution limits will be set by the Commission EU-wide, calculated on the basis of average aviation emissions in 2004-2006. This is in contrast with the system currently in place for other industrial sectors, where 'pollution credits' are allocated at national level and then approved or rejected by Brussels;
- Airlines will receive 90% of pollution permits for free. The remaining 10% will be auctioned with a view to setting a market price;
- Pollution permits allocated under the scheme can only be used (and therefore traded) by the aviation sector.
- Government and military flights are excluded, and
- Non-CO2 emissions are not tackled.

The most contentious issues in the debate on including aviation in the EU-ETS were:

- Whether or not to include **international flights** in the scheme, after non-EU airlines, especially in the US, made it clear that retaliatory action in the form of trade sanctions would be a likely consequence. The Commission plan maintains the idea of including international flights in the scheme, but proposes exempting them only until 2012, while intra-EU flights will have to come under the scheme in 2011.
- How to determine the actual **cap** on emissions (EU or national), **who** to apply it to (airlines or member states) and then **how to distribute allowances**. The Commission's proposal suggested the following:
    - Calculating the overall cap based on average aviation emissions in 2004-2006;
    - Distributing allowances to airlines, not countries;
    - Setting pollution limits EU-wide, in contrast with the current system where they are allocated at national level and then approved or rejected by Brussels;
    - Giving airlines at least 90% of pollution permits free in the start, with unlimited auctioning after 2013;
    - Allowing airlines to trade emissions with other sectors, such as power generation, which are already covered by the EU-ETS, rather than allocating aviation sector specific pollution permits that can only be used (and therefore traded) by the aviation sector;
- Acceptance by **consumers** of the **additional costs** that the measure will represent. An impact study (see above) suggested that the scheme could raise ticket prices by Euro 4.6-Euro 39.6, depending on the distance covered. However, this is not likely to impact much on customer demand as aviation is not very price sensitive;
- How to take **other greenhouse gases** into account, including nitrogen oxides (**NOx**) and the **water vapour** in aircrafts' condensation trails which also contribute to global warming. Indeed, the Intergovernmental Panel on Climate Change (IPCC) has estimated that the total impact of aviation on climate change is currently about twice to four times higher than that stemming from CO2 emissions alone.

Europe's airlines have broadly welcomed their inclusion in the ETS framework. Not only are these unlikely to be imposed on any EU-side scale over the next few years, but airlines could make money out of the imposition of the ETS.

The UK's Institute for Public Policy Research (IPPR) says that giving airlines emissions credits at no cost will give them cheap flight "If the airlines are simply given the credits, they will pass on costs to passengers, leaving the industry to pocket up to £2.7 billion in windfall profits" it states. In a separate study, global conservation organisation WWF estimated that EU airlines would make up to Euro 3.5 billion per year from inclusion in the ETS.

According to the IPPR (see: http://www.ippr.org.uk/pressreleases/?id=2488)

"Under the trading scheme, airlines will have to gain emissions credits, each worth one tonne of carbon dioxide, to cover the greenhouse gas emissions caused by their flights. The market price of these emissions credits is anywhere between Euro 5-30+. The aviation industry is likely to pass through the full costs of these credits to passengers. This could mean ticket prices going up by between 14p and £6.04 and any emissions credits given to airlines are a windfall profit. The industry could make windfall profits in the order of Euro 1.34 billion to Euro 4 billion (£0.9 billion - £2.7 billion), if all emissions credits were given away free to the airlines and EU ETS market prices were between Euro10 and Euro 30.

The UK power sector made £1 billion windfall profits in the first year of the EU ETS. "A combination of free allocations with a full pass through of marginal costs is estimated to result in increased profitability for the UK power sector," writes economic consultancy IPA. Higher plane ticket prices might lower passenger demand by 0.1 – 1.4 per cent. But with the European airlines growing at 4-5 per cent per year until 2020, these extra costs will not restrain the aviation industry's growth. Some countries' airlines are growing as fast as 14 per cent.

"These figures are based on calculations made in a report written for the European Commission, CE Delft (2005), Giving Wings to Emissions Trading."

But the key question is – how much decrease in $CO_2$ emissions for airline operations will the scheme deliver? The answer depends on how the scheme is managed.

The trade union the European Transport Federation (ETF) suggests the measure will lead to a reduction of 3% in $CO_2$ emissions - less than one year's growth of the aviation sector's emissions. ( see: http://www.transportenvironment.org/docs/Publications/2006/2006-10_can-e_te_position_paper_aviation_impacts.pdf0

The UK Green Party MEP Caroline Lucas, who drafted the Parliament's July 2006 resolution on aviation and climate change says: "If the Commission limits the scope to flights within the EU, it will undermine the environmental integrity of the scheme: just 44 million tonnes of carbon will be saved by 2020 compared to 183 if non-EU flights are included."

According to Air France Chairman and CEO, Mr. Spinetta "The success of the ETS will very much depend on the choice of its technical characteristics. A 'closed' market, on which trading schemes would be negotiated exclusively within a single industrial sector, is not adapted to the context of the air transport sector. This sector, currently undergoing growth and already having recourse to the latest available technological developments, is unable to reduce its $CO_2$ output alone."

**The Air France perspective on aviation joning the EU ETS**

Air France….welcomes the principle of the emissions trading scheme, considering this to be the most constructive solution for controlling the impact of air transport on global climate change.

However, the efficiency of such a system will depend on its technical characteristics. A "closed" market, in which permits would be traded only within a given industrial sector, is not adapted to the case of air transport. This is a sector in expansion which already makes use of the best available technologies and which, alone, cannot cut back its production of $CO_2$. It is totally, and for a long time to come, dependent on a single source of energy: jet fuel. As recommended by the International Civil Aviation Organisation, Air France is therefore in favour of an "open" market, which would enable acquiring emissions permits from other sectors able to benefit from technological solutions to reduce their emissions and to finance these through the sale of permits.

The system must not distort competition, particularly with airlines not subject to similar constraints. It must, moreover, take into account the efforts at fleet modernisation already made by each operator at the time it is put in place.

**Table 24. Potential reduction in greenhouse gas emissions**

| **European Union Environmental Trading Scheme** | | |
|---|---|---|
| **Measure** | **Potential savings** | **Forecasting agency** |
| Adoption of the EU ETS | 3% in $CO_2$ emissions, at 2007 levels | European Transport Federation |
| Adoption of the EU ETS within the EU | 44 million tonnes of $CO_2$ saved over 2007 levels | UK Green Party |
| Adoption of the EU ETS within the EU | 183 million tonnes of $CO_2$ saved over 2007 levels (the equivalent of twice Austria's annual greenhouse gas emissions) | European Commission |
| Adoption of the EU ETS globally | 183 million tonnes of $CO_2$ saved over 2007 levels | UK Green Party |

### 4.4 Emissions trading outside the EU

Airlines in the Far East are also starting to consider the application of a global ETS. According to Andrew Herdman, director general of the Association of Asia-Pacific Airlines, speaking at the start of 2007, a global ETS is a better alternative to taxes levied by countries or regulatory attempts to suppress air travel. He argued the airline industry could offset emissions for $13 billion a year, or 3% of its annual revenue, assuming that a permit to emit 1 ton of carbon dioxide would cost $20. Given the $68 billion rise in annual fuel costs between 2003 and 2006, paying only a fifth as much for the right to emit carbon dioxide is clearly workable, he said.

Meanwhile in the US there are increasing number of initiatives at national and state levels – such as President Bush's "Global Climate Change Initiative" of February 2002**,** or the McCain-Lieberman "Climate Stewardship Act" of 2003 - to reduce emissions at a similar rate to those in Europe. In the US the approach remains mainly voluntary, in contrast to the proscriptive measures being applied in Europe. Recent moves within ICAO will focus US regulatory attention much more closely in the coming months and years on developing a potential US ETS scheme for airlines.

### 4.5 CAEP/7 and emissions trading guidelines

In March 2007 ICAO's Committee on Aviation Environmental Protection (CAEP) agreed on proposed guidance to incorporate international aviation emissions into the ICAO 189 member states emission trading schemes, consistent with the United Nations Framework Convention on Climate Change process. The guidance focused on those aspects of emissions trading related to aviation-specific issues and provided preferred options for the various elements of trading systems.

Specific proposals include:

1. Aircraft operators be the accountable international aviation entity for purposes of emissions trading.
2. Obligations be based on total aggregated emissions from all covered flights performed by each aircraft operator included in the scheme.
3. States, in applying an inclusion threshold, consider aggregate air transport activity (e.g. CO2 emissions) and/or aircraft weight as the basis for inclusion.
4. States start with an emissions trading scheme that includes CO2 alone.
5. States apply the Inter-governmental Panel on Climate Change definition of international and domestic emissions for the purpose of accounting for greenhouse gas emissions as applied to civil aviation.
6. States will need to put in place an accounting arrangement that ensures that emissions from international aviation are counted

separately and not against the specific reduction targets that states may have under the Kyoto Protocol.

According to ICAO: “In regards to trading units, member states will need to consider economic efficiency, environmental integrity and equity and competitiveness when making a choice. On the question of geographic scope, the guidance recommends that states take into account an ICAO Council request that CAEP include the different options to geographic scope describing their advantages and disadvantages and start to address the integration of foreign aircraft operators under a mutually agreed basis, and continue to analyze further options.

“The guidance on emissions trading is part of a package of recommendations from CAEP to address aircraft engine emissions directly attributable to aviation in relation to local air quality and global climate effects, which includes the reduction of emissions by technological, operational and market-based measures.

“The meeting also considered long-term technology goals for nitrogen oxides (NOx) and agreed on a proposal for guidance on aircraft emissions charges related to local air quality. States were encouraged to evaluate the costs and benefits of the various measures available to them…CAEP/7 made a proposal to post information on voluntary emissions trading and other voluntary measures covered at the meeting on the ICAO public web site.

“The meeting also produced other recommendations dealing with aircraft engine emissions and aircraft noise as well as trade-offs between these two measures. “

ICAO in 2005 adopted a new set of NOx standards that are 12% more stringent than the previous levels agreed in 1999.

### 4.6 European Union initiatives and proposals beyond the ETS

The European Commission has said it will offer “a legislative proposal…to limit nitrogen oxide (NOx) emissions from aviation” in its policy strategy for 2008.

In 2002 the Centre for International Climate and Environmental Research (Oslo) (CICERO) published a Commission funded report “Study on air quality impacts of non-LTO emissions from aviation” (see: http://ec.europa.eu/environment/air/pdf/air_quality_impacts_finalreport.pdf) to evaluate to what extent pollutants emitted by aircraft beyond the LTO-cycle (i.e. above 3000 feet or approximately 1000 metres) contribute to air-quality problems in Europe.

It was intended to support the European Commission on its review of the National Emission Ceilings Directive (Directive 2001/81/EC) which requires member states to limit their annual emissions of certain eutrophying pollutants and ozone precursors. The scope of the National Emission Ceilings (NEC) directive includes aircraft LTO emissions but it does not cover aircraft emissions beyond the landing and take-off cycle (non-LTO emissions).

According to the findings:

“The study concludes that aircraft nitrogen oxide emissions above 1000 m and at cruise level (non-LTO emissions) have a small but significant impact on regional air quality levels in Europe. Nitrogen oxide (NOx) emissions from aviation affect ozone formation at ground level, increase the deposition of oxidised nitrogen, thus increasing ecosystem exposure to acidification and eutrophication. It also leads to increased regional ground-level concentrations of nitrogen dioxide and particulate nitrate. The study shows that the effect on regional air quality of non-LTO emissions of NOx is generally considerably larger than that of NOx emissions in the take-off and landing phases of aviation (LTO emissions). For nitrogen dioxide, however, the effect of NOx LTO emissions on ambient air concentrations of NO2 in the vicinity of airports is not negligible and a higher impact can be expected from dedicated studies using a higher spatial resolution than the one used in the present study.

“For the other regional air quality indicators analysed, the non-LTO NOx emissions from aviation affect surface air quality significantly more than LTO emission. This is a consequence of the predominance of non-LTO NOx emissions (95%) over LTO NOx emissions, the atmospheric vertical exchange between the surface and the free troposphere and of the high efficiency of NOx ozone production at free tropospheric levels.

“It is shown that non-LTO NOx emissions contribute by year 2000 with about 2%-3% to the deposition of oxidised nitrogen, and with about 1% to the air concentrations of secondary inorganic aerosols (SIA), nitrogen dioxide and mean ozone. The effect of the non-LTO NOx emissions becomes more significant with increasing ozone levels, so that it contributes with about a 5%0% increase to AOT40 and up to 30% to AOT60.

“In addition to the overall effects, the study also quantifies the isolated impacts of emissions occurring above the European regional domain, representing about 15% -20% of the global aircraft emissions.

“Despite the relatively low share with respect to global emissions, the estimated impact of this ‘European’ share represents about half of the total impacts from non-LTO emissions of NOx, for all components except for NO2, where the contribution of aviation sources above the European domain dominate.

“The results presented here imply that any measures addressed to reduce NOx emissions from aviation should consider more in detail their influence on the non-LTO emissions.”

For the other air-quality indicators analysed, the non-LTO NOx emissions from aviation affect surface air quality significantly more than LTO emission, according to the study. “This is a consequence of the predominance of non-

LTO NOx emissions (95%) over LTO NOx emissions, the atmospheric vertical exchange between the surface and the free troposphere and of the high efficiency of NOx ozone production at free tropospheric levels. It is shown that current (year 2000) non-LTO NOx emissions contribute with about 2%-3% to the deposition of oxidised nitrogen, and with about 1% to the air concentrations of secondary inorganic aerosols (SIA), nitrogen dioxide and mean ozone concentrations. The effect of the non-LTO NOx emissions becomes more significant when taking into account their marginal impact on exceedances (sic) of the effect threshold that environmental and health impacts are both assumed to have. Thus, the non-LTO NOx emissions have been estimated to increase the indicators for environmental impact on forest (AOT40f) with 5% to 10% and increase the indicator for health impact (AOT 60) with up to 30 %."

## Appendix one: Airline initiatives to improve environmental performance

The following appendix lists (directly from airline sources, normally annual and environmental reports) key strategies to mitigate the impact of airline operations on the environment. The words below are directly quoted in many instances from reports and are not compiled or validated by this report's authors. The authors have edited the text to remove subjective views of airlines' own environmental performance.

### 1. Air Canada

Air Canada has set five main environmental objectives for the entire company in the areas of materials and waste management, noise, energy and air emissions, environmental emergency preparedness, and environmental management policies and practices. To fulfil company objectives, each operating branch is required to set detailed environmental objectives and targets tailored to its environmental issues.

Company objectives:

- Ensure efficient use of resources, minimise waste generation and effectively manage waste disposal
- Minimise noise emissions from aircraft operations
- Optimise energy consumption and minimise air emissions resulting from air operations, ground operations and aircraft maintenance
- Respond effectively to accidental release of hazardous substances and eliminate occurrence of future incidents
- Promote sound environmental management policies and practices throughout the company.

Activities:
Air Canada's Environmental Management Systems (EMS) is a continual cycle of planning, implementing, reviewing and improving the actions they take to meet their environmental commitments. This includes environmental programmes such as:

- Glycol mitigation plans for facilities where they conduct aircraft de-icing and anti-icing operations
- Environmental compliance audits
- Aircraft noise and emissions management
- Storage tank management
- Environmental incident management
- Substitution of hazardous chemicals
- Industry co-operation: Member of ATAC, ATA and IATA committees to share information for effective management of all environmental issues and set industry standards
- Star Alliance™: Signatory to the Environmental Commitment Statement.

**2. Air France**

Air France implements a four-pronged policy aimed at developing its aviation activity without increasing noise energy and limiting the growth if its emissions, complying strictly with regulations, and communicating transparently.

Commitments:

The following initiatives are currently under way:

- Total noise energy is continuing to fall while traffic is rising
- Environmental impacts are systematically evaluated
- The best practices that are technically and economically feasible for the environment are followed when renewing the fleet. New aircraft are quieter and produce less CO2 than those they replace
- Special action plans are carried out when environmental risk makes it necessary. Air France prioritises anticipation and prevention in environmental affairs
- Air France rehabilitates operating sites when it leaves them
- Staff are fully involved in implementing environment-friendly practices. Initiatives are encouraged that factor environmental awareness into process improvement
- They maintain a dialogue with all stakeholders, including administrations, elected officials, citizens' associations and partners, so that they are fully and transparently informed about the results of their actions
- Air France encourages its partners, service providers and suppliers to implement actions that encourage environmental protection.

Air France regularly takes part in the work groups organised by the International Civil Aviation Organisation (ICAO) on improving procedures, emissions permit trading and emissions standards. The work groups bring together representatives from government, aircraft manufacturers, airlines and sometimes airports. The aim is to look at the future of air transport over the more or less long-term by:

- Modelling the environmental impact of the air transport industry;
- Introducing new procedures or regulations;
- Evaluating new technologies and defining new standards;
- Tougher certification thresholds for NOx in new engines, one of the latest moves supported by Air France. For example, starting in 2008, certification thresholds for nitrogen oxide emissions will be lowered by 12%.

**3. ANA – All Nippon Airways**

In FY2005, ANA emitted approximately 6.7 million tons of CO2, 98% of which came from the combustion of jet fuel. In FY2007, under its Ecology Plan, ANA set the goal of reducing CO2 emissions per available seat km to 12% of

FY1990 levels. In FY2005, they achieved a 10.6% reduction. They continue to approach their goal by adopting the very latest aircraft and through optimal engine maintenance.

Aviation and Climate Change

ANA activities that produce greenhouse gases include flights, aircraft maintenance and office work. Aircraft engines run on fossil fuels and produce emissions of mainly CO2 (carbon dioxide), NOx (nitrogen oxides) and H2O (water vapor). Here they discuss CO2, which accounts for 94.4%* of greenhouse gas emissions in Japan.

According to statistics from the ICAO (International Civil Aviation Organisation), aviation accounts for 2.5-3.0% of all CO2 emissions from used fossil fuels worldwide.

The share of CO2 emissions from domestic aviation in Japan was about 4.1% of transport sector emissions in FY2004, and about 0.8% of the total industrial sector emissions.

* 2006 White Paper on the Environment (Ministry of the Environment)

Control of CO2 Emissions from Jet Fuel**:**

There is currently no substitute for fossil fuels available to the aviation industry, so it is important to improve its efficiency.

ANA's CO2 emissions from aviation activities were approximately 1.80 million tons (equivalent in carbon, approx. 6.61 million tons in CO2 equivalent) in FY2005; this was 0.3% lower than in FY2004. The reduction was achieved by retiring old aircraft and replacing them with the latest aircraft, as well as by implementing measures to reduce fuel.

Although the number of seats in service increased significantly from FY1990, the CO2 emissions per ASK* decreased. Both ASK CO2 emissions and fuel consumption have decreased since FY2000 due to the business downturn stemming from the recession, terrorist attacks in the US, the war in Iraq and SARS (Severe Acute Respiratory Syndrome), but remained constant in FY2005 due to the economic recovery.

*Available Seat km (ASK): number of airlines' available seats multiplied by flight distance

Fuel-Efficient Aircraft:

Reducing CO2 emissions boils down to reducing fuel consumption. The most effective methods are:

1. Introducing fuel-efficient engines with the latest technologies;
2. Reducing air resistance through improved wing designs;

3. Reducing fuselage weight through the use of composite materials. The Boeing 787 employs all of these methods, and ANA was its first customer in July 2004, ordering 50 of them. The B787 is expected to reduce fuel consumption by 20% compared with the current B767-300.

Reducing the Environmental Burden:
As the reduction of fuel consumption directly leads to the reduction of greenhouse gas emissions, ANA position it as the most important measure for an airline. Since the first oil crisis of 1973 and the second oil crisis of 1979, ANA has been postulating and practicing various kinds of fuel-saving measures. Here are some recent examples.

EFP (Efficient Fuel Program) promotion project:
ANA started the EFP promotion project in FY2003. EFP increases fuel consumption efficiency through various methods such as:

1. Creating fuel-efficient flight plans having optimal altitude and speed, while considering weather conditions and air traffic control information;
2. Informing pilots of the most fuel-efficient point to initiate descent for landing. They monitor the amount of fuel saved each month; in FY2005 ANA saved 18,000 kilolitres of fuel over the previous year. This represents the amount of fuel required by a B777-200 to make 1,250 round trips between Tokyo and Osaka. They are working to raise awareness of the need to reduce fuel consumption by flying at optimal altitudes and speeds in FY2006.

Taxiing after landing with some engines shut down:
To help save fuel, ANA has been stopping some engines while taxiing on runways since 1994. The decision of whether or not to shut down engines is made by the captain based on the airport, weather, taxiway and aircraft conditions, and instructions from the control tower.

Fuel thus saved in FY2005 is estimated to be around 1,800 kilolitres, which equals the amount of fuel required for a B777-200 to make 125 round trips between Tokyo and Osaka.

Recovering engine performance by washing compressor:
The more an engine is used, the more dust particles stick to its compressor and thus degrade performance. ANA has been regularly washing compressors to maintain high engine performance and to reduce fuel consumption since FY2003. This effort has been extended to most of their aircraft. The amount of fuel saved from this washing in FY2005 was around 6,000 kilolitres, equal to 420 round trips between Tokyo and Osaka on a B777-200. Aiming for an even greater effect in FY2006, they planned to increase the frequency of washing by five times over the previous year.

Prioritised use of ground-power GPU:
As an environmental preservation measure, ANA has been attempting to prioritise the use of GPUs (Ground Power Units) and curb the use of APUs (Auxiliary Power Units) since 1990. An APU is a small on-board generator that provides electricity as well as pneumatic pressure for engine ignition and

cabin air conditioning. APUs are less energy efficient than GPUs as they burn onboard fuel; they therefore decided to use GPUs to a greater extent. In comparing the two, ANA found that by not using APUs they saved 33,000 kilolitres, or 160,000 barrels of fuel, in FY2005. This equals the amount of fuel needed for 2,300 round trips between Tokyo and Osaka by a B777-200.

Operation with RNAV (Area Navigation):
RNAV (Area Navigation) is a procedure for aircraft to navigate the designated flight route by radio-guidance facilities such as DME (Distance Measuring Equipment) and satellites. Not only does RNAV enable faster and shorter flights while reducing fuel consumption and engine exhaust, it also reduces noise around airports during the night.

RNAV was employed for the arrival route to Hakodate, Itami, Takamatsu, Fukuoka, and Kagoshima airports. The amount of fuel saved from the shortened path to those five airports is 1,700 kilolitres annually. This equals the amount of fuel needed for 120 round trips between Tokyo and Osaka by a B777-200. ANA will make further efforts to expand the use of RNAV in Japan and abroad.

Saving fuel through simulators:
ANA's use of flight simulators to train and evaluate flight crew reduces fuel consumption and noise. ANA introduced the devices in 1971, when the Civil Aviation Bureau approved the YS-11A flight simulator as an alternative for actual-flight training. Almost all flight training and evaluation now takes place in simulators; the devices are also used for maintenance training and evaluation.

In FY2005, simulator use at the ANA Group totalled 45,957 hours. If these hours were replaced with actual flight time, subtracting the electricity used for the simulators, they represent a savings of 307,879 kilolitres of fuel (758,614 tons of CO2). This equals 9.8% of the total jet fuel (domestic, international and other flights) used at the ANA Group in FY2005 equal to 21,000 round trips between Tokyo and Osaka by a B777-200. The ANA Group will continue to make effective use of flight simulators.

Weight reduction measures:
The ANA Group is making efforts to make cabin equipment lighter to reduce fuel consumption. Since October 2005, they have been introducing in domestic economy class new lighter-weight seats made of carbon-fibre reinforced plastic instead of the conventional aluminium alloy, resulting in an annual savings of 200 fuel drums per B777-200. And in October 2006, ANA introduced 200 new containers made mainly of Kevlar©, some 28% lighter than conventional types, mainly on the Tokyo-San Francisco route. Using these lighter containers saves approximately 2.5 fuel drums each way on this route.

Reduction of ground energy consumption (excluding aircraft):
Since FY2005, ANA has participated in “Team Minus 6%,” Japan's national global warming prevention project promoted by the Ministry of the

Environment. Among measures they have enforced is setting the air-conditioning to a higher temperature in summer. In September 2005, ANA received a certificate of appreciation from the (then) Minister of the Environment Yuriko Koike for their co-operation in the project.

ANA's ground energy consumption has been decreasing in recent years: in FY2004, it was 92.8% compared with the previous fiscal year, and 100.2% in FY2005 at 46,000 kl (crude-oil equivalent).

**4. British Airways**

In the short-term, British Airways is committed to increasing the fuel efficiency of its aircraft and buildings. It is targeting a 30% improvement in its aircraft fuel efficiency between 1990 and 2010 and a 2% per annum reduction in energy consumption in its buildings.

It supports a long-term strategy to limit air transport's climate change contribution based on robust science, sound economics and well-developed policy instruments. BA is working with UK, European and worldwide industry partners to develop this strategy.

British Airways does not accept that the right way to limit emissions is to discourage flying, by punitive taxes or constraints on industry growth : this has not been effective in curbing road transport growth and, if applied to air transport, would lead to extremely negative social and economic effects for the European economy, the company says.

Instead BA believes that a well-designed emissions trading scheme is a cost-effective and environmentally-beneficial policy instrument. Whilst an international approach through the International Civil Aviation Organisation (ICAO) must be the ultimate objective, BA recognises that some regions may need to move faster than others in developing measures to address climate change.

Air transport and emissions trading:

British Airways believes that including air transport within emissions trading – initially within the EU but eventually within a broader international scheme – is the most environmentally-effective and economically-efficient mechanism for dealing with carbon dioxide ($CO_2$) emissions from air transport.

To ensure that emissions trading can be introduced for European air transport without distorting international competition or imposing unreasonable cost burdens on airlines, a practical and pragmatic approach to the scheme design is needed. In particular BA highlights the following design elements:

- Emissions allowances should be distributed without cost using a benchmarking method to avoid high financial burden
- Allocation and target setting should be harmonised at EU level to avoid competitive distortion

- Coverage should initially focus on emissions from intra-EU air services to avoid international disputes and competitive distortion
- An international solution to integrate air transport into global policy action on climate change should be sought.

Non-CO2 effects of aircraft in the atmosphere:

Aircraft contribute to climate change through CO2 emissions and other effects in the atmosphere. CO2 emissions are significant and well understood. However, effects related to oxides of nitrogen (NOx) and cirrus cloud may also be important.

Understanding of the atmospheric effects associated with NOx, contrails and cirrus clouds is not sufficiently mature to define appropriate mitigation mechanisms at this stage. Importantly, premature action could have a perverse impact on other policy objectives, for example by increasing emissions of CO2.

Recognising that scientific uncertainty is not a reason for inaction, British Airways supports the following commitments through the Sustainable Aviation initiative:

- Provide relevant data and expertise for the scientific community to enhance understanding of the non-CO2 atmospheric effects of aviation and support improvements in metrics for quantifying and reporting effects;
- Propose appropriate mechanisms by 2012 for mitigating non-CO2 effects based on a consensus of scientific understanding;
- Continual improvement in technology towards the ACARE target of an 80% reduction in NOx emissions by 2020, based on new aircraft of 2020 relative to equivalent new aircraft in 2000.

In support of atmospheric research, British Airways is involved in a major European research project IAGOS (Integration of routine Aircraft measurements into a Global Observing System) to measure gases and aircraft effects in the atmosphere.

**5. Continental Airlines**

Continental Airlines is committed to promoting environmental responsibility within its culture. Continental recognises that greenhouse gas emissions are everyone's concern. It recognises the importance of directly addressing this issue.

The two primary means by which aviation contributes to global emissions are through aircraft operations and airport ground equipment, and Continental is committed to reducing emissions from these sources. In order to minimise the impact on the environment from its fleet and ground service equipment, Continental will continue to invest in the most effective technology and operating procedures feasible.

In addition, it will construct airport facilities in an environmentally-responsible manner and will continue to monitor the environmental impact of its business.

Today, Continental is nearly 35% more fuel efficient for every mile a passenger flies than in 1997. In order to further reduce emissions and increase fuel efficiency, Continental Airlines will continue to invest in efficient and advanced aircraft technology. It will also continue to apply responsible operating procedures to further reduce the impact of its fleet on the environment. Furthermore, it will work with national and international governments to improve air traffic control systems so that aircraft routings will result in fewer emissions.

Continental is committed to using electric rather than fossil-fuel-powered ground equipment wherever feasible. At its Houston hub, it has been using electric ground equipment since 2002 and it will have reduced its emissions from ground equipment approximately 75% by the end of 2007. It has begun a cold-weather test of this electric ground equipment at their New York/Newark hub. It is also testing the use of alternative fuel and fuel additives for ground service equipment.

Continental is committed to constructing its airport facilities in accordance with the US Green Building Council Leadership in Energy and Environmental Design (LEED) and Environmental Protection Agency Energy Star standards when feasible. As part of LEED, Continental will integrate high-efficiency components into facilities and implement programmes to conserve energy, save natural resources, reduce emissions and minimise the impact on the environment.

Continental recognises that the preservation of the environment is an essential part of its business practices. It is committed to promoting a culture that is focused on being environmentally sensitive as it works with its employees, customers, suppliers, industry organisations and the communities it serves in safeguarding the environment for future generations. In 2007, Fortune magazine named Continental one of the top 10 global companies across all industries in the Community/Environment category on its list of Global Most Admired Companies.

**6. Croatia Airlines**

The main actions taken by Croatia Airlines with the aim of caring for the environment are to reduce emissions of harmful gases that are the result of flying, among them most importantly carbon dioxide, and to reduce the level of noise in airports and the surrounding area occurring at take-off and landing.

Since carbon dioxide emissions are directly related to fuel usage, the airline pays special attention to fuel management. Reducing $CO_2$ emissions (and in the near future also costs related to $CO_2$ emissions, regarding contribution to the global climate changes), while reducing the cost of fuel purchase, which is the most important cost item for an air carrier,  make these activities economically fully sustainable.

The Croatia Airlines fleet consists of new A319/320 aircraft, which apply the most recent and advanced technology to reduce fuel consumption, gas emissions and noise levels, and the ATR 42, which use turboprop technology, again resulting in low unit fuel consumption. This has enabled the company to achieve major savings in fuel consumption, gas emissions (especially of carbon dioxide) and levels of noise.

The second important area of major change encompasses operating procedures or the use of advanced technologies for the purpose of reducing harmful effects to the environment. The basic training followed by pilots includes training on the application of operating procedures during take-off and landing to reduce noise levels, fuel consumption and $CO_2$ emissions. These procedures are followed by all the pilots wherever it is possible and after all the key safety conditions have been met, as recommended by international and national legal regulations.

Operating procedures to reduce noise at take-off are applied in airports that have passed appropriate regulations, i.e. in almost half of the flight network of Croatia Airlines (most foreign airports and that of Dubrovnik).

Special flying routes are used to lower the noise level. Procedures are used to lower the aircraft engine power levels at take-off wherever it is possible to do so, thus extending the useful life of the engine while at the same time saving fuel and reducing $CO_2$ emissions up to 25%. The effect achieved is considerable, since such procedures are followed in 95% of take-offs within the company flight network. Operating procedures lowering the level of noise at landing, which also result in fuel savings and $CO_2$ emission reductions, are followed in most domestic and foreign airports,. wherever it is possible to do so.

When planning a flight, a combination of flight planning programme (which specifies the optimum height and speed of flight depending on weather conditions) and Fuel Cost Index, which specifies the cost of fuel and duration of flight, make it possible to plan the flight to allow for optimum fuel consumption..

The advanced technology used in aircraft enables the pilots to additionally improve resource consumption during flights. Croatia Airlines pilots use these opportunities on a regular basis, adjusting the planned flight to the actual situation during the flight, in order to achieve savings by flying shorter routes and applying other procedures that result in lower fuel consumption, reduced emissions of harmful gases and lower noise levels. Pilots are offered annual refresher courses to upgrade their skills, which also include fuel management.

In the course of 2004, the company prepared and began applying the Flight Data Monitoring System, which makes it possible to monitor noise levels during each flight. Although no excessive noise levels were recorded in the year 2004, this kind of monitoring is necessary because the requirements are becoming more stringent not only in the congested European sky but also in domestic traffic, aimed at reaching sustainable tourism as well as the sustainable transportation in Croatia.

The company has defined basic procedures and work instructions regarding collection and disposal of hazardous waste, i.e. waste harmful to the environment. This is the result of complex activities undertaken by the technical sectors responsible for aircraft maintenance. The result is achieved in two ways:

1. Collection of waste within the company. Special containers have been provided for the storage of different kinds of hazardous waste (motor oil, fuel oil, batteries) and a cooled container with a double bottom for the storage of chemicals. Containers are kept in Zagreb, Split and Dubrovnik
2. Permanent disposal, carried out by a specialised company in line with legal requirements.

**7. Delta Airlines**

Delta Air Lines is partnering The Conservation Fund, a leading environmental non- profit organisation dedicated to protecting land and water resources, to become the first US airline to help its customers give back to the environment by buying trees to help offset carbon emissions associated with air travel. To kick off the programme, Delta is making a donation to The Conservation Fund for every customer taking a Delta mainline or Delta Shuttle flight on Earth Day, April 22, and is pledging a commitment to plant a tree for each of the airline's 47,000 employees.

Beginning June 1 2007, customers who purchase a ticket online at delta.com will have the option to contribute toward the offset of carbon emissions associated with air travel through a donation to The Conservation Fund. Contributions of $5.50 for a domestic roundtrip flight and $11 for an international roundtrip flight will be used by The Conservation Fund to plant trees throughout the US and abroad. A small portion of the donation also supports the organisation's education and outreach efforts.

The newly-planted forests will help to absorb carbon dioxide, filtre water, restore wildlife habitat and enhance public recreation areas. As the programme grows, Delta will invite its employees and customers to participate in ceremonial tree plantings in select cities worldwide.

Delta's new programme is just one of the airline's efforts to affect positive environmental change. Some of the airline's ongoing programs include:

- Fuel conservation/recycling initiatives such as weight-reduction efforts, engine washes, engine refurbishment, the institution of continuous descent approaches and industry leadership in single engine taxis with more than 25 million gallons of fuel saved in 2006 alone;

- A water consumption reduction system designed to reduce water consumption by 50% at the airline's Technical Operations Center (TOC). For its efforts to date, Delta received The Fox McCarthy Water Wise Award and recognition from the Georgia Association of Water Professionals;
- The incorporation of over 600 electric vehicles and other types of electric ground support equipment into the airline's fleet - all with zero emissions. Significant reductions in emissions have been achieved by converting internal combustion engines to zero emission electric units; and,
- Promoting a next generation Air Traffic Control (ATC) system – both in Europe and in the US – that affords more direct aircraft routing and subsequently results in the reduction of carbon emissions associated with air travel.

**8. easyJet**

The company's policy is to:

- Invest in new technology to have one of the youngest, cleanest and quietest fleets in the world;
- Have the highest levels of environmental efficiency - they emit 27% fewer emissions per passenger-kilometre than a typical traditional airline flying the same aircraft type;
- Monitor and reduce its environmental impact, and has published its Environmental Code to show how this will be achieved.

According to the Stern Review on the Economics of Climate Change, aviation CO2 emissions account for 1.6% of all global greenhouse gas emissions and are forecast to contribute to 2.5% in 2050. EasyJet supports the findings of the Stern review, and highlights that the contribution of the aviation industry towards global warming is significantly less than other larger polluters, even with the forecast increase in emissions by 2050. EasyJet believes that simply stopping flying would have little benefit on climate change.

easyJet strives to be efficient in the air and will do this by:

- Investing in new aircraft: It will grow its fleet using the latest technology aircraft whilst retiring older aircraft usually within 7 to 10 years of delivery. New technology aircraft are more fuel efficient than older models ;
- Efficient use of aircraft: A simple, automated pricing model means the company attracts more people to fly with it. Because it attracts more passengers per aircraft, its traditional rivals flying the same route with the same type of plane use 27% more fuel than easyJet;
- Avoiding congested hub airports: easyJet does not fly to congested hub airports, such as London Heathrow or Frankfurt Main. These types of busy hub tend to require aircraft to fly longer holding patterns and take more time to taxi to and from the runway, which uses more fuel;

- Focusing on short-haul travel: easyJet only flies to short-haul destinations. Their average length of flight in 2006 was 954 kilometres. A typical easyJet flight from London to Nice of 1050 kilometres creates emissions per passenger but these are considerably less than some long-haul flights, such as London-Miami (10 times more emissions), London-Singapore (16 times more emissions), London-Sydney (28 times more emissions).

easyJet strives to be efficient on the ground and does this by:

- Using shorter turnaround times: easyJet requires fewer gates and other airport infrastructure than other airlines;
- Minimal use of ground equipment: the company prefers not to use air bridges or motorised steps. Catering is loaded on to each plane no more than twice a day; cabin crew clean the aircraft, so there is no need to transport separate cleaning crews to the plane at every turnaround;
- Using simple airport infrastructure: There is one class of service and no cargo offering so the company doesn't need to have segregated check-in areas, complex baggage handling systems or facilities to transfer passengers from flight to flight;
- Keeping surface journeys to a minimum: easyJet only uses local airports with good public transport links;
- Minimising waste: paperless systems are used in the company's offices wherever possible; on board there is no free food that people don't want; and in aircraft maintenance the company uses chemicals, such as de-icers, that meet stringent environmental requirements and are biodegradable.

easyJet aims to help shape a greener future for aviation by:

- Using its role as the chair of the European Low Fares Airlines Association (ELFAA) environment working group to press for an EU Emissions Trading Scheme that will cover the largest carbon footprint, i.e. include flights both within Europe and all departing and arriving flights, as well as reward airlines that are environmentally efficient and penalise those that are not;
- Actively supporting the delivery of the EU's Single European Sky initiatives to improve the safety, reduce the cost and increase the productivity of Europe's highly fragmented and inefficient air traffic management system;
- Continuing discussions with aircraft and engine manufacturers to ensure that technologies developed for long-haul carriers will also applied to short-haul aircraft in the future.

**9. Fedex**

FedEx recognises effective environmental management as a global corporate priority, and is actively involved in environmental innovations and technologies designed to support this priority. In fact, FedEx is among the best Fortune 500 companies for its initiatives in environmental issues, according to the Council on Economic Priorities' Corporate Responsibility Profile for Environment.

Environmental Policy Statement: FedEx Corporation and its subsidiaries recognise that effective environmental management is one of its most important corporate priorities. It is committed to protecting and respecting the environment through outstanding environmental performance and efficiency in the conduct of its operations. As part of its ongoing efforts to attain this objective, FedEx will focus on the following initiatives:

- Commitment to a continual improvement process in environmental management;
- Evaluation of environmental impacts of FedEx packaging products, operations and facilities, with a commitment to minimise impacts and restore properties affected by its operations;
- Improvement of employee environmental performance through detailed policies and procedures, training, and recognition of excellence;
- Efficient use of natural resources to minimise waste generation through efforts that include recycling, innovation, and prevention of pollution;
- Measurement of environmental performance through auditing with employee accountability and reporting to senior management;
- Integration of environmental responsibilities and considerations into daily operations and business decision-making processes;
- Participation in the development of sound environmental policy within the transportation and business sectors;
- Commitment to emergency preparedness and response in order to minimise any potential environmental impacts resulting from day-to-day operations;
- Use of innovations and technologies to minimise atmospheric emissions and noise;
- Promotion of effective environmental management by FedEx suppliers and contractors;
- Compliance with all applicable environmental laws and regulations;
- Promotion of environmental policies to employees and the public.

FedEx is actively involved in efforts to promote cleaner air by reducing emissions through efficient route planning and the use of clean and alternative fuels. Its Environmental Management Department works to meet and exceed Environmental Protection Agency guidelines. FedEx Express maximises air and truck route efficiencies, reducing the depletion of natural resources and the amount of emissions from its fleet. The FedEx Express Global Operations Control (GOC) Center is one of the most sophisticated operations systems in the industry, tracking its air and truck fleets to ensure on-time delivery and efficiency throughout its entire global network.

FedEx Express complies with all international, federal, state and local air quality requirements and continues to consider ways to address environmental concerns.

FedEx Express is actively participating in a stakeholder process that is being led jointly by the US EPA and FAA, which is studying all of the sources of air emissions within the aviation industry in an effort to reduce air emissions. FedEx developed a proprietary “hush kit” in 1990, which significantly reduces engine exhaust and fan noise levels.
Compared to passenger airlines, FedEx has a lower utilisation of aircraft. In a 24-hour period, a FedEx aircraft traditionally completes only two take off/landing cycles. Commercial airlines complete numerous cycles during the same time period.

FedEx is sensitive to community concerns about airport noise and has been at the forefront of this issue for many years. FedEx Express has long supported a national noise policy that considers both the aviation industry and the neighbourhoods in close proximity to airports. It remains committed to upholding Federal Aviation Administration standards;

FedEx Express is concerned with aircraft noise and has taken steps to reduce noise levels for more than 10 years;

All FedEx Express aircraft meet all Federal Noise Certification Standards for its jet-powered aircraft and comply with FAA Stage 3 noise requirements. The company was one of the first airlines to commit to and complete all Stage 3 noise requirements by the year 2000;

FedEx was an active participant in a national task force that made recommendations on a national noise policy to the FAA, which led to US Congress passing the Airport Noise and Capacity Act of 1990;

In 1990, FedEx, working with Pratt & Whitney and Boeing, developed a proprietary noise reduction kit (also known as a “hush kit”) for Boeing 727s—the most common type of aircraft in the world's commercial fleet. These hush kits incorporate advanced noise-reduction technologies that significantly reduce engine exhaust and fan noise levels.

FedEx is committed to the use of innovations and technologies to minimise atmospheric emissions (greenhouse gases) from its operations and products. The switch from the FedEx Express Letter to its replacement, the FedEx Envelope, in late 1999, has reduced net greenhouse gases from its production by 12% annually;

FedEx Express is working with The Alliance for Environmental Innovation (an initiative of Environmental Defense) to develop a new generation of pickup-and-delivery trucks. The result of the Future Vehicle Project will be an environmentally- progressive truck that is 50 % more fuel-efficient (yielding a 33% decrease in greenhouse gas emissions) and produces 90% less air emissions of soot and smog;

In October 2004, FedEx Express announced that it will construct the largest corporate solar electric system atop its hub at Oakland International Airport. The 904-kilowatt solar array will provide approximately 80% of the peak load demand for the company's Oakland facility, and will add nearly one megawatt of zero-pollution electric generating capacity to the city of Oakland, California;

The retirement of Boeing 727 aircraft is reducing greenhouse gas emissions due to fuel burn efficiencies in new aircraft.

**10. Iberia**

Environmental protection is among Iberia's corporate priorities, taking into account environmental issues in all its processes and operations. Iberia´s present and future processes and operations will comply with the applicable legislation concerning the protection of the environment.

- Iberia undertakes to reduce to a minimum the harmful effects to the environment caused by its activities. This includes products and services contracted by Iberia from suppliers and other service providers;
- Iberia will encourage and promote the implementation of certified Environmental Management Systems in all those operational areas with significant environmental impact;
- Iberia will involve itself actively in national and international actions dedicated to resolving global environmental problems and to providing sustainable development. Iberia will support the development of public programmes and actions aimed at protecting, improving and raising awareness of the environment;
- Iberia will provide training, motivation and awareness-raising of its staff so that they carry out their duties with environmental responsibility;
- Iberia will periodically carry out environment audits on its environmental management systems and will continuously improve their performance.
- Iberia will promote open dialogue with its employees and with the public at large in areas relating to the environment and will provide information on its environmental actions.

One of the main impacts of the aviation sector is constituted by the atmospheric emissions from jet engines, not only at a local level around airports but also at a global level with regard to emissions generated during the cruising phase. The aviation industry is constantly seeking alternatives that can help to reduce these emissions through research, development and co-operation initiatives. Iberia actively participates in these efforts.

Aircraft emit gases and particles directly to the upper and lower troposphere, thus altering the atmosphere's composition and contributing to the greenhouse effect. At the same time, ground support vehicles, equipment and maintenance facilities also affect air quality in and around airports.

Nowadays the impact of the emissions due to air traffic is relatively small compared to other sources of greenhouse gas emissions. The greenhouse gas with the highest incidence is carbon oxide (CO 2) and the contribution of air traffic in the emissions of such gas is around 3-4% of the total emissions.

Iberia encourages the development of Environmental Management Systems in order to control and reduce harmful effects from its activities, through the carrying out of procedures to minimise the impact in each one of the stages of air transport service provision. Iberia´s Airports Division has certified its Integrated Quality and Environment Management System, ISO 9001:2000 and ISO 14001:1996, by AENOR, for the activity of passenger and ramp handling in the 39 national airports, with a total of 8,000 employees affected;

In 2004 Iberia obtained its certification for its Environmental Management System ISO 14001:96 in the area of aircraft maintenance at the installations in Madrid (La Muñoza). Throughout 2005 the migration from ISO 14001:96 to ISO 14001:2004 has taken place. Iberia has given information to its employees about the innovations and implications (i.e. change in the procedures).The certification of the ISO 14001:2004 in "La Muñoza" is one of the certificates with the greatest scope granted by AENOR in terms of surface area affected, variety and number of environmental aspects, as well as the number of people involved (4000 employees). With this second certificate, the main areas of the company with a relevant impact on the environment are covered by environmental management systems (67% of the ground staff).

**11. JAL**

The JAL Group Basic Environmental Policy and Action Guidelines:

The JAL Group, fulfilling its mission as a public transportation organisation, generates environmental impacts such as consumption of fossil fuels and noise emission. It recognisesthat approaches to the environment are vital management issues, and therefore aims for symbiosis with the global environment and strives to contain the environmental load in all its business activities.

In accordance with the Basic Environmental Policy, the JAL Group will follow the action guidelines described below in all its business activities and disclose its contents and end results.

The JAL Group Environmental Action Guidelines:

- JAL will comply with environmental laws and regulations and make proactive approaches to the environment;
- JAL will promote the efficient use of various energy sources and resources;
- JAL will promote waste reduction and proper waste disposal and recycling;
- JAL will select environmentally- friendly products, materials and the like including aircraft;.
- JAL will enhance environmental awareness and make social contributions.

Based on Sky Eco [2010] (JAL Group Mid- and Long-term Environmental Action Programme), the following have been identified as major action programmes for FY2004.

Environmental Action Programme for FY2004 established March 2004

Priority items

Promotion of environmental management:

- Build environmental management systems
- Environmental auditing
- Environmental accounting.

Action Programmes:

- Acquire ISO 14001 or equivalent environment management system certification for two or more sites within the group;
- Carry out environmental audits of major airport stations in Japan;
- Carry out environmental accounting of the entire group, including Japan Airlines Domestic and its affiliated airlines.

Prevention of global warming

- Reduce $CO_2$ emissions from aircraft
- Reduce thermal and electric energy consumption
- Promote use of GPUs

Action programmes:

- To attain mid-and long-term objectives, continue to introduce new aircraft that consume fuel more efficiently, and other concrete fuel reduction measures;
- Achieve a reduction of 1% from the previous year in annual thermal and electric energy consumption by Japan Airlines International and Japan Airlines Domestic;
- Establish a system to grasp thermal and electric energy consumption of the entire group;
- Actively use mobile GPUs to increase the GPU usage rate.

Prevention of air pollution

- Introduce low-pollution, low-emission vehicles

Action programmes

- Promote introduction of low-pollution and low-emission vehicles;
- Proactively establish a system to grasp the annual fuel consumption and travel distance of all the vehicles used by the group.

Promotion of resource recycling

- Reduce wastes and promote recycling
- Use resources efficiently
- Green purchasing

Action programmes

- Promote recycling of uniforms;
- Promote recycling of polluted sludge into cement;.
- Promote 100% recycling of paper through sorted collection;
- Promote recycling of in-flight wastes;
- Reduce water usage by 5% from a year ago;
- Promote green purchasing in Cabin Attendants, Cargo and Mail, Engineering and Maintenance and other divisions and manage the results;
- Promote use of environmentally-friendly products for cabin service goods;
- Achieve an 80% or higher green purchasing ratio cost-wise of stationery and office supplies for Japan Airlines International and Japan Airlines Domestic. Also grasp the tabulation results and performance of the group.

Management of chemicals

- Promote integrated MSDS management by using the Intranet and also strive to unify the management system to grasp the amount of chemical transfers;
- Reduce the total use and emission of PRTR Law-regulated chemicals by 4% or more from FY2001 levels.

Environmental communication

- Publish an Environmental Report
- Utilize the Intranet
- Promote environmental education

Action programmes:

- Include views of field staff in charge of environment in the Environment Report. Also, introduce activities of group companies other than Japan Airlines International and Japan Airlines Domestic;
- Actively disclose environmental data of the group;
- Capitalise on the Intranet and update information for sharing environment-related knowledge and information among Group employees;
- Establish an education programme by identifying the educational needs, by job type and job title.

Environmental social activities

- Launch new social activities related to natural environment protection;
- Promote the development of a new Tropospheric Observation Project by extending the current project, aiming for commencement of the project in FY2006;
- Co-sperate in the Siberian forest fire prevention project.

**12. KLM**

KLM is working on a sustainability policy, aimed at the creation of economic prosperity, social value and a quality environment. KLM endeavours to achieve its corporate goals by maintaining an equal balance between these three pillars. This involves the conservation of opportunities for future generations to realise their primary needs, such as the need for mobility, income, good working conditions and deployment opportunities and a high-quality living environment.

The sustainability policy endeavours to find a balance between:

- The economical dimension. KLM strives to deliver added value to customers, employees and shareholders. The economic interests of aviation are farther-reaching. Both the regional and national economies are dependent on the availability of a reliable international network;
- KLM's social policy. Reliable, punctual, caring and friendly. These are the KLM values that are central to everything that the company does. They characterise its service and its relationships with customers, employees and the environment;
- Caring for the environment. Pressure on the environment has increased with the growth of the aviation industry. KLM constantly strives to improve environmental impact by investing in new aircraft, the adaptation of business processes and by adopting an environment-conscious purchasing policy.

KLM considers sustainable development to be a continuous process, without a set destination. Today's economic realities make this process even more challenging. Assuring the continuity of the company always remains the first requirement when creating social and ecological values.

Environmental Management

Commitments:

- Compliance with environmental regulations and ISO 14001;
- Commitment to Good Environmental Practice (GEP).

2005-06 Actions:

- ISO 14001 re-certification for next 3-year period;
- Implemented GEP at 9 outstations.

Next Steps:

- Implement ISO 14011 standard and assure compliance and enhance supply chain management;
- Implement GEP at all KLM outstations.

Climate Change

Commitments:

- Limit environmental impact of aircraft, reducing CO2 per passenger-kilometre;
- Improve the energy efficiency of ground operations.

2005-06 Actions:

- Introduce new fleet of A330-200s;
- Reduced weight of catering products (by optimised loading, adjustments of trolleys etc);
- Implement the 41 measures itemised in action plan.

Next steps:

- Continue fleet renewal and weight reduction measures;
- Multi-discipline working group to investigate how to further optimise fuel consumption. Focus on Engine Waterwash project, flight planning with optimum cost index, and optimising the calculation of zero fuel weight;
- Continue implementation of energy-efficient ground operations, further improve energy efficiency by approximately 20% by 2007.

Local Environment

Commitments:

- Control local emissions through fleet renewal;
- Operate within noise limits and reduce noise levels as much as possible;
- Minimise waste

2005-06 Actions:

- Introduce new A330-200 aircraft and 15 ground-support machines;
- Develop 4-pillar noise policy;
- Participated in sound-proofing programmes and in pilot projects on reducing noise;
- Improved waste separation (eg by using plastic foils).

Next Steps:

- Continue with fleet renewal and renew Ground Support Machines in accordance with 3-year plan;
- Participation in plot projects, sound-proofing and noise reduction operational procedures (eg reduced flap approach and continuous descent approach at night);
- Continue with waste prevention and separation at source.

**13. Korean Air**

Korean Air continues to develop and grow with a focus of harmony between the environment and air travel. Based on its environment-conscious management, Korean Air joins in environmental conservation efforts that span the globe, and has established the following environmental policies to advance its social responsibility standards:

- Activation of environment-friendly management practices;
- Assessment, prevention, and management of potential environment-harming elements from business activities;
- Pursuit of ongoing environmental pollution prevention and environment improvement efforts;
- Environmentally-friendly use of natural resources and rise in resource recycling;
- Adherence to environment-related laws and rulings as well as establishment of strict internal environmental standards;
- Improvement of environment-related reliability via transparent environmental management activities;
- Sharing of environmental information through training and fostering of environmental awareness among all employees;
- Continued expansion of local social environmental protection activities.

Environmental management system

All facets of the environmental management system of Korean Air, including general head office activities as well as those related to aircraft equipment, aerospace, in-flight meals, hotels, etc. are recognised with ISO14001 certification. Each division establishes a detailed plan of activities in stages based on the overall environmental policies, and through subsequent implementation and ongoing improvement cycles, the negative environmental impacts resulting from various business activities of the company are reduced.

Environmental accident countermeasure system

Various environmental accident scenarios are identified and subject to mock-up training in order to raise employee awareness and to minimise the resulting damage, should such an accident occur. In addition, via close co-operative links maintained with related organisations - such as the Ministry of Construction and Transportation, the Korea Airports Corporation, and various regional anti-pollution organisations - large co-ordinated responses are possible if necessary.

Environmental education

To enhance overall environmental management capability, periodic environmental training sessions are held for all employees to increase their environmental awareness, and much effort is being invested in fostering environmental specialists who pass through a programme of conservation courses. Moreover, employees are encouraged to become more familiar with domestic and international environmental trends and issues by attending outside training programmes, seminars, and workshops.

Global environmental protection activities

In May 2004, to assist in environmental protection activities and the reduction of environmental damage seen every year by the blowing of massive dust clouds from the vast Gobi Desert across the Asian continent, Korean Air visited the Baganuur region of Mongolia and commissioned the creation of a lush forest. As part of a "training abroad" programme, 102 new Korean Air employees travelled to Mongolia last year carrying approximately three thousand poplar trees to plant in this forest. The forest continues to be well maintained, and is planned for expansion in the future.

Environmental impact:

In order to minimise the company's impact on the environment, Korean Air purchases the latest, quietest and most fuel-efficient models of aircraft, while improving service procedures and investing in environment-friendly maintenance technologies. .

With the establishment of a vision for its environmental stewardship, that of "improving the quality of life through the harmonisation of aviation and the environment," Korean Air pursues sustainable growth while decreasing the impact of its operations on the environment. It actively participates in worldwide efforts to improve the environment, strives to meet increasing demand for aviation safety and security, and has adopted environmental management practices aimed at enhancing its operating processes, all the while aiming to fulfil Korean Air's corporate responsibilities in terms of environmental stewardship.

Impact of aviation on the environment:

Airlines have continued to make efforts to decrease the impact of their operations on the global environment and in recent times, such efforts have begun to show results. For example, many airlines, including Korean Air, have invested in efficient new aircraft and have improved operational procedures to achieve economic and environmental goals, resulting in reductions in oil consumption, fuel emissions and noise.

Fuel efficiency of aircraft:

Today's aircraft are 70% more fuel efficient than those of 40 years ago and over 20% more efficient than those of 10 years ago. The latest aircraft use a mere 3.5 litres of fuel per 100 passenger-km, resulting in reductions of CO emissions by 50% and HC emissions by 90% compared to previous models.

Noise:

Today's most advanced aircraft are 20dB quieter than those of 30 years ago, commonly perceived as a reduction of 75% .

Sustainable future:

Aircraft manufacturers are currently investing in R&D efforts aimed at improving fuel efficiencies by more than 50% by 2020, curtailing NOx emissions by more than 80%, and reducing noise during takeoffs and landings by more than 50%. Korean Air plans to add fuel-efficient, next-generation aircraft such as the A380 and B787 to its fleet, as such aircraft consume just 3 litres or less of fuel per 100 passenger-km.

Major environmental impacts of airlines:

Because the development of environment-friendly fuels to replace conventional fuels for aircraft is expected to take place over a long period, and because the global demand for airline travel is growing at around 4% every year, the most immediate and effective way to minimise environmental damage from aircraft fuel emissions is to put the most advanced, fuel-efficient aircraft into service. The latest models of aircraft also operate at reduced noise levels, decreasing the impact on neighbourhoods and areas adjacent to airports. Korean Air makes continued efforts to reduce its impact on the environment with purchases of new, fuel-efficient aircraft, improvements in service procedures and investments in environmentally-friendly maintenance technologies.

Use of fossil fuels:

Replacing Old Aircraft with New Models:
The average age of aircraft in Korean Air's fleet in 2005 stood at 7.3 years, much lower than the average of 11.3 years of other IATA members.

Takeoffs and landings:

Although Korean Air's fleet of aircraft make much less noise than in the past, noise pollution remains a concern of communities in close proximity to airports. During takeoffs and landings, gases emitted below an altitude of 900m contain $CO_2$, CO, HC, and $NO_x$, all of which negatively affect air quality around airports.

Aviation and a sustainable future:

All operations of an airline including flights, cabin services, aircraft maintenance, ground support activities and sales have an impact on the environment. In particular, airlines burn non-renewable fossil fuels, which have an effect on climate change and on the quality of air in local communities. Additionally, aircraft takeoffs and landings create noise pollution in communities adjacent to airports.

Korean Air fully understands that it must balance the demand for global air travel with a consideration for the impact of its operations on society and the environment. Korean Air's goal is to secure social, economic and environmental sustainability while remaining interdependent and balanced in its approach to the environment.

Environmental management system:

Korean Air seeks to fulfil its corporate responsibilities through environmental management practices.

In committing to uphold its corporate responsibilities, Korean Air has adopted a number of environmental policies. The company aims to prevent potential damage to the environment through environment-friendly processes and procedures. Korean Air also seeks to use environmentally-friendly resources, to recycle waste resources, and to abide by all relevant environmental laws and regulations.

Operating the environmental management system:

Outcomes of EMS operations:

Korean Air received its first ISO14001 EMS certificate in 1996 and its third re-certification in 2005. In the most recent re-certification in 2005, Korean Air changed its certifying organisation to the BSI (British Standards Institute) so as to receive more objective evaluations and advice concerning improvements to the EMS. Korean Air endeavours to establish an increasingly effective EMS, while meeting the requirements and expectations of the certification organisation.

Evaluation of environmental impacts:

Korean Air conducted company-wide environmental impact evaluations in 2005 and found a total of 54 important environmental impacts. Korean Air then responded with various measures designed to decrease the airline's impact on climate change, to increase the recycling of wastes while saving energy, to replace the use of hazardous chemical materials, to reduce the amount of emissions from vehicles and to provide support for local communities.

Korean Air established and implemented detailed goals as put forth by individual departments (a total of 66 environmental goals) and realised 62 of the goals.

Korean Air has established emergency response systems at airports and devised regulations for the operation of such systems. It also created an organisational chart for emergencies and placed emergency equipment in appropriate locations so as to be able to respond rapidly and effectively to emergencies. Though saving lives is their first and foremost priority in any emergency, it also strives to minimise environmental pollution.

In order to minimise damage in the event of an accident, Korean Air conducts mock drills and evaluates the readiness of all emergency procedures on a regular basis. Korean Air has also established an environmental response centre to respond to incidents involving the environment and organised an environmental emergency taskforce team. The team's mandate includes the handling of social problems arising from environmental issues and petitions.

2006 Major environmental management plans

Korean Air is in the process of building an environmental performance evaluation system. In order to respond to the United Nation’s Framework Convention on Climate Change, it wwas aiming to develop, by the end of 2006, a system to manage its levels of greenhouse gas emissions and reinforce its online environmental education system and its global communications regarding the environment with the publication of a sustainability report. Korean Air’s mid- to long-term environmental management goal is to integrate the characteristics of airlines into its current EMS. Notably, Korean Air is in the process of introducing new environmental accounting standards and performance evaluations.

After building an integrated fuel management system covering all sectors including flight operations, maintenance, general controls, passengers, cargoes, and in-flight meals, Korean Air took active measures to deal with the world's highest-ever oil prices so as to manage and save fuel efficiently.

Aircraft fuel:

Korean Air seeks to reduce fuel consumption with the introduction of new, highly efficient aircraft. With the development of new engine technologies and improvements in fuselage mechanics, fuel efficiency has improved by 70% or more since the 1970s. Of late, airpcraft have become a more environmentally-friendly means of transport as the latest models consume a mere 3.5l of fuel per 100 passenger-km and emit significantly less CO2, one of the main culprits of global warming. In addition to its economic responsibilities, Korean Air is making every effort to improve the environment for future generations as part of the company’s social and environmental responsibilities and commitments.

Fuel consumption:

In 2005, Korean Air’s consumption of aircraft fuel totalled 4,236,959 kilolitres, an increase of approximately 2.5% from 2004. CO2 emissions also rose at roughly the same rate as fuel consumption to 1.081 million tons. However, the fuel ratio or fuel consumption per 100RTK, stood at 33.48l, a small 1.87% increase over the previous year. The company attributes this outcome to company-wide efforts at reducing the consumption of fuel, including the steady introduction of advanced aircraft and improved flight procedures.

Fuel efficiency:

The International Air Transportation Association (IATA) established common goals for all member airlines, which aim to raise fuel efficiencies for all new aircraft by 26% or more between 1990 and 2012. In particular, member airlines are expected to achieve improved efficiencies of at least 10% from 2000 to 2010. The fuel efficiency of IATA member airlines in 2005 was 41.12l per 100RTK or 7.5% higher than the original goal. Korean Air's 33.48l per 100RTK in 2005 was 22% higher than the average efficiency of IATA member airlines.

Fuel-saving activities:

After building the integrated fuel management system covering all sectors including flight operations, maintenance, general controls, passengers, cargoes, and in-flight meals, Korean Air took active measures to deal with the world's highest-ever oil prices so as to manage and save fuel efficiently. In 2005, it proceeded with 50 fuel-saving projects in all sectors with an overall aim of saving KRW30 billion in fuel costs. As a result, it succeeded in saving KRW34.6 billion, and consumption per hour of flight decreased remarkably while improving at a rate of 2.4% for passenger planes and 0.4% for cargo planes.

Establishment of fuel management system:

Korean Air has sought to establish a fuel management system for all its operations. The company utilises the system to oversee relevant activities in its core sectors. To enhance the system, Korean air integrates the 6-Sigma methods, the recommendations of the ICAO/IATA, systematic methods of analysis and an FTS (Fuel Tracking System). In addition, Korean Air has standardised and systemised all management tasks and these are outlined in a new company-wide fuel management manual. The company has optimised its fuel management system to reduce short-term fuel costs by sharing relevant information with other airlines through a fuel management network built on global standards.

Regular washing of engines:

During flights, air pollutants and minute particles of dust build up inside an aircraft engine. This build-up begins to impede the engine's compressors, decreasing efficiency. To counteract such problems, Korean Air has instituted the regular washing of engines with water to maintain the efficiency of compressors and the power of engine outputs. The result has been an elevation in fuel efficiencies by 0.5% and fuel cost savings of approximately KRW3.9 billion, while cutting down on $CO_2$ emission.

Aircraft modernisation:

Korean Air continually introduces new aircraft, in line with company policies on modernisation and unitisation. It is currently in the process of replacing B747s, its main aircraft for long-distance routes, with the latest B777s, and the A300-600 models, used for mid- to long-distance flights, with A330 models. In addition, it has completed the replacement of older F100 and MD80 models, used on short-distance routes, with the latest B737s. The fuel savings improved with these replacements by 17% on average.

Replacing old aircraft with new models:

The average age of aircraft in Korean Air's fleet in 2005 stood at 7.3 years.

Korean Air endeavours to observe global environmental regulations, minimise noise and reduce emissions while upholding its social and environmental responsibilities. In purchasing new aircraft, Korean Air holds to strict standards in terms of noise and gas emissions. It also selects engines that meet and exceed current international environmental standards while predicting its future operational needs and requirements for when the aircraft is to be delivered. Because the upholding of environmental standards is essential to Korean Air, it always secures warranties in contracts to guarantee the maintenance of environmental standards.

Over the past 40 years, the aviation industry "has decreased emissions by more than 70%." Since that time, with many areas of the world developing rapidly and consequent rises in living standards, demand has increased for airline services as people seek a better quality of life. With an eye towards satisfying demand for airline services while minimising the impact on the environment, Korean Air strives to modernise its aircraft and raise efficiencies in its transport operations as a matter of policy. Its efforts to reduce consumption of fossil fuels and curtail emissions are part of the overall effort to promote the sustainable development of the company while reducing the impact on the environment.

Convention on climate change and the aviation industry

Jet engine fuel takes up a large portion of an airline's total costs. Korean Air endeavours to meet and exceed global regulations regarding fuel consumption and the emission of greenhouse gases by modernising aircraft, harmonising transport networks, raising load factors, improving procedures, and curtailing the weight of loads.

Emissions by division:

However, increasing demand for airline services has continued to push fuel consumption totals ever higher. Korean Air seeks to reduce fuel consumption by taking advantage of technological developments and by improving operating procedures. The Kyoto Protocol obliges domestic airlines to decrease the amount of emissions of greenhouse gases, but does not include emissions of such gases by international airlines due to the special characteristics of international flights. The UN's ICAO is currently seeking to establish global policies on global warming gases in the aviation sector, targeting the year of 2007 for the release of the new standards, and although the ICAO is in the process of reviewing an emissions trading system to reduce aircraft emissions, a number of technological problems remain to be solved.

Emissions of greenhouse gases in Korea (by industry):

The amount of CO2 emissions by Korean Air's domestic operations amounts to 0.2% of Korea's total CO2 emissions and 1% of the total in the transport sector. If emissions by Korean Air's international operations are included, (they are currently excluded from the Kyoto Protocol), the company emits around 2% of Korea's total CO2 emissions.

Emitted gases/pollutants:

With an eye towards satisfying demand for airline services while minimising the impact on the environment, Korean Air strives to modernise its aircraft and raise efficiencies in its transport operations as a matter of policy.

Emissions by aircraft and support vehicles/equipment

Aircraft produce emissions during flights and while operating on the ground using an APU (Auxiliary Power Unit). The amount of emissions produced varies depending on the conditions at takeoff and landing and at cruising altitudes of over 900m. The main greenhouse gases emitted by aircraft are CO2 (71.7%) and water vapours (28.2%). The total CO2 emissions include figures of operation both domestic and international aircraft (including leased ones).

Emissions during LTO (landing and takeoff) cycle:

An LTO cycle includes aircraft takeoffs, landings and movement below 900m in the vicinity of an airport. During the cycle, aircraft emit gases such as NOx, HC, and CO, which affect air quality in nearby communities. Over the past 40 years the development of aircraft engine technologies has led to a 50% decrease in CO emissions and a 90% decrease in HC emissions during the LTO cycle. Korean Air strives to minimise local air pollution by adhering to LTO regulations and procedures and by minimising the use of aircraft engines on the ground.

Although RTK increased 47.6% from the year 2000, Korean Air's fuel consumption increased by 31.67% over the same period due to the company's efforts to raise fuel efficiency and load factors. The unit price growth rate (kg-CO2/*100RTK), instead, was reduced by 9.47%.

The maximum limits for aircraft engine emissions of HC, NOx, and CO are set by the ICAO which oversees regulations and set higher standards. Furthermore, at the sixth meeting of ICAO's CAEP (Committee on Aviation Environmental Protection), the committee decided to apply a 12% stricter NOx emissions limit for new engines than the current standards starting in 2008.

Currently, 56.9% of Korean Air's aircraft engines already conform to the new NOx standards.

NOx emissions from operations:

NOx emissions resulting from Korean Air's operations make up 1.3% of the total NOx emissions from industrial activities in Korea. At the same time, the potential detrimental effects of NOx emissions on the ozone layer and on climate change have yet to be proven conclusively by the scientific community.

Aircraft noise:

Korean Air strives to minimise noise by introducing the latest models of aircraft and by diversifying flight procedures in accordance with prevailing conditions and aircraft performance. Korean Air endeavours to decrease noise with the introduction of the latest aircraft and the application of advanced operating procedures.

Noise pollution caused by the aviation industry has a significant effect on social and natural environments. Most residents living near airports regard noise from takeoffs and landings to be a more serious environmental problem than air pollution or the effect on climate change. Noise pollution in the vicinity of airports can be classified into engine noise during takeoffs and landings, engine noise from tests on the ground, noise from APUs (Auxiliary Power Unit) and GPUs (Ground Power Unit), as well as noise from support vehicles. In order to reduce noise pollution, Korean Air purchases quieter, more advanced aircraft while retiring older, noisier airplanes. Korean Air also strives to do its best in following operational procedures that minimise noise.

Aircraft development and ICAO noise reduction policies

In comparison to aircraft of the 1960s, technological advancements such as the development of better engines, enhanced fuel efficiencies and improvements in operating procedures have contributed greatly to the curtailing of aircraft noise over the last several decades. During takeoffs and landings, today's aircraft are quieter than their predecessors of 40 years ago by 20dB or more.

The ICAO began regulating noise levels of civilian aircraft in 1969 and since that time, the organisation has continued to revise its regulations on a regular basis. Currently, approvals of all civilian aircraft are subject to Chapter 3 standards as set forth by the ICAO. However, aircraft seeking approval from 2006 are expected to conform to Chapter 4 standards, which are 10dB lower than the current Chapter 3 standards. Korean Air's fleet consists of 116 aircraft, and of these, 114 or 98% conform to Chapter 4 standards. The remaining aircraft, two B747-200F cargo planes meet Chapter 3 standards, but are slated for retirement in the near future.

A noise footprint indicates the extent of the geographical area affected by noise from aircraft during takeoffs and landings. Technological developments in engines and air dynamics have significantly decreased the extent of the areas affected by aircraft noise.

Engine test noise countermeasures:

Engine tests on the ground are first conducted in an engine test cell before being tested at an aircraft run-up shelter. The engine test cell, which includes noise prevention facilities for performance tests, is used to test an engine after maintenance and before being fitted on an aircraft. An aircraft run-up shelter is an outdoor fence-type facility where an aircraft's engines are checked.

Korean Air recognises the need to minimise the impact of its aircraft on the environment. Thus the airline continues to modernise its fleet by introducing the latest and most advanced models. Korean Air has been replacing its older model B747-200 cargo planes with B747-400ERFs, which are 20% or more quiet during takeoffs.

Ground support activities:

Korean Air closely scrutinises its impact on the environment not only in its flight operations, but also in its ground operations. Korean Air's maintenance and ground support operations also have an impact on the environment and it is crucial that such impacts are minimised. To this end, Korean Air monitors, adjusts and makes necessary changes to procedures. It has introduced a variety of facilities to enhance operational practices and concerted efforts to reduce energy consumption.

Utilisation of GPU and energy usage:

Korean Air's ground operations contribute to the emission of various gases due to the burning of fossil fuels during engine tests, the use of APUs (Auxiliary Power Units) and GPUs (Ground Power Units), and the operation of flight-support vehicles. Two methods are used to supply power, cooling and heating services to aircraft on the ground. One method is via the APU on each aircraft and the other is via the mobile GPU. The problem with the APU is that such units consume a relatively large amount of fuel and create more emissions than do mobile GPUs. For this reason, Korean Air uses GPUs for most ground support activities, whenever possible. GPUs create less noise than APUs, thereby contributing to a quieter environment at airports. In addition, since June 2005, it has adopted a new and more environment-friendly system that uses a GPS (Ground Power Service) and PC-Air (Pre-Condition Air) system in boarding bridges to meet energy needs on the ground.

Other environmental activities

Watertight management systems secure safety and protect the environment. Korean Air effectively monitors the impact of its operations on the environment through stringent environmental management practices. Every year, Korean Air undertakes evaluations of the impact of its operations on the environment and on communities to find ways to minimise such impacts. Work includes soil surveys to determine pollution levels, the management of wastes, wastewater and hazardous chemical materials.

Waste:
Korean Air's aircraft maintenance, general operations and transport services produce various types of waste, which can be categorised as either general waste, mainly from transportation services, or industrial waste, mainly from maintenance work reflecting the special characteristics of worksites. Food wastes from in-flight services are incinerated to ensure safety and sanitation, and other wastes such as paper, wood, cans, and plastic bottles and so on are separated and recycled. The amount of wastes produced by Korean Air in 2005 stood at 19,521 tons, of which, 7,436 tons was recycled.

Korean Air Chemical Management System (KCMS):

Most of the chemical products used in aircraft maintenance are pre-selected by aircraft manufacturers. In order to decrease the impact of such chemicals on the environment, Korean Air aims to use more advanced and environment-friendly products in its maintenance operations, and it does so by facilitating a steady exchange of information with the manufacturers of its aircraft. Korean Air currently uses about 1,200 different types of chemical products in its aircraft maintenance programmes. In 2005, it developed the KCMS in order to integrate and manage, via the internet, a wide range of chemical materials used at various worksites.

The KCMS offers user-friendly information on products and materials, in addition to detailed information on the proper handling and storage of chemical materials. The system utilises such real-time information to process permit applications for the import of chemical materials, helping to streamline and integrate the purchase of required products.

Wastewater treatment:

Korean Air operates 11 wastewater treatment centres, which are capable of handling a maximum of 3,243 tons of wastewater a day, in order to protect water resources from pollution. Korean Air's standards for discharges are stricter than current legal standards while its TMS (Tele-Metering System) monitors wastewater treatment processes at all workplaces on a real-time basis.

Washing of aircraft:
Korean Air washes its aircraft on a regular basis to protect painted surfaces and remove environmental pollutants such as yellow sand from exposed metal. Aircraft are washed in an exclusive 70 sq metre space using strong, yet environment-friendly detergents made from natural solutions. All wastewater from the washing of aircraft flows into a wastewater disposal facility and undergoes several reprocessing procedures.

Anti-icing and de-icing:

In winter, to ensure flight safety, snow or frost on aircraft needs to be removed prior to takeoff. The anti-icing and de-icing fluids used for such removals contain propylene glycol, which becomes a component of the waste leading to contamination of the water used in the process. The amount of fluid used is dependent on the frequency and amount of snow. Wastewater is collected using a special water absorbent pad and vacuum and handled by contractors specialising in such materials.

Gimpo Airport has built and utilises seven anti-icing and de-icing worksites at its hardstands. Anti-icing and de-icing worksites were included in the design stage of the Incheon International Airport and sites were built near runways so as to decrease flight delays and to prevent anti-icing and de-icing fluids from flowing into drains.

**14. Lufthansa**

Group-wide environmental organisation

In the course of its activities Lufthansa consumes energy and natural resources and generates waste and emissions. To keep these effects on the environment to the strict minimum, Deutsche Lufthansa AG has set up a group-wide environmental organisation. Since 1995, there have been Environmental Commissioners or contact persons for environmental issues in each relevant management department – at the group level and at all wholly-owned Lufthansa subsidiaries. In 1996, Lufthansa adopted Guidelines for Environmental Protection with company-wide validity.

All contact partners for environmental issues meet regularly at the group-wide Environmental Forum to confer about shared goals and activities in the area of environmental care and to exchange experiences.

Systematic environmental management:

All operational processes and activities with an impact on the environment are systematically captured, documented and evaluated at the Lufthansa Group. The basis for this work is a comprehensive database. Every year, the latest data from all Group companies concerning energy and kerosene consumption, emissions, noise, waste materials, freshwater consumption and wastewater volumes are fed into this database. Also captured are important personnel ratios and economic data. Based on this data, the environmental experts at Lufthansa calculate important ratios, which are used to continuously improve the Group's environmental performance. In 1996, Lufthansa Technik "became the first company in the aviation maintenance industry to introduce an environmental management system based on the European eco-audit regulations EMAS." Three years later, the company also obtained certification according to the international environmental standard

ISO 14001. Lufthansa CityLine has operated an environmental management system since 1999; it comprises all of the company's areas and its three locations. CityLine remains the world's only airline to be certified in accordance with both EMAS and ISO 14001.

As the mobility of travellers and goods increases, the burdens placed on nature and the environment grow accordingly. This is why Lufthansa has long since aimed at limiting the effects of its activities on the environment as much as possible. At Lufthansa, a comparison of transport performance and environmental pollution demonstrates that increasing needs of mobility do not necessarily mean a proportionate increase in fuel consumption and emissions.

Lufthansa increases efficiency and reduces emissions:
Since 1991, the companies within the Lufthansa Group have been able to continuously decouple their transport performance from environmental effects. While transport performance increased by more than 218 %, kerosene consumption rose by 116.5%. Half of the airline's growth was therefore realised without additional burdens on the environment.

Decoupling of transport performance and environmental burden

Lufthansa has its sights set on further efficiency goals: the passenger fleets' specific fuel consumption is to be reduced by 33% from 1991 to 2008, and by 38% from1991 to 2012. Associated with this goal is a simultaneous reduction in the specific emissions of carbon dioxide. In 2005, Lufthansa's passenger fleets achieved a reduction of 29.2%. The specific emissions of carbon monoxide (CO) per 100 passenger kilometres measured in 2005 were the lowest values ever recorded at the airline. The previous year's low emissions level for unburned hydrocarbons (UHCs) was maintained in 2005. While specific emissions of nitric oxide (NOx) increased, they were still significantly below the levels customary until 2002.

**15. Monarch Airlines**

There have been many reports in the media about aviation's contribution to global warming and its impact upon the environment. Monarch takes its environmental responsibilities seriously and is continuing to take steps to improve its environmental performance.

Sustainable Aviation:
Whilst emissions trading is supported as the best way forward for the environment and the industry, its implementation is a few years away. As a more immediate step, Monarch has signed up to an initiative within the UK called 'Sustainable Aviation' (details can be found at www.sustainableaviation.co.uk). This grouping of airlines, airports, manufacturers and air traffic control is seeking to respond to the challenge of building a sustainable future. Mindful that currently foreseen technological advances will not on their own be sufficient to offset the emissions increases associated with projected growth, the industry recognises that it must find new

approaches to address the effects on the environment. A range of measures including operational and market-based controls has to be considered.

Carbon offsetting:
Monarch has made it possible for each individual passenger to pay, or offset, the impact of their carbon use by funding a range of projects through an organisation called Climate Care. Information about the projects, as well as a carbon emissions calculator, is available on www.climatecare.org/monarch

Fuel efficiency:
Since there is currently no proposed alternative to kerosene for powering the jet engine, Monarch continues to look to operate its aircraft in the most efficient manner possible. One of its early commitments to Sustainable Aaviation was to provide details on the fuel efficiency of its operations. In order to permit a comparison between freight and passenger operations, signatories to Sustainable Aviation have agreed to use the common metric of the amount of fuel consumed in litres to move 1 metric tonne of payload over 1 kilometre.

Monarch's results for 2005 (the first full year of operation since signing up to the initiative) shows a value of 0.31511. In other words, each litre of fuel moved one passenger plus their bags (at an assumed combined average of 100 kilos) 31.73 kilometres. This is equivalent to 89.62 miles per gallon per passenger.

Technological improvements:
Whilst technological improvements are not seen as the complete answer to the issue of carbon use, they offer the opportunity to make significant improvements. In August 2006, Monarch announced the selection of the Boeing B787 aircraft to replace its existing wide body fleet. This next generation aircraft offers a big step forwards in efficiency and offers improvements of up to 23% in fuel consumed for each passenger carried compared to the aircraft it will replace.

In time, manufacturers are looking to make yet further remarkable improvements in efficiency through new airframe and engine designs. The Advisory Council for Aeronautical Research in Europe (ACARE), a body combining governments, the European Commission and industry, has set targets for aircraft entering service in 2020 relative to those entering service in 2000 to reduce fuel and thus CO2 by 50% and Nitrous Oxide (NOx) by 80%. This is a challenging target but work is progressing to bring this into reality.

**16. Qantas**

Qantas is committed to implementing processes and policies that will help protect the environment for generations to come. Its aim is world-class environment performance. Its commitment is outlined in its Group Environment Policy. Qantas is actively involved in resource management including recycling, and water and energy efficiency projects.

Recycling initiatives

Aluminium cans are collected from domestic services and the proceeds of the sales go to the Starlight Children's Foundation, the Cranio Maxillo Facial Foundation in Adelaide, the Royal Children's Hospital Foundation in Brisbane and the Endeavour Foundation in Cairns.

In addition, wine corks from domestic and international lounges around Australia are donated to Guides Australia, which uses the proceeds of sale for environmental projects and to support membership for financially-disadvantaged members. Qantas has also launched a programme in domestic terminals and onboard to encourage passengers to remove their newspapers from the aircraft by providing recycling boxes at their CityFlyer gates.

Included in its range of new food-service equipment are pieces that are designed with the environment in mind. Development of this new product brought about many challenges, including the need to maximise opportunities for recycling and minimise the generation of waste on the environment. Together, Qantas and Visy Recycling have closed the loop. For each piece of equipment, all stages of the product life cycle have been considered, from the choice of materials, to waste recovery and recycling.

Energy efficiency:
Qantas continues to work with the NSW Sustainable Energy Development Authority (SEDA) through the Energy Smart Business programme on energy efficiency initiatives.

Water savings:
Qantas has recently signed a voluntary agreement with the Sydney Water Every Drop Counts programme, which assists businesses to use water wisely. A review of water use across its facilities has already resulted in substantial water savings. It will continue to review its processes and activities to identify further opportunities for water savings.

Landcare Australia:
Qantas has signed up as a partner with Landcare Australia, who provide a bridge between local environment groups and the government and business in caring for the environment. Landcare Australia is best known for its tree-planting and bush- regeneration activities. Landcare and Qantas are working on a number of regeneration initiatives throughout regional Australia including sites at Mildura, Coffs Harbour and Wagga Wagga.

**17. Ryanair**

Ryanair's steady growth is being achieved in the most environmentally-friendly and sustainable way by investing in the latest aircraft and engine technologies (which have reduced fuel burn and CO2 emissions by 45% over the past 8 years) and the implementation of certain operational and commercial decisions that help to further minimise environmental impacts (by an additional 7% between 1998 and 2006).Ryanair is currently the industry leader in terms of environmental efficiency and it is constantly working towards further improving its performance.

Ryanair is investing Euro17 billion on its fleet replacement and expansion programme, which commenced in 1999. All of Ryanair's older Boeing 737-200 aircraft have now been replaced with new Boeing 737-800 Next Generation aircraft.

Ryanair's current fleet of 107 Boeing 737-800 Next Generation aircraft have an average age of just 2.5 years (against the average world fleet age of around 11 years) and future growth plans provide for the acquisition of a further 140 brand new aircraft of this type.

The Boeing 737-800 Next Generation aircraft has a superior fuel burn to passenger kilometre ratio than that of the 737-200 aircraft. The move from these older aircraft to new 737-800 Next Generation aircraft alone has reduced Ryanair's fuel consumption and CO2 emissions per passenger kilometre by 45%.

Fuel emissions:

Ryanair has minimised and continues to reduce fuel burn and CO2 emissions per passenger kilometre. This has been achieved through the combination of: numerous fuel saving measures (including the use of the latest aircraft and engine technology, e.g., winglets); and commercial measures aimed at maximising passenger numbers per flight in order to spread the fuel use and CO2 emissions over the greatest number of passengers (efficient seat configuration and high load factors).

Other characteristics of Ryanair's low-cost business model include, for example: the use of secondary airports and point-to-point services, which help to increase fuel efficiency and limit emissions. Ryanair avoids long taxiing times and holding patterns at congested primary airports, and delivers passengers to their destination directly on one flight (point-to-point), as opposed to forcing passengers onto connecting flights through congested main hub airports, which require two take-offs and two landings.

The combination of these operations and commercial initiatives and Ryanair's substantial investment in new aircraft has led to an overall reduction in fuel consumption and emissions of almost 52% between 1998 and 2006. Ryanair's fuel burn per 100 revenue passenger kilometres (RPKs) is currently in the range of 3.8 litres and is expected to decrease further due to fuel - saving measures currently being implemented. For example, the fleet-wide installation of winglets on all Ryanair's aircraft will itself further reduce fuel burn andCO2 emissions by up to 4%.

Noise:

All Ryanair aircraft comply with current noise requirements and the use of winglets will further reduce the noise affected area at airports by 6.5% and the implementation of numerous operational measures; the remote location of the majority of airports Ryanair operates from; the absence of night operations; and compliance with all local noise restrictions.

Waste:

Ryanair's low-fare, low-cost business model does not include offering free meals, drinks or newspapers to passengers, and thus results in a substantial reduction in the amount of waste generated by Ryanair flights, compared to traditional airlines that produce large amounts of waste from food, packaging and newspapers distributed free.

Ryanair is fundamentally opposed to any form of environmental taxation (ticket tax, fuel tax, emissions levy, etc.) as such measures have repeatedly failed to have any reduction effect on emissions. For example, motor vehicles are heavily taxed both at point of purchase and in terms of fuel, yet the surge in car ownership across Europe and the world continues unabated. Taxing air transport will not have any effect whatsoever on reducing greenhouse gas emissions but will have substantial adverse effects on European economic growth.

Ryanair proves that air transport can be environmentally friendly whilst continuing to deliver huge economic benefits in terms of low-cost air travel for consumers, increased tourism, regional and social cohesion, job creation, inward investment, etc.

## 18. SAS

SAS Group has chosen The CarbonNeutral Company in London to administer all payment transactions. Accordingly, SAS will not have any knowledge of individual choices to pay or not pay CO2 compensation. The CarbonNeutral Company's independent third-party auditor is KPMG. The CarbonNeutral Company is the one of the most experienced suppliers of carbon-dioxide reduction projects and sustainable development activities for many well-known major customers.

The SAS Group's major customers and partners can offset carbon-dioxide emission through the previously-established channels or through direct contact with The CarbonNeutral Company via its website; the company's partnership with  The CarbonNeutral Company all SAS Group passengers travelling from the UK to Scandinavia (and beyond) to offset their emissions through new, clean energy emission reduction projects around the world.

The carbon offset programme marks the next step in SAS' campaign to champion greener aviation.  The announcement is in line with the airline's call for greater support and collaboration between national governments towards the goal of a sustainable future for aviation.  The airline is announcing its new carbon offset scheme as its "green landings" programme gathers momentum in Sweden.

As of today, SAS UK customers wishing to offset the impact of their air travel on the environment can book tickets through the SAS website, www.flysas.co.uk, and then follow the links to The CarbonNeutral Company (TNCT).  Once there, customers can calculate, and then offset, their related emissions.

## 19. Singapore Airlines

In March 2006, the Airline set up the SIA Environmental Committee to track emerging aviation environmental issues, co-ordinate responses and provide counsel to management on these environmental issues that may impact on the company's operations. The Committee is chaired by the senior executive vice-president (Operations and Services), and comprises representatives from Company Planning, Engineering, Flight Operations, International Relations, Public Affairs and Safety, Security & Environment.

Transition to ISO 14001:2004:

The international Organization for Standardisation ISO 14001:2004 Environmental Management System (EMS) was published on 15 November 2004, after a 4-year review. This standard replaced the 1996 edition which has been technically revised. The main aims of the revision are to enhance compatibility with ISO 9001:2000, and to improve the clarity of the ISO14001:1996 texts.

Other continual improvement efforts achieved in 2005-06 included the successful replacement of chillers using non- CFC refrigerants, conversion of hardcopies of EMS and other manuals into the web-based or electronic (paperless) format; and the use of thinner (70 gsm) paper for general office administration.

Fuel productivity:

Fuel accounted for 35.0% of the SIA Group expenditure, up from 25.2% a year ago. Net of hedging, fuel expenditure rose $1,547 million to $4,240 million as jet fuel prices increased to an average of US$77 per barrel in 2005-06 from US$55 per barrel last year. Fuel efficiency and productivity have been a key priority for SIA for a number of years, and is especially so with soaring fuel prices.

SIA recognises that it has an important role to play in reducing the emission of greenhouse gases. It fully supports the International Civil Aviation Organisation (ICAO) which is working to develop a series of measures to help the aviation industry as a whole reduce its contribution to climate change. These measures include voluntary agreements, emissions trading and other offset mechanisms.

It also fully supports the work of agencies, such as IATA and AAPA, that are working to improve air traffic management so that aircraft can make the most fuel-efficient, and therefore the least polluting, journeys.

In this respect it supports the moves made by all IATA members to adopt a voluntary fuel-efficiency goal aiming to achieve a 10% fuel efficiency improvement for their total fleet by 2010. This would reduce the total release of carbon dioxide emissions into the atmosphere by almost 350 million tonnes compared to a scenario in which year 2000 efficiency levels would be frozen.

The key challenge for the aviation industry and for SIA is to improve the fuel productivity of its aircraft: the more efficient use of fuel reduces the amount of CO2 and other pollutants produced for every kilometre a passenger or kilogram of cargo is carried. Fuel productivity is calculated in terms of load carried and distance flown per unit of fuel consumed (Load-tonne-km/American gallon), while their carbon dioxide emission is expressed in kilograms of CO2 per load-tonne-km flown.

SIA is therefore committed to improving the fuel productivity of its fleet. The key elements of SIA's fuel productivity programme are:

- Fleet modernisation programme that ensures that its aircraft are as technologically advanced and fuel-efficient as possible;
- Flight operations procedures that minimise fuel use without compromising safety;
- Maintenance programmes for both airframe and engines that ensure operational efficiency and enhance fuel efficiency;

- Route planning procedures that ensure that SIA planes fly the most fuel-efficient routes possible;-weight crockery and cargo containers) and aircraft modifications that minimise the weight of the aircraft.

The development of SIA's fuel productivity improvement initiative has been a team effort that has involved staff from many departments in the company.

Fuel productivity of SIA fleet as measured by load-tonne-km per US gallon (LTK/AG) in 2005-06 increased by 1.9% over the previous year to 9.52 LTK/AG. This improvement could be attributed to fuel conservation measures and network efficiency. Correspondingly, its CO2 emission per unit of LTK also improved in equal ratio.

During the year, Singapore Airlines continued to pursue its policy of fleet renewal and modernisation. The company works closely with its suppliers to ensure the best environmental performance possible.

During the year, Singapore Airlines took delivery of one Boeing 777-300, bringing the B777 operating fleet size to 58. As at 31 March 2006, the operating fleet comprised 90 passenger aircraft – 27 B747-400s, 58 B777s and five A340-500s. The average age of the fleet was six years and four months. This compares favourably with the industry average.

SIA Cargo took delivery of two B747-400 freighters during the year, bringing its operating fleet to 16 freighters by 31 March 2006.

One of the key features of SIA's future fleet modernisation programme is the purchase of the Airbus A380. SIA has 10 aircraft on firm order and 15 on option. The Airbus A380 has been marketed as one of the most environmentally-friendly aircraft available that will comply with ICAO Annex 16 standards on engine noise and emission at the point of certification.

The year up to end March 2007 will herald many exciting developments for the group. Singapore Airlines is gearing up to be the first to fly the all new Airbus A380-800 and to introduce the Boeing B777-300ER by the end of the year. The company is expecting to take delivery of seven Airbus A380-800s and nine Boeing 777-300ERs, while five B747-400s will be decommissioned during the year. The operating fleet will comprise 101 passenger aircraft by 31 March 2007.

Local air quality

During take-off and landing, aircraft emissions can have a significant impact on the local air quality at ground level. The area where this cycle of operations takes place is the landing and takeoff zone (LTO) – an area extending up to 900 metres above the ground at and around an airport. Aircraft enter the LTO zone about 20 kilometres out from the runway and leave about seven kilometres after takeoff.

The company takes a two-pronged approach to improving the performance of its fleet. This involves prioritising aircraft that produce low emissions as part of its fleet renewal programme and investigating ways in which its operational practices can be improved.

SIA is pleased to report that all of its passenger fleet, freighters and SilkAir aircraft comply with current ICAO Standards for NOx, CO and UHC emissions. In addition, the fleet also meets the more stringent 2004 ICAO Emission Standards for NOx.

Computation of LTO emissions is based on measurements during certification, which is subject to certain conditions and assumptions. However, actual aircraft operation may differ. In particular, the computation assumes full engine thrust for every take-off, but SIA uses reduced thrust as appropriate, which reduces emissions.

The total amount of local air emissions measured during the LTO cycle went up during 2005-06. A major factor influencing this result is the increase in the number of flights that SIA operated during the year (in comparison with 2004-05).

In Singapore, Changi Airport is sited well away from the centre of the city and approach routes are designed to avoid areas of high habitation. SIA supports the authorities at Changi, and at other airports it uses around the world, in the development and implementation of procedures that keep noise levels to a minimum.

SIA's entire fleet has achieved compliance to ICAO Chapter 3 Standard for noise certification. All SIA aircraft also meet the more stringent Chapter 4 Standard. Chapter 4 is 10 EPNdB quieter than the standard required under Chapter 3 and will only apply to all new aircraft produced from 2006 onwards.

The company's energy efficiency strategy for buildings and equipment incorporates a comprehensive maintenance and refurbishment programme as well as conservation measures. To ensure that all its relevant plants are operating at optimum efficiency it has an on-going programme to explore opportunities for changes to operational procedures and equipment to enhance efficiency. Water saving is promoted using a similar multi-pronged approach.

Highlights of SIA's resource efficiency programmes during 2005-06 include:

- Retrofitting of equipment with latest technologies that promote energy efficiency;
- Energy efficiency upgrades to air-conditioning and chiller units;
- Optimisation of air-conditioning and chiller operations;
- Constant environmental management checks on water distribution facilities;
- Use of non-chemical water treatment for cooling towers;
- Closer monitoring of consumption patterns.

Some of the major energy conservation projects undertaken during the year include replacement of cooling towers at the compant's Training Centre with different capacities to allow optimisation of electricity usage.

At its head office in Airline House, single Air Handling Units (AHU) were replaced with dual AHUs with smaller capacities to enable more flexible operations during off-peak hours. In addition, the air volume controls in the air-conditioning ducting system were replaced for more efficient air distribution. The time programmes of the chillers were adjusted taking into account the building load profile and usage patterns. Other measures taken were: use of energy efficient lamps, closure of some areas of the building during off-peak periods, and adjusting the operating hours for lighting and air-conditioning. As a consequence of these measures, a total saving in electricity consumption of 2,600 mwh a year has been achieved.

In December 2005, the SIA Computer Centre (CCB) located in Changi was named an "Energy Smart" building. The CCB won the inaugural Building Energy Efficiency award instituted by the Energy Sustainability Unit of the National University of Singapore and the National Environmental Agency. The award gives recognition to buildings that make efficient use of energy without compromising air quality and the comfort of occupants. With the introduction of an energy management programme, the Centre achieved a 10% reduction in energy consumption over the last year.

The refrigeration system of cold rooms at SATS Airfreight Terminal 5 was upgraded to a non-CFC type.

The boilers in its in-flight kitchens have fully switched to town gas instead of using diesel fuel, thus contributing to reduced emissions and cost savings.

New initiatives to reduce energy use that are currently being assessed include:

- Installation of variable speed drives to optimize chillers, chilled water pumps, condenser water pumps and cooling tower performance; and
- Replacement of existing EXIT lights with the LED type at the cargo airfreight terminals.

Waste management

At the heart of the company's approach to waste management are the following key programmes aimed at reducing the amount of waste generated:

- Promotion and facilitation of waste reduction efforts aimed at reducing usage, and reuse and recycling wherever possible. Recycling tips are regularly highlighted in newsletters and circulars;
- Steady improvements in the way ground support operations are carried out to maximise the use of materials, minimise breakdowns and unnecessary waste disposal;
- Modifications in the design of vehicles and equipment to reduce replacement parts and to minimise the production of potential wastes such as tyres, spare parts and components.

Some of these initiatives and efforts towards waste minimisation and better use of resources are highlighted below.

Changing to cushioned solid tyres:

The company's SATS Maintenance team came up with the idea of using cushioned solid tyres instead of pneumatic ones on transporters and tractors, which resulted in substantial savings, and in addition, gives tractor drivers a more comfortable ride.

Pneumatic tyres used previously were prone to punctures. For a 12-month period, about 2,300 pneumatic tractors tyres and 170 tyres and tubes on transporters were replaced. Following a six-month trial for transporters and tractors with the new tyres, it was estimated that annual savings of over $15,000 for tractors and $47,000 for the transporters could be achieved. The other benefits of the new tyres include lower vehicle downtimes, savings in manpower to repair punctured tyres and lower disposal cost of unserviceable tyres.

Speed-limiting device:

Another idea from SATS Maintenance involved the design of a device called a protection plate to restrict adjustments to the fuel assembly of tow tractors to limit speed. With the vehicles keeping to the manufacturer's recommended speed, fuel economy and engine reliability was achieved, thus reducing wear and tear and cost.

Guards for hi-lift lights:

Ways were also found to reduce wastage and cost through the installation of guards for hi-lift lights. Damages to light cover assemblies are costly. Thanks to this idea, replacement of light assemblies was reduced by about 80% thus providing considerable savings in man-hour cost and replacement spare parts.

Electronic ticketing:

Plans to fully switch over to electronic tickets (ET) are on track with 7 out of 10 tickets issued as at end-March 2006 being ET. By end-2006, 90% of all tickets were planned to be ET, in line with the company's aim to fully implement paperless ticketing by mid-2007. This is six months ahead of the International Air Transport Association's deadline of end-2007. As part of the effort, Interline ET (IET) is also fast gathering steam. IET now covers 13 STAR Alliance partners and 5 other major airlines. Twenty more carriers are scheduled to join by end of this year.

Recycling efforts:
Singapore, a highly urbanised city-state has limited land, and landfill for waste disposal is costly. In doing its part to conserve the limited landfill, the

company's recycling efforts have consistently been recovering about 20% of their general waste. It strongly encourages all staff to do their part in waste minimisation and recycling.

**20. TUI Airlines**

At the beginning of 2005, 10 new Boeing 737-800 aircraft were ordered for Hapagfly, aircraft which are fitted with modern environmentally-aware technology. Amongst other things, the Boeing 737-800 is characterised by a further lowering of its kerosene consumption and by lower pollutant and noise emissions. Thomsonfly is committed to minimising the effects it has on the environment, wherever economically possible, to standards beyond the legal requirements. For example, investments in modern aircraft, an efficient seating configuration inside the aircraft and a high load factor mean the airline can point to excellent specific fuel consumption for the fleet. Since 1997, with the Clean Air Programme, a more environmentally-friendly and emission-reducing business operation has been promoted. One of the many innovations in modern aircraft is a flight management computer that provides pilots with information on the most fuel-efficient configuration for the flight. In addition, a modern flight management system enables efficient route planning.

TUI airlines increasingly use state-of-the-art aircraft to reduce kerosene consumption, emissions, and aircraft noise. The further development of the environmental standards regulating the TUI affiliated airline companies – Thomsonfly, TUIfly Nordic, Corsairfly, and TUIfly – is co-ordinated by the Quality Management of TUI Airline Management and supported by TUI AG Environmental Management. The success of these endeavours highlights that environmental challenges and compliance with high environmental standards are compatible with the achievement of economic targets.

Hapagfly (now TUIfly) was the first airline worldwide to fit its Boeing 737-800s with the new winglets. This was back in 2001/2002.

Winglets are 2.4-metre-high wing tips which stick out at right angles at the very end of the wings. Although only weighing 68 kg, winglets are exceedingly strong thanks to their high-tech construction using carbon fibre strengthened synthetics, aluminium and titanium. Although winglet technology has a long successful history, winglets of this size have never been used before on passenger aircraft. Even the largest passenger aircraft in the world, the Jumbojet, has winglets, although they are only 1.8 m high.

The new technology has outstanding advantages: the winglets reduce kerosene consumption by approximately 5%. There is a corresponding reduction in emissions. The planned savings for the whole Hapagfly Boeing fleet is therefore 17,400 tonnes of kerosene per year. And emissions of the greenhouse gas carbon dioxide drop accordingly by around 55,100 tonnes per year. This makes a considerable contribution to CO2 reduction and climate protection. In addition, the shorter take-off distance and steeper take-off angle reduce the size of the noise footprint on the ground.

Fitting winglets to the Boeing 737-800s, and conducting the authorisation and test flights in the US, was facilitated by close co-operation between Hapagfly and the manufacturer Boeing Aviation Partners.

Comprehensive efficiency enhancement programmes for flight planning, flight operations and maintenance generate considerable energy savings, and even reductions in aircraft noise in some cases:

Hapagfly (now TUIfly) initiated a programme in 2002 to increase the efficiency of its fleet. It also reappraised and modified the measures that were already in place. Overall, this has reduced annual consumption by 2.8 million litres of kerosene. One measure was systematic cleaning using a special method to combat the tendency of aircraft engines to gradually become less fuel-efficient.

Thomsonfly introduced its new fuel saving programme in 2002: kerosene consumption was slashed by optimising flight planning and operations, and using mobile power units to reduce engine idling times. Moreover, a new route planning system was introduced which is able to select routes with the highest fuel efficiency. This system can also be used to select routes which minimise noise pollution over populated or specially protected areas.

**21. Virgin Atlantic**

Virgin Atlantic is committed to reducing its environmental impacts where it can by becoming a more efficient business, leading the industry to practical and technical solutions and engaging, inspiring and empowering its staff and customers to help meet this challenge.

As part of its sustainable aviation strategy, Virgin Atlantic was due to unveil a scheme in the first half of 2007 where passengers can offset their flights, and help to take greater responsibility for their carbon emissions. The offsetting facility will be part of a series of initiatives by the airline, including working with other stakeholders within the aviation industry, to tackle global warming.

Virgin Atlantic is continuing to evaluate more efficient ways of operating its existing fleet of aircraft, until the manufacturers can develop technological solutions to reduce carbon emissions, such as innovative aircraft design or viable alternative fuels.

Starting grids: - The Starting Grids concept, which was announced by Richard Branson in September 2006, is aimed at reducing emissions from aircraft taxiing from the airport terminal to the end of the runway. Together with other key industry partners, Virgin Atlantic has undertaken some successful initial trials and will be continuing to work on this in 2007.

Proposals for starting grids were unveiled by the Virgin Atlantic chairman, Sir Richard Branson, at the end of September 2006. A starting grid is a holding area, close to a runway, consisting of several parking bays for aircraft. It means that aircraft can be towed closer to a runway before take-off, substantially reducing the time that engines need to be running. An aircraft would only need to start its engines once on the grid, around 10 minutes before take-off. The test trials, at London's Heathrow and Gatwick airports, took place throughout December on a series of Virgin Atlantic Boeing 747-400 departures. Virgin Atlantic worked alongside BAA and NATS during the trials, which were aimed at validating the operational procedures needed for starting grids in order for them to become commonplace. A longer, more detailed trial is then expected to take place in the first quarter of 2007. Teams from Virgin Atlantic are also holding talks with the international airports in San Francisco and Los Angeles, as well as JFK in New York, about the timing of similar trials.

Putting planes on a diet – Virgin Atlantic has also been working hard to remove any extraneous weight from its aircraft. Weight (and the fuel needed to fly it around) is now a key consideration in developing new onboard products and services, and finding lighter-weight alternatives to existing materials can add up to considerable emissions reductions over the course of a year.

Other initiatives - Where Virgin Atlantic can't have a direct impact on reducing its emissions and environmental footprint, it is working closely with other sectors of the industry to develop models of best practice that can be adopted globally. Initiatives such as Continuous Descent Approach need the co-operation of many different companies and organisations, but Virgin is confident that it will allow airlines to operate their aircraft even more efficiently in the not-too-distant future.

On the ground:

All of the electricity Virgin Atlantic purchases to run its key office sites is from renewable sources and it is looking into extending this across all of its ground operations. Virgin Atlantic has a well-established recycling scheme at all of its office locations and ensures that waste from its engineering facilities is disposed of in the appropriate manner. It has undertaken a thorough review of all its various waste streams and, during 2007, will seek to reduce its waste streams yet further.

It is also developing a comprehensive sustainable procurement policy which will be rolled out to key suppliers in 2007. These moves by Virgin Atlantic follow Sir Richard Branson's commitment for Virgin Group to invest $3billion over the next 10 years in renewable energy initiatives.

## Appendix two – aeronautical research programmes with environmental mitigation elements, part-funded by the European Commission – source European Commission

Please note – these programmes have been referenced directly from European Commission research website pages.

**ALCAS**

**Advanced Low Cost Aircraft Structures**

**Action Line:** AERO-2003-1.3.2.2 Full-composite structures (wing and fuselage) for large and small size aircraft

| **Coordinator** | |
|---|---|
| **Contact Person:**<br>Name: PHIPPS, David<br>Tel: +44-11-79365982<br>Fax: +44-11-79365480 | **Organisation:**<br>AIRBUS UK LIMITED<br>New Filton House, PO Box 77, Filton<br>UNITED KINGDOM |

The objective is to reduce the operating costs of relevant European aerospace products by 15%, through the cost effective application of carbon fibre composites to aircraft primary structure, taking into account systems integration. The project will seek to reduce aircraft operating costs by realising the weight-saving potential of composite materials, by reducing the manufacturing costs of composite components, and by reducing maintenance costs. This project will include new design concepts and methods that exploit the full potential of these materials, as well as novel manufacturing and assembly processes. The project will integrate and validate mature and new composite technologies through the design, manufacture and testing of appropriate wing and fuselage assemblies that represent both airliner and business jet products.

The project will be organised into four technical platforms: The Airliner Wing platform covers inner wing and centre box of a large civil airliner, focusing on the centre box to lateral wing root joint, the landing gear and pylon integration and the highly loaded, complex curvature lower cover. The Airliner Fuselage platform addresses key fuselage challenges and complex design features, including large cut-outs and large damages in curved panels, keel beam and landing gear load introduction, tyre impact damage, post-buckling and elementary crash analysis. The Business Jet Wing platform focuses on reducing cost by combining parts into an integrated wing structure, includes architecture studies to identify the best wing joint configuration. The Business Jet Fuselage platform studies double curved rear fuselage with sandwich shell concept and VTP/HTP and engine integration. A Project Management and Training platform will integrate the technical activities and ensure a co-ordinated approach to generic tasks such as knowledge capture, dissemination and exploitation.

| **Project details** | |
|---|---|
| **Project Reference:** 516092 | **Contract Type:** Integrated Project |
| **Start Date:** 2005-02-01 | **End Date:** 2009-01-31 |
| **Duration:** 48 months | **Project Status:** Execution |
| **Project Cost:** 101.17 million euro | **Project Funding:** 53.4 million euro |

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| **Participant Organiation:** ECOLE NATIONALE SUPERIEURE DE L'AERONAUTIQUE ET DE L'ESPACE | **Country:** FRANCE |
| **Participant Organisation:** ORDIMOULE S.A. | **Country:** FRANCE |
| **Participant Organisation:** COMPOSITE TOOLING & STRUCTURES LIMITED | **Country:** UNITED KINGDOM |
| **Participant Organisation:** ECOLE CENTRALE DE NANTES | **Country:** FRANCE |
| **Participant Organisation:** AEROFORME S.A. | **Country:** FRANCE |
| **Participant Organisation:** NEDTECH ENGINEERING B.V. | **Country:** NETHERLANDS |
| **Participant Organisation:** SIGMATEX (UK) LTD | **Country:** UNITED KINGDOM |
| **Participant Organisation:** NOVATOR AB | **Country:** SWEDEN |
| **Participant Organisation:** SECONDA UNIVERSITA DEGLI STUDI DI NAPOLI | **Country:** ITALY |
| **Participant Organisation:** UNIVERSITA DEGLI STUDI DI PISA | **Country:** ITALY |
| **Participant Organisation:** ISSOIRE-AVIATION | **Country:** FRANCE |
| **Participant Organisation:** ECOLE NATIONALE SUPERIEURE DES ARTS ET INDUSTRIES TEXTILES | **Country:** FRANCE |
| **Participant Organisation:** UNIVERSITY OF WALES SWANSEA | **Country:** UNITED KINGDOM |
| **Participant Organisation:** UNIVERSITY OF PLYMOUTH | **Country:** UNITED KINGDOM |
| **Participant Organisation:** CRANFIELD UNIVERSITY | **Country:** UNITED KINGDOM |
| **Participant Organisation:** COMPOSITES TESTING LABORATORY (CTL LTD) - TASTAIL TEORANTA | **Country:** IRELAND |
| **Participant Organisation:** FEDERAL STATE UNITARY ENTREPRISE CENTRAL AEROHYDRODYNAMIC INSTITUTE | **Country:** RUSSIAN FEDERATION |
| **Participant Organisation:** TUSAS HAVACILIK VE UZAY SANAYII A.S. | **Country:** TURKEY |
| **Participant Organisation:** SAAB AB | **Country:** SWEDEN |
| **Participant Organisation:** LABINAL SA | **Country:** FRANCE |
| **Participant Organisation:** INSTITUTO NACIONAL DE TECNICA AEROESPACIAL | **Country:** SPAIN |

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| **Participant Organisation:** ABHAIR CUMAISC TEORANTA / IRISH COMPOSITES | **Country:** IRELAND |
| **Participant Organisation:** CT INGENIEROS, AAI, S.L. | **Country:** SPAIN |
| **Participant Organisation:** ASSOCIACION DE INVESTIGACION Y COOPERACION INDUSTRIAL DE ANDALUCIA | **Country:** SPAIN |
| **Participant Organisation:** THE ADVANCED COMPOSITES GROUP LTD | **Country:** UNITED KINGDOM |
| **Participant Organisation:** DASSAULT-AVIATION | **Country:** FRANCE |
| **Participant Organisation:** AIRBUS ESPAÑA SL | **Country:** SPAIN |
| **Participant Organisation:** RIGAS TEHNISKA UNIVERSITATE | **Country:** LATVIA |
| **Participant Organisation:** WOJSKOWA AKADEMIA TECHNICZNA | **Country:** POLAND |
| **Participant Organisation:** STORK FOKKER AESP BV | **Country:** NETHERLANDS |
| **Participant Organisation:** TECHNISCHE UNIVERSITEIT DELFT | **Country:** NETHERLANDS |
| **Participant Organisation:** GKN AEROSPACE SERVICES LTD | **Country:** UNITED KINGDOM |
| **Participant Organisation:** SHORT BROTHERS PLC | **Country:** UNITED KINGDOM |
| **Participant Organisation:** INBIS LIMITED | **Country:** UNITED KINGDOM |
| **Participant Organisation:** EADS CCR | **Country:** FRANCE |
| **Participant Organisation:** TEKNILLINEN KORKEAKOULU | **Country:** FINLAND |
| **Participant Organisation:** UNIVERSIDAD POLITECNICA DE MADRID | **Country:** SPAIN |
| **Participant Organisation:** EADS-CONSTRUCCIONES AERONAUTICAS S.A. | **Country:** SPAIN |
| **Participant Organisation:** AIRBUS DEUTSCHLAND GMBH | **Country:** GERMANY |
| **Participant Organisation:** VYZKUMNY A ZKUSEBNI LETECKY USTAV A.S. | **Country:** CZECH REPUBLIC |
| **Participant Organisation:** KUNGLIGA TEKNISKA HOEGSKOLAN | **Country:** SWEDEN |
| **Participant Organisation:** SAMTECH SA | **Country:** BELGIUM |
| **Participant Organisation:** ISRAEL AIRCRAFT INDUSTRIES LTD. | **Country:** ISRAEL |

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| **Participant Organisation:** CENTRE D'ESSAIS AERONAUTIQUE DE TOULOUSE | **Country:** FRANCE |
| **Participant Organisation:** TECHNISCHE UNIVERSITAET DRESDEN | **Country:** GERMANY |
| **Participant Organisation:** SONACA SA | **Country:** BELGIUM |
| **Participant Organisation:** MESSIER-DOWTY LIMITED | **Country:** UNITED KINGDOM |
| **Participant Organisation:** ALENIA AERONAUTICA S.P.A. | **Country:** ITALY |
| **Participant Organisation:** RUAG AEROSPACE | **Country:** SWITZERLAND |
| **Participant Organisation:** AIRBUS FRANCE SAS | **Country:** FRANCE |
| **Participant Organisation:** EADS DEUTSCHLAND GMBH | **Country:** GERMANY |
| **Participant Organisation:** TWI LIMITED | **Country:** UNITED KINGDOM |
| **Participant Organisation:** PATRIA AEROSTRUCTURES OY | **Country:** FINLAND |
| **Participant Organisation:** ADVANCED TOOLING SYSTEMS (ATS) KLEIZEN | **Country:** NETHERLANDS |
| **Participant Organisation:** ALL RUSSIAN SCIENTIFIC RESEARCH INSTITUTE OF AVIATION MATERIALS | **Country:** RUSSIAN FEDERATION |
| **Participant Organisation:** UNIVERSITY OF PATRAS | **Country:** GREECE |
| **Participant Organisation:** DEUTSCHES ZENTRUM FUER LUFT- UND RAUMFAHRT E.V. | **Country:** GERMANY |
| **Participant Organisation:** STICHTING NATIONAAL LUCHT-EN RUIMTEVAARTLABORATORIUM | **Country:** NETHERLANDS |

**TIMECOP-AE**

**Toward innovative methods for combustion prediction in aero-engines**

**Action Line:** AERO-1.2 Improving environmental impact with regard to emissions and noise

| **Co-ordinator** | |
|---|---|
| **Contact Person:**<br>Name: BERAT, Claude<br>Tel: +33-05-59125036<br>Fax: +33-05-59125145 | **Organisation:**<br>TURBOMECA S.A.<br>Technical Direction - Components Department - Combustion Service (DT/CP/CC)<br>BP 64511<br>FRANCE |

The aim of the TIMECOP-AE project is to provide the necessary combustion prediction methods that enable the development of practical advanced combustion systems for future engines that will reduce emission levels and fuel consumption. Predictive tools are required to be able to reduce NOx emissions, to decrease the development time and costs of new combustion systems and to improve the operability of lean-burn combustion systems.

All promising approaches to satisfy future emission levels regulations are based on lean combustion technology. However, lean combustion compromises combustor operability, including ignition, altitude re-light, pull-away, weak extinction performance and thermo-acoustic instability behaviour. It is of prime importance to evaluate this transient behaviour in the design stage to ensure good operability. Without these tools the development of these advanced combustion systems will depend on many rig tests.

These are costly and time consuming and will reduce competitiveness. During the last five years big advances have been made in the field of reactive Large Eddy Simulation (LES) with gaseous fuels. This approach gives promising results with respect to turbulence modelling and can be used to model unsteady processes. Within this proposal the LES tools will gain the capability for modelling the combustion process within conventional and Low Emission combustors over a wide range of operating conditions on liquid fuels.

The operating conditions include mentioned transient phenomena. To be able to model these phenomena improvements are required in the models of turbulence, chemistry, turbulence-chemistry interactions, and liquid spray models. The methods and models will be evaluated against high quality validation data, which will be obtained by several validation experiments. Some are designed to validate specific models, and one is a generic combustor, representative of an aero-engine combustor, and permits to assess the full range of models.

| **Project details** | |
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| **Project Reference:** 30828 | **Contract Type:** Specific Targeted Research Project |
| **Start Date:** 2006-06-01 | **End Date:** 2010-05-31 |
| **Duration:** 48 months | **Project Status:** Execution |
| **Project Cost:** 7.11 million euro | **Project Funding:** 4.8 million euro |

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| **Participant Organisation:** THE CHANCELLOR, MASTERS AND SCHOLARS OF THE UNIVERSITY OF CAMBRIDGE | **Country:** UNITED KINGDOM |
| **Participant Organisation:** Imperial College of Science, Technology and Medicine | **Country:** UNITED KINGDOM |
| **Participant Organisation:** Technische Universiteit Eindhoven | **Country:** NETHERLANDS |
| **Participant Organisation:** Department of Mechanics and Aeronautics, University of Rome "La Sapienza" | **Country:** ITALY |
| **Participant Organisation:** Office National d'Etudes et de Recherches Aérospatiales' | **Country:** FRANCE |
| **Participant Organisation:** INSTITUT NATIONAL POLYTECHNIQUE DE TOULOUSE | **Country:** FRANCE |

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| **Participant Organisation:** University of Karlsruhe, Institut für Thermische Strömungsmaschinen | **Country:** GERMANY |
| **Participant Organisation:** Loughborough University | **Country:** UNITED KINGDOM |
| **Participant Organisation:** Foundation for Research and Technology | **Country:** GREECE |
| **Participant Organisation:** Rolls-Royce plc | **Country:** UNITED KINGDOM |
| **Participant Organisation:** CZESTOCHOWA UNIVERSITY OF TECHNOLOGY | **Country:** POLAND |
| **Participant Organisation:** Technische Universität Darmstadt | **Country:** GERMANY |
| **Participant Organisation:** Institut Français du Pétrole | **Country:** FRANCE |
| **Participant Organisation:** Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas | **Country:** SPAIN |
| **Participant Organisation:** CENTRALE RECHERCHE SA | **Country:** FRANCE |
| **Participant Organisation:** Centre National de la Recherche Scientifique | **Country:** FRANCE |
| **Participant Organisation:** Deutsches Zentrum fuer Luft- und Raumfahrt e.V. | **Country:** GERMANY |
| **Participant Organisation:** AVIO S.P.A. | **Country:** ITALY |
| **Participant Organisation:** Snecma | **Country:** FRANCE |
| **Participant Organisation:** MTU Aero Engines GmbH | **Country:** GERMANY |
| **Participant Organisation:** Rolls-Royce Deutschland Ltd & Co KG | **Country:** GERMANY |

**AERONET III**

**Aircraft Emissions and Reduction Technologies (AERONET III)**

**Action Line:** AERO-1.1 Strengthening competitiveness

| **Co-ordinator** | |
|---|---|
| **Contact Person:**<br>Name: JUNIOR, Alf<br>Tel: +49-22-036013029<br>Fax: +49-22-036013906 | **Organisation:**<br>DEUTSCHES ZENTRUM FUER LUFT UND RAUMFAHRT E.V.<br>DLR Brussels Office<br>Linder Hoehe<br>GERMANY |

Forecasts show continuing annual growth of 3%-4% for air transport to meet the needs of a modern society. Despite great progress in the efficiency of aircraft and reductions in aero-engines emissions, further R&D is necessary to safeguard the environmental sustainability of the whole air transport system for future generations. The Vision 2020 for Aeronautics and the Strategic Research Agenda of ACARE point out the environment related aims as reduction by 50% of CO2 and of NOx by 80% by the year 2020 referred to technology being available for implementation at that time. But minor emissions, soot and particulates have to be reduced as well. Developing the necessary knowledge base and making it available to the stakeholders in production and operation is essential for the future European air transportation industry in its global competition. For this reason, AERONET III is proposed as a platform where all the stakeholder communities can exchange information and discuss views and experiences gathered in different EC projects and national programmes. The intention is to identify gaps of knowledge, support the policy and regulatory process and to strengthen the body of European expertise. Through AERONET III with its 22 members from industry, Sees, national research centres, and universities from nine European countries the latest knowledge will be shared on aircraft and engine technology, operations, air transport, airports, emissions inventories and co-ordinated with the atmospheric sciences and policy and regulations activities. Joint actions will be initiated and performed such as workshops, studies, and reports, the results being made available to the public through electronic and print media. The network will be organised by a Co-ordination and Management Team from four European aeronautical research centres under the project co-ordinator DLR and guided by a high-level Steering Group representing all included interest groups.

| **Project details** | |
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| **Project Reference:** 502882 | **Contract Type:** Coordination action |
| **Start Date:** 2004-04-01 | **End Date:** 2008-03-31 |
| **Duration:** 48 months | **Project Status:** Execution |
| **Project Cost:** 1.86 million euro | **Project Funding:** 1.8 million euro |

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| **Participant Organisation:** SNECMA | **Country:** FRANCE |
| **Participant Organisation:** FLUGHAFEN ZUERICH AG -UNIQUE | **Country:** SWITZERLAND |
| **Participant Organisation:** UNIVERSITAET KARLSRUHE (TECHNISCHE HOCHSCHULE) | **Country:** GERMANY |
| **Participant Organisation:** SNECMA MOTEURS SA | **Country:** FRANCE |
| **Participant Organisation:** SHELL AVIATION LIMITED | **Country:** UNITED KINGDOM |
| **Participant Organisation:** ROLLS-ROYCE DEUTSCHLAND LTD&CO KG | **Country:** GERMANY |
| **Participant Organisation:** ROLLS ROYCE PLC | **Country:** UNITED KINGDOM |
| **Participant Organisation:** QINETIQ LIMITED | **Country:** UNITED KINGDOM |
| **Participant Organisation:** INSTYTUT LOTNICTWA | **Country:** POLAND |
| **Participant Organisation:** GROMOV FLIGHT RESEARCH INSTITUTE | **Country:** RUSSIAN FEDERATION |
| **Participant Organisation:** | **Country:** GERMANY |

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| FORSCHUNGSZENTRUM KARLSRUHE GMBH | |
| **Participant Organisation:** DEUTSCHE LUFTHANSA AG | **Country:** GERMANY |
| **Participant Organisation:** BERGISCHE UNIVERSITAET WUPPERTAL | **Country:** GERMANY |
| **Participant Organisation:** AIR BP LTD | **Country:** UNITED KINGDOM |
| **Participant Organisation:** THE MANCHESTER METROPOLITAN UNIVERSITY | **Country:** UNITED KINGDOM |
| **Participant Organisation:** STICHTING NATIONAAL LUCHT- EN RUIMTEVAART LABORATORIUM | **Country:** NETHERLANDS |
| **Participant Organisation:** EUROCONTROL - EUROPEAN ORGANISATION FOR THE SAFETY OF AIR NAVIGATION | **Country:** BELGIUM |
| **Participant Organisation:** UNIVERSITY OF SHEFFIELD | **Country:** UNITED KINGDOM |
| **Participant Organisation:** AIRBUS UK LIMITED | **Country:** UNITED KINGDOM |
| **Participant Organisation:** NATIONAL TECHNICAL UNIVERSITY OF ATHENS | **Country:** GREECE |
| **Participant Organisation:** MTU AERO ENGINES GMBH | **Country:** GERMANY |
| **Participant Organisation:** AUXITROL SA | **Country:** FRANCE |
| **Participant Organisation:** FEDERAL OFFICE FOR CIVIL AVIATION | **Country:** SWITZERLAND |
| **Participant Organisation:** OFFICE NATIONAL D'ETUDES ET DE RECHERCHES AEROSPATIALES | **Country:** FRANCE |
| **Participant Organisation:** SWEDISH DEFENCE RESEARCH AGENCY | **Country:** SWEDEN |

**ELECT-AE**

**European low emission combustion technology in aero-engines**

**Action Line:** AERO-1.1 Strengthening competitiveness

| **Coordinator** | |
|---|---|
| **Contact Person:**<br>Name: V.D. BANK, Ralf<br>Tel: +49-33-70861373<br>Fax: +49-33-7086511373493370863086 | **Organisation:**<br>ROLLS-ROYCE DEUTSCHLAND LTD & CO KG<br>Combustors & Turbine / Combustor Aero- |

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| | Thermal & Fuel Preparation [ OE-51]<br>Eschenweg 11<br>GERMANY |

European companies are pooling their resources to develop commercially viable low emissions combustion systems and ELECT-AE will provide the impetus to bring together the key engine manufacturers and research establishments to enable this. The development of a concerted research strategy involves many complex interactions, and the continuous improvement of the corresponding perspective and processes will finally provide significant gearing. Timescales for the development of aero-engine combustors are long.

There is a clear vision and forecast of environmental needs. The ambitious ACARE targets, especially the demand for 80% reduction of NOx emissions from aviation, require very well focused and balanced RTD initiatives for the near future to prepare the technology for a successful implementation of a new generation of aero-engine combustors and therefore a highly integrated research strategy platform. The proposed CA "European Low Emission Combustion Technology in Aero-Engines" is dedicated to the support of the implementation of the ACARE goals as formulated in their"Vision 2020 document, i.e. strengthening the competitiveness of the European jet engine manufacturers and diminution of the environmental impact of civil aviation with regard to emissions and thus generating economical and ecological benefits for European Society.

Therefore targets have been developed for this CA, designed to support the establishing of a research strategy in respect to actual measures and actions in the context of combustion technology for low emission of pollutants: Strategy on How-To-Do technology development; tintegration and strengthening of the European Research Area; enhance exploitation in Europe; dissemination of European research results and exchange of information in Europe. Search and identification of appropriate SMEs and capable research partners in the EU and from candidate countries.

| **Project details** | |
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| **Project Reference:** 12236 | **Contract Type:** Co-ordination action |
| **Start Date:** 2005-01-01 | **End Date:** 2008-12-31 |
| **Duration:** 48 months | **Project Status:** Execution |
| **Project Cost:** 1.49 million euro | **Project Funding:** 1.49 million euro |

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| **Participant Organisation:** SNECMA | **Country:** FRANCE |
| **Participant Organisation:** MTU AERO ENGINES GMBH & CO KG | **Country:** GERMANY |
| **Participant Organisation:** OFFICE NATIONAL D'ETUDES ET DE RECHERCHES AROSPATIALES' | **Country:** FRANCE |
| **Participant Organisation:** DEUTSCHES ZENTRUM FÜR LUFT- UND RAUMFAHRT E.V. | **Country:** GERMANY |
| **Participant Organisation:** TURBOMECA SA | **Country:** FRANCE |
| **Participant Organisation:** SNECMA MOTEURS SA | **Country:** FRANCE |

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| **Participant Organisation:** ROLLS-ROYCE PLC | **Country:** UNITED KINGDOM |
| **Participant Organisation:** ALSTOM POWER LTD | **Country:** UNITED KINGDOM |
| **Participant Organisation:** AVIO S.P.A. | **Country:** ITALY |

**NEWAC**

**NEW Aero Engine Core concepts**

**Action Line:** AERO-1.4 Increasing operational capacity and safety of the air transport system

| **Coordinator** | |
|---|---|
| **Contact Person:**<br>Name: WILFERT, Guenter<br>Tel: +49-89-14894347<br>Fax: +49-89-148999272 | **Organisation:**<br>MTU Aero Engines GmbH<br>Technology Management<br>Dachauerstr. 665 Postfach 80995<br>GERMANY |

NEWAC will provide a step change for low emission engines by introducing new innovative core configurations to strongly reduce CO2 and NOx emissions. This breakthrough will be achieved by developing and validating new core configurations using heat management (intercooler, cooling air cooler, recuperator), improved combustion, active systems and improved core components. NEWAC will design and manufacture these innovative components and perform model, rig and core tests to validate the critical technologies.

The NEWAC core configurations include an Inter-cooled Recuperative Aero-engine (IRA) operating at low overall pressure ratio (OPR), an inter-cooled core configuration operating at high OPR, an active core and a flow controlled core operating at medium OPR. NEWAC will complement past and existing EC projects in the field, e.g. EEFAE in FP5 and VITAL in FP6.

The main result will be fully validated new technologies enabling a 6% reduction in CO2 emissions and a further 16% reduction in NOx relative to ICAO-LTO cycle. Most importantly, the project will address the challenges involved in delivering these benefits simultaneously. NEWAC will deliver together with EEFAE (-11% CO2, -60% NOx), national programmes and expected results of VITAL, the overall CO2 reduction of 20% and the NOx reduction close to 80% at a technology readiness level of 5, contributing to the attainment of the ACARE targets.

NEWAC will achieve this technology breakthrough by integrating 41 actors from the European leading engine manufacturers, the engine-industry supply chain, key European research institutes and SMEs with specific expertise. The advance and benefits that NEWAC will bring to Europe in terms of more efficient and environment-friendly air transport will be disseminated widely to all stakeholders. Furthermore a training programme will ensure the transfer of expertise and knowledge to the wider research community and especially to the new member states of the EU.

| **Project details** | |
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| **Project Reference:** 30876 | **Contract Type:** Integrated Project |
| **Start Date:** 2006-05-01 | **End Date:** 2010-04-30 |
| **Duration:** 48 months | **Project Status:** Execution |
| **Project Cost:** 71.2 million euro | **Project Funding:** 40 million euro |

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| **Participant Organisation:** EnginSoft spa | **Country:** ITALY |
| **Participant Organisation:** Délégation Générale pour l'Armement / Centre d'Essais des Propulseurs | **Country:** FRANCE |
| **Participant Organisation:** Wytwórnia Sprzetu Komunikacyjnego "PZL-Rzeszów" Spólka Akcyjna | **Country:** POLAND |
| **Participant Organisation:** Vibro-Meter SA | **Country:** SWITZERLAND |
| **Participant Organisation:** Volvo Aero Corporation | **Country:** SWEDEN |
| **Participant Organisation:** Université de Technologie de Belfort-Montbéliard | **Country:** FRANCE |
| **Participant Organisation:** Universität Stuttgart | **Country:** GERMANY |
| **Participant Organisation:** Ecole Centrale de Lyon | **Country:** FRANCE |
| **Participant Organisation:** Université de Liège | **Country:** BELGIUM |
| **Participant Organisation:** Universitaet Karlsruhe (TH) | **Country:** GERMANY |
| **Participant Organisation:** UNIVERSITÀ DEGLI STUDI DI FIRENZE | **Country:** ITALY |
| **Participant Organisation:** TURBOMECA | **Country:** FRANCE |
| **Participant Organisation:** Graz University of Technology | **Country:** AUSTRIA |
| **Participant Organisation:** Techspace Aero | **Country:** BELGIUM |
| **Participant Organisation:** University of Sussex | **Country:** UNITED KINGDOM |
| **Participant Organisation:** Sulzer Metco AG (Switzerland) | **Country:** SWITZERLAND |
| **Participant Organisation:** Steigerwald Strahltechnik GmbH | **Country:** GERMANY |
| **Participant Organisation:** Société des Nouvelles Applications des Techniques de Surface | **Country:** FRANCE |
| **Participant Organisation:** SNECMA | **Country:** FRANCE |
| **Participant Organisation:** Aachen University of Technology | **Country:** GERMANY |
| **Participant Organisation:** Rolls-Royce Group plc | **Country:** UNITED KINGDOM |
| **Participant Organisation:** Rolls-Royce | **Country:** GERMANY |

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| Deutschland Ltd & Co KG | |
| **Participant Organisation:** PCA Engineers Limited | **Country:** UNITED KINGDOM |
| **Participant Organisation:** THE CHANCELLOR, MASTERS AND SCHOLARS OF THE UNIVERSITY OF OXFORD | **Country:** UNITED KINGDOM |
| **Participant Organisation:** NATIONAL TECHNICAL UNIVERSITY OF ATHENS | **Country:** GREECE |
| **Participant Organisation:** Loughborough University | **Country:** UNITED KINGDOM |
| **Participant Organisation:** SCITEK Consultants Ltd | **Country:** UNITED KINGDOM |
| **Participant Organisation:** Ecole Polytechnique Fédérale de Lausanne | **Country:** SWITZERLAND |
| **Participant Organisation:** Cranfield University | **Country:** UNITED KINGDOM |
| **Participant Organisation:** Chalmers University of Technology | **Country:** SWEDEN |
| **Participant Organisation:** CENTRE DE RECHERCHE EN AERONAUTIQUE, ASBL | **Country:** BELGIUM |
| **Participant Organisation:** THE CHANCELLOR, MASTERS AND SCHOLARS OF THE UNIVERSITY OF CAMBRIDGE | **Country:** UNITED KINGDOM |
| **Participant Organisation:** AVIO S.p.A. | **Country:** ITALY |
| **Participant Organisation:** Aristotle University of Thessaloniki | **Country:** GREECE |
| **Participant Organisation:** ARTTIC | **Country:** FRANCE |
| **Participant Organisation:** Prvni brnenska strojirna Velka Bites, a.s. | **Country:** CZECH REPUBLIC |
| **Participant Organisation:** AIRBUS France SAS | **Country:** FRANCE |
| **Participant Organisation:** OFFICE NATIONAL D'ETUDES ET DE RECHERCHES AEROSPATIALES | **Country:** FRANCE |
| **Participant Organisation:** DEUTSCHES ZENTRUM FÜR LUFT- UND RAUMFAHRT E.V. | **Country:** GERMANY |

**TLC**

**Towards lean combustion**

**Action Line:** AERO-1.2 Improving environmental impact with regard to emissions and noise

| **Coordinator** | |
|---|---|
| **Contact Person:**<br>Name: PENANHOAT, Olivier<br>Tel: +33-01-60598228<br>Fax: +33-01-60597712 | **Organisation:**<br>SNECMA<br>Combustion Department<br>2, Boulevard du Général Martial Valin<br>FRANCE |

The mitigation of aviation emissions in terms of their environmental impact is a priority for both air quality (local impact) and the greenhouse effect (global impact). For a fixed engine cycle, the margin of progress depends on the combustor technology. Lean combustion is the breakthrough which should enable high-level reductions in NOx emissions both during the LTO cycle (air quality) and at cruise speeds (global impact). In addition, lean combustion also enhances particulate reduction.

Injection systems form the most critical issue in achieving a satisfactory level of lean combustion and will be the technological focus for the project. Within this framework, a wide range of experiments will be carried out on mono-sector or tubular combustors. This new programme will be a crucial effort in achieving sufficient maturity for the single annular combustor application. The objectives will be an 80% reduction in NOx emissions in relation to the CAEP2 regulation limit during the LTO cycle, and low NOx emission indices at cruise speed (EINOx=5g/kg as target). Other gaseous emissions and soot performance characteristics will be also precisely evaluated.

In this prospect, the project will support the adaptation of most advanced, non-intrusive laser-based measurement techniques to combustors  actual conditions and their application (in addition to intrusive techniques) to experiments of various concepts of injection systems. The injection systems tested will derive from the LOPOCOTEP programme or other projects and from advanced CFD optimisation of new concepts. The entire range of operating conditions will be experimentally evaluated (LTO points, cruise speeds). Auto-ignition and flashback risk issue as well as lean extinction limit will be assessed. Advanced CFD simulation will also exploit the data from the fundamental experiments, thereby enabling calibration of the latest codes in emissions predictions.

| **Project details** | |
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| **Project Reference:** 12326 | **Contract Type:** Specific Targeted Research Project |
| **Start Date:** 2005-03-01 | **End Date:** 2009-02-28 |
| **Duration:** 48 months | **Project Status:** Execution |
| **Project Cost:** 7.55 million euro | **Project Funding:** 5.1 million euro |

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| **Participant Organisation:** ACIES | **Country:** FRANCE |
| **Participant Organisation:** CENTRE EUROPÉEN POUR LA RECHERCHE ET LA FORMATION AVANCÉE EN CALCULS SCIENTIFIQUES | **Country:** FRANCE |
| **Participant Organisation:** UNIVERSITÀ DEGLI STUDI DI NAPOLI FEDERICO II - DIPARTIMENTO DI INGEGNERIA CHIMICA | **Country:** ITALY |
| **Participant Organisation:** UNIVERSITY | **Country:** GERMANY |

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| OF KARLSRUHE (TH) | |
| **Participant Organisation:** DEUTSCHES ZENTRUM FÜR LUFT- UND RAUMFAHRT E.V. | **Country:** GERMANY |
| **Participant Organisation:** OFFICE NATIONAL D'ETUDES ET DE RECHERCHES AÉROSPATIALES | **Country:** FRANCE |
| **Participant Organisation:** CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE | **Country:** FRANCE |
| **Participant Organisation:** ECOLE CENTRALE DE NANTES | **Country:** FRANCE |
| **Participant Organisation:** UNIVERSITY OF ROME "LA SAPIENZA", DEPARTMENT OF MECHANICS AND AERONAUTICS | **Country:** ITALY |
| **Participant Organisation:** LUNDS UNIVERSITET | **Country:** SWEDEN |
| **Participant Organisation:** UNIVERSITY DEGLI STUDI DI GENOVA - DIPARTIMENTO DI MACCHINE, SISTEMI ENERGETICI E TRASPORTI | **Country:** ITALY |
| **Participant Organisation:** TURBOMECA | **Country:** FRANCE |
| **Participant Organisation:** ROLLS-ROYCE DEUTSCHLAND LTD & CO KG | **Country:** GERMANY |
| **Participant Organisation:** SNECMA MOTEURS | **Country:** FRANCE |
| **Participant Organisation:** FUNDACION EMPRESA UNIVERSIDAD DE ZARAGOZA | **Country:** SPAIN |
| **Participant Organisation:** AVIO S.P.A. | **Country:** ITALY |
| **Participant Organisation:** MTU AERO ENGINES GMBH & CO. KG | **Country:** GERMANY |
| **Participant Organisation:** INSTYTUT MASZYN PRZEPLYWOWYCH IM. ROBERTA SZEWALSKIEGO POLSKIEJ AKADEMII NAUK | **Country:** POLAND |
| **Participant Organisation:** MTU AERO ENGINES GMBH | **Country:** GERMANY |

**INTELLECT DM**

**Integrated Lean Low Emission Combustor Design Methodology (INTELLECT DM)**

**Action Line:** AERO-1.2 Improving environmental impact with regard to emissions and noise

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| **Coordinator** |

| **Contact Person:** | **Organisation:** |
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| Name: V.D. BANK, Ralf<br>Tel: +49-33-70861373<br>Fax: +49-33-708651137349337086 3086 | ROLLS-ROYCE DEUTSCHLAND LTD&CO KG<br>Combustors & Turbine (OE-5)<br>Eschenweg 11<br>GERMANY |



The objective of this proposal is to develop a design methodology for lean burn low emission combustors to achieve a sufficient operability over the entire range of operating conditions whilst maintaining low NOx emission capability. A knowledge-based design system will form the framework to capture existing combustor design knowledge and knowledge generated in this project. Through pressing demand for emission reduction, very ambitious future NOx reduction targets of 80% by 2020 have been set. Existing design rules, for conventional combustion systems, cannot be applied for lean low emission combustors. It is therefore important to embody new design rules quickly, so that the new technology can be incorporated faster into future products. The aim is to create the first building blocks of such an integrated combustor design system. The system will incorporate preliminary design tools to make first estimates of the arrangement for lean burn combustion, which meets operability, external aero-dynamics, cooling and emissions needs. Guidelines for the design of lean low NOx combustors for reliable and safe operation will be derived. Incorporation of these guidelines for lean low NOx combustion in the knowledge-based combustor engineering tool is in order to strengthen European competitiveness by reducing development costs and time. Lean blow out limit, ignition and altitude relight will be investigated. The airflow distribution and the aero-design of pre-diffusers for lean low NOx combustion with up to 70% air consumption will be optimised. Wall temperature prediction and testing for highly efficient cooling design will be performed. An assessment of generated knowledge and implementation in the knowledge-based system will take place. The new lean burn concepts have to gain customer and market acceptance to be fully competitive. Answers to principal questions concerning the operability and airworthiness of low NOx combustors will be given.

| **Project details** | |
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| **Project Reference:** 502961 | **Contract Type:** Specific Targeted Research Project |
| **Start Date:** 2004-01-01 | **End Date:** 2007-12-31 |
| **Duration:** 48 months | **Project Status:** Execution |
| **Project Cost:** 7737.00 euro | **Project Funding:** 5 million euro |

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| **Participant Organisation:** SNECMA | **Country:** FRANCE |
| **Participant Organisation:** UNIVERSITAET KARLSRUHE (TECHNISCHE HOCHSCHULE) | **Country:** GERMANY |
| **Participant Organisation:** IMPERIAL COLLEGE OF SCIENCE, TECHNOLOGY AND MEDICINE | **Country:** UNITED KINGDOM |
| **Participant Organisation:** UNIVERSITAET DER BUNDESWEHR MUENCHEN | **Country:** GERMANY |
| **Participant Organisation:** CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE | **Country:** FRANCE |

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| **Participant Organisation:** DEUTSCHES ZENTRUM FUER LUFT UND RAUMFAHRT E.V. | **Country:** GERMANY |
| **Participant Organisation:** TURBOMECA SA | **Country:** FRANCE |
| **Participant Organisation:** SNECMA MOTEURS SA | **Country:** FRANCE |
| **Participant Organisation:** LUNDS UNIVERSITET | **Country:** SWEDEN |
| **Participant Organisation:** UNIVERSITA DEGLI STUDI DI FIRENZE | **Country:** ITALY |
| **Participant Organisation:** THE CHANCELLOR, MASTERS AND SCHOLARS OF THE UNIVERSITY OF CAMBRIDGE | **Country:** UNITED KINGDOM |
| **Participant Organisation:** TECHNICAL UNIVERSITY OF CZESTOCHOWA | **Country:** POLAND |
| **Participant Organisation:** ROLLS ROYCE PLC | **Country:** UNITED KINGDOM |
| **Participant Organisation:** OFFICE NATIONAL D'ETUDES ET DE RECHERCHES AEROSPATIALES | **Country:** FRANCE |
| **Participant Organisation:** AVIO S.P.A. | **Country:** ITALY |
| **Participant Organisation:** AVIO S.P.A. | **Country:** ITALY |
| **Participant Organisation:** CENTRE EUROPEEN DE RECHERCHE ET DE FORMATION AVANCEE EN CALCUL SCIENTIFIQUE | **Country:** FRANCE |
| **Participant Organisation:** LOUGHBOROUGH UNIVERSITY | **Country:** UNITED KINGDOM |

**NACRE**

**New Aircraft Concepts REsearch**

**Action Line:** AERO-2003-1.3.2.1 New concepts for the future generation of aircraft configurations

| **Co-ordinator** | |
|---|---|
| **Contact Person:**<br>Name: FROTA, João<br>Tel: +33-56-7190844<br>Fax: +33-56-1934877 | **Organisation:**<br>AIRBUS SAS<br>Engineering - Future Projects<br>1 Rond-point Maurice BELLONTE BP 31707<br>31707 BLAGNAC<br>FRANCE |

Over the past 50 years, the main driver for aircraft design was to improve aircraft operational efficiency, which led to converge to an almost universal configuration, which now dominates the commercial aircraft market. Given that air traffic is forecasted to more than double in the next 20 years and that both environmental and economical pressure will strongly increase, significant progress will need to be achieved in both improving the efficiency and minimising the environmental impact of aircraft. This may not no longer be achievable with today's configuration.

Designing suitable Novel Aircraft Concepts will require developing capabilities in the complete range of aeronautical disciplines and technologies. The New Aircraft Concepts Research (NACRE) Integrated Project will investigate, from 2005 to 2009, into the development of the concepts and technologies required for Novel Aircraft Concepts at aircraft component level: Wing, Fuselage, Engine Integration on a range of Novel Aircraft Concepts: the Pro-active Green aircraft, the Payload-Driven Aircraft and the Simple Flying Bus. NACRE will take full benefit of the preliminary activities initiated in Europe on Novel Aircraft Concepts in the frame of the FP5 projects ROSAS, VELA & NEFA.

The NACRE consortium is composed of 35 partners from 13 countries (including Russia), providing an impressive spread of expertise throughout the EU. Stepping into the second century of controlled flight, the NACRE project team is animated by the same innovative enthusiasm and solid rationale pioneered by the Wright brothers. The permanent assessment of alternative concepts, to be performed within NACRE, will guarantee both that the best capabilities are available and that the spirit for engineering innovation is preserved and developed for further exploitation.

| **Project details** | |
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| **Project Reference:** 516068 | **Contract Type:** Integrated Project |
| **Start Date:** 2005-04-01 | **End Date:** 2009-03-31 |
| **Duration:** 48 months | **Project Status:** Execution |
| **Project Cost:** 30.34 million euro | **Project Funding:** 16.91 million euro |

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| **Participant Organisation:** SMITHS AEROSPACE LIMITED TRADING | **Country:** UNITED KINGDOM |
| **Participant Organisation:** POLITECHNIKA WARSZAWSKA (WARSAW UNIVERSITY OF TECHNOLOGY) | **Country:** POLAND |
| **Participant Organisation:** UNIVERSITÄT STUTTGART | **Country:** GERMANY |
| **Participant Organisation:** FEDERAL STATE UNITARY ENTERPRISE AEROHYDRODYNAMIC INSTITUTE | **Country:** RUSSIAN FEDERATION |
| **Participant Organisation:** SNECMA SA | **Country:** FRANCE |
| **Participant Organisation:** AIRCELLE SA | **Country:** FRANCE |
| **Participant Organisation:** SNECMA SA | **Country:** FRANCE |
| **Participant Organisation:** AIRCELLE SAS | **Country:** FRANCE |

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| **Participant Organisation:** UNIVERSITY OF SOUTHAMPTON | **Country:** UNITED KINGDOM |
| **Participant Organisation:** POLITECHNIKA WARSZAWSKA (WARSAW UNIVERSITY OF TECHNOLOGY) | **Country:** POLAND |
| **Participant Organisation:** UNIVERSITÄT STUTTGART | **Country:** GERMANY |
| **Participant Organisation:** KUNGLIGA TEKNISKA HÖGSKOLAN | **Country:** SWEDEN |
| **Participant Organisation:** FEDERAL STATE UNATARY ENTERPRISE AEROHYDRODYNAMIC INSTITUTE | **Country:** RUSSIAN FEDERATION |
| **Participant Organisation:** SNECMA MOTEURS | **Country:** FRANCE |
| **Participant Organisation:** PIAGGIO AERO INDUSTRIES SPA | **Country:** ITALY |
| **Participant Organisation:** OFFICE NATIONAL D'ETUDES ET DE RECHERCHES AÉROSPATIALES | **Country:** FRANCE |
| **Participant Organisation:** STICHTING NATIONAAL LUCHT - EN RUIMTEVAARTLABORATORIUM (NATIONAL AEROSPACE LABORATORY) | **Country:** NETHERLANDS |
| **Participant Organisation:** MTU AERO ENGINES GMBH | **Country:** GERMANY |
| **Participant Organisation:** DEUTSCHES ZENTRUM FR LUFT- UND RAUMFAHRT E.V. | **Country:** GERMANY |
| **Participant Organisation:** DASSAULT AVIATION | **Country:** FRANCE |
| **Participant Organisation:** ARTTIC | **Country:** FRANCE |
| **Participant Organisation:** THE PROVOST FELLOWS AND SCHOLARS OF THE COLLEGE OF THE HOLY AND UNDIVIDED TRINITY OF QUEEN ELIZABETH NEAR DUBLIN (HEREINAFTER CALLED TCD) | **Country:** IRELAND |
| **Participant Organisation:** INTEGRATED AEROSPACE SCIENCES CORPORATION (INASCO) | **Country:** GREECE |
| **Participant Organisation:** ROLLS-ROYCE PLC | **Country:** UNITED KINGDOM |
| **Participant Organisation:** EADS DEUTSCHLAND GMBH, CORPORATE RESEARCH CENTER | **Country:** GERMANY |

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|---|---|
| **Participant Organisation:** ROLLS-ROYCE DEUTSCHLAND LTD & CO. KG | **Country:** GERMANY |
| **Participant Organisation:** TECHNISCHE UNIVERSITAET MUENCHEN | **Country:** GERMANY |
| **Participant Organisation:** UNIVERSITY OF GREENWICH | **Country:** UNITED KINGDOM |
| **Participant Organisation:** MESSIER-DOWTY LIMITED | **Country:** UNITED KINGDOM |
| **Participant Organisation:** INSTITUTO NACIONAL DE TÉCNICA AEROESPACIAL | **Country:** SPAIN |
| **Participant Organisation:** IBK INGENIEURBUERO DR. KRETZSCHMAR | **Country:** GERMANY |
| **Participant Organisation:** AIRCRAFT RESEARCH ASSOCIATION LIMITED | **Country:** UNITED KINGDOM |
| **Participant Organisation:** AIRBUS ESPAÑA, S.L. SOCIEDAD UNIPERSONAL | **Country:** SPAIN |
| **Participant Organisation:** ALENIA AERONAUTICA S.P.A. | **Country:** ITALY |
| **Participant Organisation:** PEDECE (PROJECTO, EMPREENDIMENTOS, DESENVOLVIMENTO E EQUIPAMENTOS CIENTIFICOS DE ENGENHARIA) | **Country:** PORTUGAL |
| **Participant Organisation:** HUREL-HISPANO | **Country:** FRANCE |
| **Participant Organisation:** AIRBUS DEUTSCHLAND GMBH | **Country:** GERMANY |
| **Participant Organisation:** VYZKUMNY A ZKUSEBNI LETECKY USTAV, A.S. | **Country:** CZECH REPUBLIC |
| **Participant Organisation:** AIRBUS FRANCE SAS | **Country:** FRANCE |
| **Participant Organisation:** AIRBUS UK | **Country:** UNITED KINGDOM |
| **Participant Organisation:** SWEDISH DEFENCE RESEARCH AGENCY | **Country:** SWEDEN |
| **Participant Organisation:** CENTRO ITALIANO RICERCHE AEROSPAZIALI SCPA | **Country:** ITALY |

**DIALFAST**

**Development of Innovative and Advanced Laminates for Future Aircraft Structure**

**Action Line:** AERO-1.3 Improving aircraft safety and security,AERO-2002-1.3.1.1e Structural weight reduction

| **Coordinator** | |
|---|---|
| **Contact Person:**<br>Name: RENNER, Michael<br>Tel: +49-42-15383635<br>Fax: +49-42-15383081 | **Organisation:**<br>AIRBUS DEUTSCHLAND GMBH<br>Department Metal Technology (ESWOG);<br>Metal Design Principles (ESDO)<br>Kreetslag 10<br>GERMANY |

The technical focus of this project is the development of new generations of Fibre Metal Laminates-FML and Metal Laminates-ML, that provide significantly improved strength and stiffness properties for tailored fuselage applications. The fatigue properties of these innovative Laminates, which are not yet available, are required to match those of the rather expensive GLARE® material. The objective of significantly increased static behaviour and a well-balanced combination of mechanical properties will be achieved by the use of alternative constituents such as new fibres, advanced metals and modified pre-preg systems. The high manufacturing costs of FML will be reduced by using less expensive material systems such as high-performance ML. Appropriate manufacturing and joining technologies require validation for the progressive laminates. Corrosion is a problem to be quantified and resolved with new sizing and treatments. A further essential task is the development of material models and static failure criteria for the prediction of the material behaviour of FML and ML in both the microscopic and the macroscopic scale. Finally, optimisation criteria for the design of coupons and structural elements will be developed and experimentally verified for laminates with the aim to reduce the overall weight of the aircraft fuselage. The technological objective is a fuselage skin weight reduction of up to 30% when compared to GLARE®. This is achieved by an increase in static properties of 10% to 100%, depending on the specific value considered. The strategic objectives are an increase in the operational capacity of 10%, a reduction in the direct operating cost of 10% and finally a reduction in the fuel consumption of 10% and therefore a reduced environmental impact with regard to emissions and noise. The strategic and economic objective is a reduction in the product cost of 5% derived due from a fuselage skin material cost reduction of 20%.

| **Project details** | |
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| **Project Reference:** 502846 | **Contract Type:** Specific Targeted Research Project |
| **Start Date:** 2004-01-01 | **End Date:** 2007-12-31 |
| **Duration:** 48 months | **Project Status:** Execution |
| **Project Cost:** 6.31 million euro | **Project Funding:** 3.56 million euro |

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| **Participant Organisation:** LINKOEPINGS UNIVERSITET | **Country:** SWEDEN |
| **Participant Organisation:** UNIVERSITA DEGLI STUDI DI PISA | **Country:** ITALY |
| **Participant Organisation:** EADS CCR | **Country:** FRANCE |
| **Participant Organisation:** AIRBUS DEUTSCHLAND GMBH | **Country:** GERMANY |
| **Participant Organisation:** LINKOEPINGS UNIVERSITET | **Country:** SWEDEN |
| **Participant Organisation:** UNIVERSITA DEGLI STUDI DI PISA | **Country:** ITALY |

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| **Participant Organisation:** FIBRE METAL LAMINATES CENTRE OF COMPETENCE | **Country:** NETHERLANDS |
| **Participant Organisation:** FOKKER AEROSTRUCTURES BV | **Country:** NETHERLANDS |
| **Participant Organisation:** ALENIA AERONAUTICA SPA | **Country:** ITALY |
| **Participant Organisation:** TECHNISCHE UNIVERSITEIT DELFT | **Country:** NETHERLANDS |
| **Participant Organisation:** STICHTING NATIONAAL LUCHT- EN RUIMTEVAARTLABORATORIUM | **Country:** NETHERLANDS |
| **Participant Organisation:** GIE EADS CCR | **Country:** FRANCE |
| **Participant Organisation:** EUROPEAN AERONAUTIC DEFENSE AND SPACE COMPANY - EADS DEUTSCHLAND GMBH | **Country:** GERMANY |
| **Participant Organisation:** EADS DEUTSCHLAND GMBH | **Country:** GERMANY |
| **Participant Organisation:** ISTRAM - INSTITUTE OF STRUCTURES AND ADVANCED MATERIALS | **Country:** GREECE |

**IDEA**

**Integrated design and product development for the eco-efficient production of low-weight aeroplane equipment (IDEA)**

**Action Line:** AERO-2002-1.3.1.1e Structural weight reduction

| **Coordinator** | |
|---|---|
| **Contact Person:**<br>Name: WENDT, Joachim<br>Tel: +49-24-71123019<br>Fax: +49-24-71123099 | **Organisation:**<br>RWP GMBH<br>RWP GMBH<br>Am Muensterwald 11<br>52159 ROETGEN<br>GERMANY |

The project aims at substituting aircraft components like seat frames and electronic casings by cast magnesium parts. Integration of Mg-alloys into the aerospace industry will reduce aircraft's weight, improve noise damping and reduce fuel consumption and air pollution. Although Mg-alloys are increasingly used in automotive industry, Mg-technology needs to be further developed for aerospace industry. Nowadays less than 20 cast Mg-alloys are available, however approximately 97% of CAS-tings are made of AZ91, AM50/60 and WE54 or AS21. Until now it is believed that potential increase of Mg-alloys application is in the automotive industry, especially in components subjected to elevated temperature (gear box, oil panel, engines). Thus, there is a need to increase the number of Mg-alloys for aerospace applications with their specific requirements to strength, damping properties, corrosion resistance etc. Since there is a lack of knowledge on characteristics and advantages of Mg-alloys and a lack of approved standards for Mg-components, the project will inform aviation designers on usability of Mg-alloys and contribute to standardisation.

Project objectives:

1.To develop new light weight Mg-alloys fulfilling requirements for cast ability, corrosion resistance and mechanical properties of cast components like strength, damping properties, high performance impact etc.

2.To optimise high pressure die casting, investment casting, and sand casting processes for Mg-alloys including the development of a novel ceramic shell for Mg-investment casting.

3.To develop and use specific simulation tools for determination of local mechanical part properties and virtual standard tests of Mg-castings.

4.To prepare a design manual for cast magnesium components as a guide for aviation designers to select convenient Mg-alloys and production methods for aircraft components.

5.To produce 2 demonstrators for typical thick-walled and thin-walled aerospace applications.'

| **Project details** | |
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| **Project Reference:** 503826 | **Contract Type:** Specific Targeted Research Project |
| **Start Date:** 2004-01-01 | **End Date:** 2006-12-31 |
| **Duration:** 36 months | **Project Status:** Completed |
| **Project Cost:** 4.87 million euro | **Project Funding:** 2.89 million euro |

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| **Participant Organisation:** STONES FOUNDRIES LIMITED | **Country:** UNITED KINGDOM |
| **Participant Organisation:** FRAUNHOFER-GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG E.V. | **Country:** GERMANY |
| **Participant Organisation:** MONDRAGON GOI ESKOLA POLITEKNIKOA S.COOP. | **Country:** SPAIN |
| **Participant Organisation:** UNIVERSITE HENRI POINCARE NANCY 1 | **Country:** FRANCE |
| **Participant Organisation:** RAZVOJNI CENTER ORODJARSTVA SLOVENIJE | **Country:** SLOVENIA |
| **Participant Organisation:** VTT VALTION TEKNILLINEN TUTKIMUSKESKUS | **Country:** FINLAND |
| **Participant Organisation:** SPECIALVALIMO J. PAP OY | **Country:** FINLAND |
| **Participant Organisation:** MAGNESIUM RESEARCH INSTITUTE | **Country:** ISRAEL |
| **Participant Organisation:** ISRAEL AIRCRAFT INDUSTRIES LTD | **Country:** ISRAEL |
| **Participant Organisation:** FEMALK ALUMINIUM DIE CASTING FOUNDRY LTD | **Country:** HUNGARY |

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| **Participant Organisation:** INFERTA INSTITUT FUR FERTIGUNGSTECHNICK IM AUTOMOBILBAU GMBH | **Country:** GERMANY |
| **Participant Organisation:** KERN GMBH | **Country:** GERMANY |
| **Participant Organisation:** TECHNION - ISRAEL INSTITUTE OF TECHNOLOGY | **Country:** ISRAEL |

**TELFONA**

**Testing for Laminar Flow on New Aircraft**

**Action Line:** AERO-2003-1.3.1.1d Aerodynamics

| **Coordinator** | |
|---|---|
| **Contact Person:**<br>Name: SAWYERS, David Michael<br>Tel: +44-11-79363435<br>Fax: +44-11-79365161 | **Organisation:**<br>AIRBUS UK<br>Aerodynamic Design and Data domain<br>NEW FILTON HOUSE BS99 7AR<br>UNITED KINGDOM |

TELFONA will deliver upstream aerodynamics research that will enable innovative aircraft configuration development leading to a step change in aircraft performance. The project will contribute to the drive to strengthen the competitiveness of European manufacturing industry and to the need to improve the environmental impact of aircraft with regards to emissions. The major objective of the TELFONA project is the development of the capability to predict the in-flight performance of a future laminar flow aircraft using a combination of wind tunnel tests and CFD calculations. This research responds to an opportunity to design a pro-green aircraft configuration with a wing with a significantly higher aspect ratio and lower sweep than today's standard. This configuration has lower drag and higher lift/drag ratio than today's designs. The reduction in wing sweep opens the opportunity for the wing to be designed for natural laminar flow, introducing a further drag reduction. It is predicted that the combined drag reduction could be 20% leading to large reductions in emissions. The achievement of the objective will give the aircraft manufacturers within TELFONA confidence that the flight performance of such an aircraft can be predicted prior to aircraft project launch. The project objective will be achieved through the evaluation of the flow characteristics of the European Transonic Windtunnel, the development of advanced methods for transition prediction and boundary layer flow modelling and the validation of all new techniques through the design of a high-performance wing for a pro-green aircraft configuration. The project consortium consists of 15 organisations from 8 different countries whose researchers have significant experience in the areas of wing design, laminar flow technology and wind tunnel testing. TELFONA is structured into 5 technical workpackages and a dedicated workpackage for project management and exploitation activities.

| **Project details** | |
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| **Project Reference:** 516109 | **Contract Type:** Specific Targeted Research Project |
| **Start Date:** 2005-05-01 | **End Date:** 2008-10-31 |
| **Duration:** 42 months | **Project Status:** Execution |
| **Project Cost:** 5.17 million euro | **Project Funding:** 3.03 million euro |

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|---|---|
| **Participant Organisation:** TECHNISCHE UNIVERSITÄT BERLIN | **Country:** GERMANY |
| **Participant Organisation:** SWEDISH DEFENCE RESEARCH AGENCY (TOTALFÖRSVARETS FORSKNINGSINSTITUT, FOI) | **Country:** SWEDEN |
| **Participant Organisation:** EUROPEAN TRANSONIC WINDTUNNEL GMBH | **Country:** GERMANY |
| **Participant Organisation:** DEUTSCHES ZENTRUM FR LUFT- UND RAUMFAHRT E.V. | **Country:** GERMANY |
| **Participant Organisation:** CENTRO ITALIANO RICERCHE AEROSPAZIALI SCPA | **Country:** ITALY |
| **Participant Organisation:** AIRBUS ESPANA, S.L. SOCIEDAD UNIPERSONAL | **Country:** SPAIN |
| **Participant Organisation:** KUNGLIGA TEKNISKA HOGSKOLAN | **Country:** SWEDEN |
| **Participant Organisation:** PIAGGIO AERO INDUSTRIES S.P.A | **Country:** ITALY |
| **Participant Organisation:** IMPERIAL COLLEGE OF SCIENCE, TECHNOLOGY & MEDICINE | **Country:** UNITED KINGDOM |
| **Participant Organisation:** OFFICE NATIONAL D'ETUDES ET DE RECHERCHES AEROSPATIALES | **Country:** FRANCE |
| **Participant Organisation:** AIRBUS DEUTSCHLAND GMBH | **Country:** GERMANY |
| **Participant Organisation:** ALMA CONSULTING GROUP SAS | **Country:** FRANCE |
| **Participant Organisation:** INSTITUTO SUPERIOR TECNICO | **Country:** PORTUGAL |
| **Participant Organisation:** VYZKUMNY A ZKUSEBNI LETECKY USTAV, A.S. | **Country:** CZECH REPUBLIC |

**VITAL**

**EnVIronmenTALly Friendly Aero Engine**

| **Co-ordinator** | |
|---|---|
| **Contact Person:**<br>Name: KORSIA, Jean Jacques<br>Tel: +33-16-0599333<br>Fax: +33-16-0597764 | **Organisation:**<br>SNECMA MOTEURS<br>Research & Technology Department<br>2 Bld du Général Martial Valin<br>FRANCE |

VITAL will provide a breakthrough in low noise and low emission engine architectures. This breakthrough will be achieved by developing and validating novel lightweight and low-noise technologies for commercial aircraft engines and thus provides a key step towards achieving the ACARE environmental goals in terms of CO2 and noise. VITAL will design, manufacture and rig test the critical technologies required to achieve this goal: low-noise and low-weight fan technologies and architectures (direct drive turbo fan and contra-rotating turbo fan), low-weight structures for very high bypass ratio engines, more efficient low-pressure turbo machinery, advanced low-pressure torque shaft and overall engine installation.

To complement these technological advances VITAL will provide a techno-economic and environmental risk assessment and accompanying optimiser tool for measuring the impact of engines on the environment as well as their economic impact and make this tool available to all stakeholders via a dissemination activity. VITAL will also take up the results of on-going research programmes in the field of noise and emissions and will deliver a fully validated, novel technology base together with the roadmap to enable a 20% reduction in CO2 emissions and a 6dB reduction in aircraft engine noise (per certification point) and hence contribute to the full realisation of the ACARE goals by 2020.VITAL will achieve this technology breakthrough by bringing together 53 actors from the European aero-engine industry made up of the leading engine manufacturers, the engine-industry supply chain, key European research institutes and SMEs with specific expertise.
The advance and benefits that VITAL will bring to Europe at large in terms of more efficient and environmentally-friendly air transport will be disseminated throughout the project to all stakeholders.

| **Project details** | |
|---|---|
| **Project Reference:** 12271 | **Contract Type:** Integrated Project |
| **Start Date:** 2005-01-01 | **End Date:** 2008-12-31 |
| **Duration:** 48 months | **Project Status:** Execution |
| **Project Cost:** 90.24 million euro | **Project Funding:** 50.36 million euro |

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| **Participant Organisation:** SNECMA | **Country:** FRANCE |
| **Participant Organisation:** HOEGSKOLAN VAEST | **Country:** SWEDEN |
| **Participant Organisation:** AIRCELLE | **Country:** FRANCE |
| **Participant Organisation:** NATIONAL RESEARCH & DEVELOPMENT INSTITUTE FOR GAS TURBINES COMOTI | **Country:** ROMANIA |
| **Participant Organisation:** VOLVO AERO NORGE AS | **Country:** NORWAY |
| **Participant Organisation:** VOLVO AERO CORPORATION | **Country:** SWEDEN |
| **Participant Organisation:** UNIVERSITA' DI LECCE | **Country:** ITALY |
| **Participant Organisation:** UNIVERSITAET STUTTGART | **Country:** GERMANY |
| **Participant Organisation:** UNIVERSITÀ | **Country:** ITALY |

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| DEGLI STUDI DI GENOVA - DIPARTIMENTO DI MACCHINE, SISTEMI ENERGETICI E TRASPORTI | |
| **Participant Organisation:** UNIVERSITA' DEGLI STUDI DI FIRENZE | **Country:** ITALY |
| **Participant Organisation:** UNIVERSIDAD POLITÉCNICA DE MADRID | **Country:** SPAIN |
| **Participant Organisation:** SICOMP AB | **Country:** SWEDEN |
| **Participant Organisation:** POLITECNICO DI TORINO | **Country:** ITALY |
| **Participant Organisation:** INDUSTRIA DE TURBO PROPULSORES, S.A. | **Country:** SPAIN |
| **Participant Organisation:** HUREL-HISPANO | **Country:** FRANCE |
| **Participant Organisation:** GRAZ UNIVERSITY OF TECHNOLOGY | **Country:** AUSTRIA |
| **Participant Organisation:** FORCE TECHNOLOGY | **Country:** DENMARK |
| **Participant Organisation:** EAST-4D GMBH LIGHTWEIGHT STRUCTURES | **Country:** GERMANY |
| **Participant Organisation:** TECHNISCHE UNIVERSITT DRESDEN | **Country:** GERMANY |
| **Participant Organisation:** CHALMERS TEKNISKA HOEGSKOLA AB | **Country:** SWEDEN |
| **Participant Organisation:** FUNDACIÓN CENTRO DE TECNOLOGÍAS AERONÁUTICAS | **Country:** SPAIN |
| **Participant Organisation:** CENTRO DE ESTUDIOS E INVESTIGACIONES TÉCNICAS DE GIPUZKOA | **Country:** SPAIN |
| **Participant Organisation:** ALLVAC LIMITED | **Country:** UNITED KINGDOM |
| **Participant Organisation:** CHALMERS TEKNISKA HOEGSKOLA AB | **Country:** SWEDEN |
| **Participant Organisation:** ROLLS-ROYCE PLC | **Country:** UNITED KINGDOM |
| **Participant Organisation:** GKN AEROSPACE SERVICES LTD | **Country:** UNITED KINGDOM |
| **Participant Organisation:** AVIO S.P.A. | **Country:** ITALY |
| **Participant Organisation:** UNIVERSITE PIERRE-ET-MARIE-CURIE | **Country:** FRANCE |
| **Participant Organisation:** STICHTING NATIONAAL LUCHT EN RUIMTEVAARTLABORATORIUM | **Country:** NETHERLANDS |
| **Participant Organisation:** THE | **Country:** UNITED KINGDOM |

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| CHANCELLOR, MASTERS AND SCHOLARS OF THE UNIVERSITY OF OXFORD | |
| **Participant Organisation:** CENTRE DE RECHERCHE EN AERONAUTIQUE, ASBL | **Country:** BELGIUM |
| **Participant Organisation:** THE UNIVERSITY OF NOTTINGHAM | **Country:** UNITED KINGDOM |
| **Participant Organisation:** CRANFIELD UNIVERSITY | **Country:** UNITED KINGDOM |
| **Participant Organisation:** WYTWORNIA SPRZETU KOMUNIKACYJNEGO "PZL-RZESZOW" S.A. | **Country:** POLAND |
| **Participant Organisation:** SHORT BROTHERS PLC | **Country:** UNITED KINGDOM |
| **Participant Organisation:** PCA ENGINEERS LIMITED | **Country:** UNITED KINGDOM |
| **Participant Organisation:** CENTRE DE RECHERCHE ET DE FORMATION AVANCE EN CALCUL SCIENTIFIQUE | **Country:** FRANCE |
| **Participant Organisation:** UNIVERSITAET DER BUNDESWEHR MUENCHEN | **Country:** GERMANY |
| **Participant Organisation:** TECHSPACE AERO | **Country:** BELGIUM |
| **Participant Organisation:** OFFICE NATIONAL D'ETUDES ET DE RECHERCHES AÉROSPATIALES | **Country:** FRANCE |
| **Participant Organisation:** MS COMPOSITES | **Country:** FRANCE |
| **Participant Organisation:** VON KARMAN INSTITUTE FOR FLUID DYNAMICS | **Country:** BELGIUM |
| **Participant Organisation:** FISCHER ADVANCED COMPOSITE COMPONENTS AG | **Country:** AUSTRIA |
| **Participant Organisation:** THE SWEDISH DEFENCE RESEARCH AGENCY | **Country:** SWEDEN |
| **Participant Organisation:** AIRBUS FRANCE SAS | **Country:** FRANCE |
| **Participant Organisation:** ROLLS-ROYCE DEUTSCHLAND LTD AND CO. KG | **Country:** GERMANY |
| **Participant Organisation:** CENTRAL INSTITUTE OF AVIATION MOTORS | **Country:** RUSSIAN FEDERATION |
| **Participant Organisation:** UNIVERSITY TROLLHATTAN/UDDEVALLA | **Country:** SWEDEN |

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|---|---|
| **Participant Organisation:** PHOTON LASER ENGINEERING GMBH | **Country:** GERMANY |
| **Participant Organisation:** GLOBAL DESIGN TECHNOLOGY | **Country:** BELGIUM |
| **Participant Organisation:** MTU AERO ENGINES GMBH & CO. KG | **Country:** GERMANY |
| **Participant Organisation:** ECOLE NATIONALE SUPÉRIEURE DE L'AÉRONAUTIQUE ET DE L'ESPACE | **Country:** FRANCE |
| **Participant Organisation:** VIBRATEC | **Country:** FRANCE |
| **Participant Organisation:** DEUTSCHES ZENTRUM FÜR LUFT- UND RAUMFAHRT E.V. | **Country:** GERMANY |
| **Participant Organisation:** ARTTIC | **Country:** FRANCE |
| **Participant Organisation:** UNIVERSITY OF SOUTHAMPTON | **Country:** UNITED KINGDOM |

**REMFI**

**Rear Fuselage and Empennage Flow Investigation (REMFI)**

**Action Line:** AERO-1.3 Improving aircraft safety and security

| **Coordinator** | |
|---|---|
| **Contact Person:**<br>Name: ABBAS BAYOUMI, Adel Sayed<br>Tel: +34-91-6241445<br>Fax: +34-91-6243260 | **Organisation:**<br>AIRBUS ESPANA SL<br>Aerodynamics - Airbus Spain<br>Avenida John Lennon s/n<br>SPAIN |

It is known that business needs are placing an ever-increasing demand on the aeronautics industry to develop and manufacture aircraft at lower costs, with improved flight capabilities and a reduced impact on the environment. Hence, a primary objective for the aerospace industry is to offer products that not only meet the operating criteria but also significantly reduce the direct operating costs. Furthermore, research effort with respect to an improved understanding of the flow physics around fuselage / tail combinations remained limited, as investigations naturally concentrated on the wing and its interaction with the fuselage. However, a successful design approach towards the development of modern transport aircraft has to take the empennage as well. Thus, the improvements to be achieved by REMFI focus on three main aspects, the enhanced understanding of the tail flow physics, improved computational predictions for fuselage/tail design and analysis and improved experimental capabilities and measuring techniques for tail flows. This aims at providing means to: increase the empennage aerodynamic efficiency and reduce loads; improve flight safety; improved empennage performance and weight for optimised gaps effects, including Reynolds number effects; investigate sting mounting arrangement effects on empennage wind tunnel measurements; enhance the current scaling methodologies to free-flight conditions; reduce fuel burn (this has a positive effect on energy saving and reduction of emissions to the environment); novel design concepts for integrated fuselage / empennage designs with significant interaction between rear fuselage and belly fairing; investigate novel flow control devices (speed brakes) on fuselage and vertical tail; shorten the design cycle; reduce the cost of the aerodynamic design of tail and fuselage and reduce the maintenance costs.

| Project details | |
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| **Project Reference:** 502895 | **Contract Type:** Specific Targeted Research Project |
| **Start Date:** 2004-03-01 | **End Date:** 2007-02-28 |
| **Duration:** 36 months | **Project Status:** Completed |
| **Project Cost:** 6.37 million euro | **Project Funding:** 3.51 million euro |

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| **Participant Organisation:** RHEINISCH-WESTFAELISCHE TECHNISCHE HOCHSCHULE AACHEN | **Country:** GERMANY |
| **Participant Organisation:** UNIVERSIDAD POLITECNICA DE MADRID | **Country:** SPAIN |
| **Participant Organisation:** EUROPEAN TRANSONIC WINDTUNNEL GMBH | **Country:** GERMANY |
| **Participant Organisation:** OFFICE NATIONAL D'ETUDES ET DE RECHERCHES AEROSPATIALES | **Country:** FRANCE |
| **Participant Organisation:** AIRCRAFT RESEARCH ASSOCIATION LIMITED | **Country:** UNITED KINGDOM |
| **Participant Organisation:** TECHNISCHE UNIVERSITAET CAROLO-WILHELMINA ZU BRAUNSCHWEIG | **Country:** GERMANY |
| **Participant Organisation:** DASSAULT AVIATION S.A. | **Country:** FRANCE |
| **Participant Organisation:** KUNGLIGA TEKNISKA HOEGSKOLAN | **Country:** SWEDEN |
| **Participant Organisation:** INSTITUTO NACIONAL DE TECNICA AEROESPACIAL | **Country:** SPAIN |
| **Participant Organisation:** AIRBUS DEUTSCHLAND GMBH | **Country:** GERMANY |
| **Participant Organisation:** SWEDISH DEFENCE RESEARCH AGENCY | **Country:** SWEDEN |
| **Participant Organisation:** AIRBUS FRANCE SAS | **Country:** FRANCE |
| **Participant Organisation:** DEUTSCHES ZENTRUM FUER LUFT UND RAUMFAHRT E.V. | **Country:** GERMANY |
| **Participant Organisation:** CENTRE INTERNACIONAL DE METODES NUMERICS EN ENGINYERIA | **Country:** SPAIN |
| **Participant Organisation:** TECHNISCHE UNIVERSITAET BERLIN | **Country:** GERMANY |

**ADVACT**

**Development of Adavanced Actuation concepts to provide a step change in technology used in future aero-engine control systems (ADVACT)**

**Action Line:** AERO-1.2 Improving environmental impact with regard to emissions and noise

| **Co-ordinator** | |
|---|---|
| **Contact Person:**<br>Name: MITCHELL, Peter Francis<br>Tel: +4+-41-332260193<br>Fax: +44-13-32249513 | **Organisation:**<br>ROLLS ROYCE PLC<br>Controls R & T<br>Buckingham Gate 65<br>SW1E6AT LONDON<br>UNITED KINGDOM |

Major strides have been made in monitoring and control for gas turbines engines. Very little has changed in what is physically controlled or the actuator mechanisms themselves. Variables on civil aircraft remain largely restricted to fuel input, guide vanes and bleed valves. All other components have been redesigned as a compromise between efficiency at different operating conditions and the need to maintain table operation over the entire operating range. Recent developments in available actuation mechanisms have been identified as providing many opportunities for new control functions that could provide a major step change in the capabilities of the machines. Internal company reviews and internationally reported programmes have identified many control functions and mechanisms that could be used. Just one application of these technologies has already been identified as saving Euro 0.3 million per aircraft per year on transatlantic flights and a fleet $CO_2$ reduction of 8 million tonnes per year by 2020. There is a continual push to improve system performance for a number of commercial and legislative objectives. These can be largely grouped as cost, competitive position and environmental impact. Advanced Actuation will help to address these issues with improved engine performance. To achieve this there is a need for imaginative research into the basic technologies that have already been identified and extensive studies to consider the manufacturing, operational and environmental issues.

The programme has three main elements:

Quantify the performance and operational benefits of extended actuation capabilities;

Research into selected technologies for the gas turbine environment (MEMS, SMA, Advanced Electromagnetics, Boundary Layer Manipulation and Active Vibration Control);

Evaluate the selected technologies in key applications (egg. variable nozzle, virtual VGV, tip seals).

| **Project details** | |
|---|---|
| **Project Reference:** 502844 | **Contract Type:** Specific Targeted Research Project |
| **Start Date:** 2004-07-01 | **End Date:** 2008-06-30 |
| **Duration:** 48 months | **Project Status:** Execution |
| **Project Cost:** 6.63 million Euro | **Project Funding:** 4.39 million Euro |

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| **Participant Organisation:** DAIMLER CHRYSLER AG | **Country:** GERMANY |

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| **Participant Organisation:** SNECMA SA | **Country:** FRANCE |
| **Participant Organisation:** CRANFIELD UNIVERSITY | **Country:** UNITED KINGDOM |
| **Participant Organisation:** OFFICE NATIONAL D'ETUDES ET DE RECHERCHES AEROSPATIALES | **Country:** FRANCE |
| **Participant Organisation:** INDUSTRIA | **Country:** FRANCE |
| **Participant Organisation:** INSTITUT NATIONAL DES SCIENCES APPLIQUEES DE TOULOUSE | **Country:** FRANCE |
| **Participant Organisation:** TECHNISCHE UNIVERSITAET DRESDEN | **Country:** GERMANY |
| **Participant Organisation:** UNIVERSITY OF BIRMINGHAM | **Country:** UNITED KINGDOM |
| **Participant Organisation:** TURBOMECA SA | **Country:** FRANCE |
| **Participant Organisation:** AVIO S.P.A. | **Country:** ITALY |
| **Participant Organisation:** CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE | **Country:** FRANCE |
| **Participant Organisation:** UNIVERSITY OF SHEFFIELD | **Country:** UNITED KINGDOM |
| **Participant Organisation:** DAIMLERCHRYSLER AG | **Country:** GERMANY |
| **Participant Organisation:** SNECMA MOTEURS SA | **Country:** FRANCE |
| **Participant Organisation:** THE CHANCELLOR, MASTERS AND SCHOLARS OF THE UNIVERSITY OF CAMBRIDGE | **Country:** UNITED KINGDOM |
| **Participant Organisation:** POLITECNICO DI TORINO | **Country:** ITALY |
| **Participant Organisation:** MTU AERO ENGINES GMBH | **Country:** GERMANY |
| **Participant Organisation:** VON KARMAN INSTITUTE FOR FLUID DYNAMICS | **Country:** BELGIUM |

**ECATS**

**Environmentally Compatible Air Transport System**

**Action Line:** AERO-1.2 Improving environmental impact with regard to emissions and noise

| **Co-ordinator** | |
|---|---|
| **Contact Person:**<br>Name: MATTHES, Sigrun | **Organisation:**<br>DEUTSCHES ZENTRUM FUER LUFT- |

| | |
|---|---|
| Tel: +49-81-53282524<br>Fax: +49-81-53281841 | UND RAUMFAHRT<br>DLR, Institut fuer Physik der Atmosphaere<br>Linder Hoehe<br>GERMANY |



The Network of Excellence, ECATS, will be a durable and long-lasting means of co-operation and communication within Europe, made up of a number of leading research establishments and universities who have expertise in the field of aeronautics and the environment. The overall goals of ECATS are to create a European virtual institute for research of environmental compatible air transport; to develop and maintain durable means for co-operation and communication within Europe and to strengthen Europe's excellence and its role and influence in the international community. The Joint Research Programme will take into account engine technology, alternative fuels, aviations impact on local air quality, operational aspects of aviation, and the development of scenarios. Lasting integration will be achieved by joint management and working structures, joint decision-making processes and will be supported through specific integration activities as a common web-based information and communication system, common education, training and exchange programmes, co-ordinated use of facilities and equipment, dissemination and joint management of innovation. The excellence and commitment of the ECATS partners, many of whom are already linked through their participation in AERONET, will guarantee an effective and durable integration. Support by community funding will be applied for a period of 5 years.

| **Project details** | |
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| **Project Reference:** 12284 | **Contract Type:** Networks of Excellence |
| **Start Date:** 2005-01-15 | **End Date:** 2010-01-14 |
| **Duration:** 60 months | **Project Status:** Execution |
| **Project Cost:** 7.29 million Euro | **Project Funding:** 6.92 million Euro |

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| **Participant Organisation:** UNIVERSITY OF PATRAS | **Country:** GREECE |
| **Participant Organisation:** NATIONAL TECHNICAL UNIVERSITY OF ATHENS | **Country:** GREECE |
| **Participant Organisation:** UNIVERSITY OF KARLSRUHE | **Country:** GERMANY |
| **Participant Organisation:** THE MANCHESTER METROPOLITAN UNIVERSITY | **Country:** UNITED KINGDOM |
| **Participant Organisation:** BERGISCHE UNIVERSITAT WUPPERTAL | **Country:** GERMANY |
| **Participant Organisation:** OFFICE NATIONAL D'ETUDES ET DE RECHERCHES AEROSPATIALES | **Country:** FRANCE |
| **Participant Organisation:** SWEDISH DEFENCE RESEARCH AGENCY | **Country:** SWEDEN |
| **Participant Organisation:** UNIVERSITETE I OSLO | **Country:** NORWAY |
| **Participant Organisation:** NATIONAL | **Country:** GREECE |

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| AND KAPODISTRIAN UNIVERSITY OF ATHENS | |
| **Participant Organisation:** FORSCHUNGSZENTRUM KARLSRUHE GMBH | **Country:** GERMANY |
| **Participant Organisation:** THE UNIVERSITY OF SHEFFIELD | **Country:** UNITED KINGDOM |
| **Participant Organisation:** STICHTING NATIONAAL LUCHT-EN RUIMTEVAARTLABORATORIUM | **Country:** NETHERLANDS |

**ULTMAT**

**Ultra high temperature Materials for turbines (ULTMAT)**

| **Co-ordinator** | |
|---|---|
| **Contact Person:**<br>Name: DRAWIN, Stefan<br>Tel: +33-14-6734556<br>Fax: +33-14-6734164 | **Organisation:**<br>OFFICE NATIONAL D'ETUDES ET DE RECHERCHES AEROSPATIALES<br>Metallic Materials and Processing Department<br>Av de la Division Leclerc, 29<br>BP72 CHATILLON<br>FRANCE |

The ULTMAT project aims at providinga sound technological basis for the introduction of innovative materials, namely Mo- and Nb-base silicide multiphase alloys, which will allow a 100-150°C increase in airfoil material operating temperature in air-/rotorcraft engines and in aero derivative land-based gas turbines over those possible with Ni-base single-crystal super alloys. The increased temperature capability will allow reduction of specific fuel consumption, CO2 emissions and cooling air requirement, which will lead to a further increase in efficiency and reduction in component weight. The project aims at securing European competitiveness in future high-efficiency, low-emission turbines and at guaranteeing European access to performance-enabling materials technology.

The objectives are to:
Define new alloy compositions and processing routes, using powder or ingot technologies, which enable a manufacturing route to be identified for components which show an acceptable compromise between lowland high temperature mechanical properties and oxidation resistance;
Design oxidation resistant coating systems;
Identify the critical materials properties, processing requirements, and factors, such as cost, that would hinder the material's industrialisation;
Assess the implementation of the materials in turbines (machining, joining);
Carry out a technical-economical assessment for the introduction of these materials in high-performance turbines andfor the implications on future component and/or turbine design. The project focuses initially on finding potential alloys and processing routes; in a second phase the most promising alloy systems (one Mo-base and one Nb-base, with their processing route) will be scaled-up for intense testing and dummy parts manufacturing. ULTMAT will be carried out by a 12-member consortium, from 5 Member States and 1 candidate country, grouping major European turbine manufacturers and end-users, research centres and universities.'

| **Project details** |
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| **Project Reference:** 502977 | **Contract Type:** Specific Targeted Research Project |
| **Start Date:** 2004-01-01 | **End Date:** 2007-12-31 |
| **Duration:** 48 months | **Project Status:** Execution |
| **Project Cost:** 4.87 million euro | **Project Funding:** 3.06 million euro |

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| **Participant Organisation:** THE UNIVERSITY OF SHEFFIELD | **Country:** UNITED KINGDOM |
| **Participant Organisation:** SNECMA SA | **Country:** FRANCE |
| **Participant Organisation:** WALTER ENGINES A.S. | **Country:** CZECH REPUBLIC |
| **Participant Organisation:** AVIO S.P.A. | **Country:** ITALY |
| **Participant Organisation:** ROLLS ROYCE PLC | **Country:** UNITED KINGDOM |
| **Participant Organisation:** ELECTRICITE DE FRANCE | **Country:** FRANCE |
| **Participant Organisation:** WALTER A.S. | **Country:** CZECH REPUBLIC |
| **Participant Organisation:** SNECMA MOTEURS SA | **Country:** FRANCE |
| **Participant Organisation:** UNIVERSITE HENRI POINCARE NANCY 1 | **Country:** FRANCE |
| **Participant Organisation:** UNIVERSITY OF SURREY | **Country:** UNITED KINGDOM |
| **Participant Organisation:** TURBOMECA SA | **Country:** FRANCE |
| **Participant Organisation:** UNIVERSITY OF BIRMINGHAM | **Country:** UNITED KINGDOM |
| **Participant Organisation:** PLANSEE AG | **Country:** AUSTRIA |
| **Participant Organisation:** OTTO VON GUERICKE UNIVERSITAET MAGDEBURG | **Country:** GERMANY |

**AEROTEST**

**Remote Sensing Technique for Aeroengine Emission Certification and Monitoring (AEROTEST)**

| **Co-ordinator** | |
|---|---|
| **Contact Person:**<br>Name: LEGRAS, Olivier<br>Tel: +33-24-8667833<br>Fax: +33-24-8667855 | **Organisation:**<br>AUXITROL SA<br>AUXITROL - Aerospace Sensors Division<br>5 Allee Charles Pathe<br>FRANCE |

It has been demonstrated in the last 5 years that non-intrusive techniques like FTIR spectroscopy annuli are relevant to aero-engine exhaust gases measurement and have been compared with intrusive method. This success has opened the path for their standardisation. At the same time, the aircraft engine industry stresses the need for a measurement method compatible with cost effectiveness, short-term implementation, fast availability of results and accuracy meeting ICAO emission certification needs. First objective: address standardisation issues to promote the techniques to ICAO for engine emission certification. A complete QA/QC approach will be followed, at all levels (instrument, operation, data format) to ensure accuracy and repeatability of the technique. Procedures for instrument calibration set up and operation will be developed. Validity of the data will be verified in laboratories and in test beds. All this stresses the need for fundamental and experimental studies on calibration, inversion methods and models to achieve the accuracy and repeatability goals. A particular attention is given to soot measurement. Second objective: develop validated techniques for gas turbine monitoring using emission data. The ability to perform non-intrusive measurements, which are much faster and cheaper to perform than gas sampling, opens up such possibilities for the use of emissions data (NOx and smoke levels in particular). A model of engine emissions affected by component failure will be developed and correlated to engine emission measurements. The project is directly relevant to Area 2 of Aeronautic and Space priority "Improving environmental impact with regards to emissions and noise", and particularly to the technical domain 1.3.1.2e)"combustion". The project objective answers the need for measurement of the composition of engine exhaust gaseous emissions with emphasis on NOx, soot and UHC.

| **Project details** | |
|---|---|
| **Project Reference:** 502856 | **Contract Type:** Specific Targeted Research Project |
| **Start Date:** 2004-03-01 | **End Date:** 2007-02-28 |
| **Duration:** 36 months | **Project Status:** Completed |
| **Project Cost:** 3692.00 euro | **Project Funding:** 2.5 million euro |

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|---|---|
| **Participant Organisation:** BERGISCHE UNIVERSITAET WUPPERTAL | **Country:** GERMANY |
| **Participant Organisation:** NATIONAL TECHNICAL UNIVERSITY OF ATHENS | **Country:** GREECE |
| **Participant Organisation:** UNIVERSITY OF READING | **Country:** UNITED KINGDOM |
| **Participant Organisation:** CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE | **Country:** FRANCE |
| **Participant Organisation:** LUNDS UNIVERSITET | **Country:** SWEDEN |
| **Participant Organisation:** RHEINISCH-WESTFAELISCHE TECHNISCHE HOCHSCHULE AACHEN | **Country:** GERMANY |
| **Participant Organisation:** BERGISCHE UNIVERSITAET GESAMTHOCHSCHULE WUPPERTAL | **Country:** GERMANY |

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| **Participant Organisation:** FORSCHUNGSZENTRUM KARLSRUHE GMBH | **Country:** GERMANY |
| **Participant Organisation:** SC OPTOELECTRONICA 2001 SA | **Country:** ROMANIA |
| **Participant Organisation:** DEMAG DELAVAL INDUSTRIAL TURBOMACHINERY LTD | **Country:** UNITED KINGDOM |
| **Participant Organisation:** ROLLS ROYCE PLC | **Country:** UNITED KINGDOM |
| **Participant Organisation:** KEMA NEDERLAND BV | **Country:** NETHERLANDS |

**EUROLIFT II**

**European High Lift Programme II (EUROLIFT II)**

**Action Line:** AERO-1.3 Improving aircraft safety and security

| **Co-ordinator** | |
|---|---|
| **Contact Person:**<br>Name: RUDNIK, Ralf<br>Tel: +49-53-12952410<br>Fax: +49-53-12952320 | **Organisation:**<br>DEUTSCHES ZENTRUM FUER LUFT UND RAUMFAHRT E.V.<br>Institut für Aerodynamik und Strömungstechnik<br>Linder Hoehe Postfach 51147<br>GERMANY |

Meeting the short- and long-term goals of future aircraft development as specified in Vision 2020 will be indispensable to keep and extend the competitiveness of European aircraft manufacturers. High lift aerodynamics has the potential to provide major contributions to approach these objectives with respect to efficiency and environmentally-friendly design. Efficiency is in terms of improved aircraft performance by advanced, but simple high lift systems with reduced maintenance requirements. But also increased efficiency of industrial design processes by incorporating highly effective theoretical and experimental tools in a carefully-balanced manner. Environmental friendliness is in terms of r le low noise emissions as one of the most important prerequisites for the growth of air traffic. Noise emissions are primarily related to the take-off and landing phase. Advanced high lift systems with a reduced number of slots and edges hold promise to reduce noise emissions considerably. A prerequisite to meet these goals will be the use of advanced numerical and theoretical simulation tools, together with a thorough understanding of the dominant high lift flow phenomena for new configurations, for which experienced based extrapolation rules have reached their limit. The EUROLIFT II project is intended to provide these tools and knowledge, building up consequently on the results and experience of the predecessor, EUROLIFT II.

The major objectives of EUROLIFT II are:
To provide specific physical understanding of the various vortex dominated flow effects at the cut-outs of a high lift system including the scale effects up to flight conditions. In addition to the purely viscous dominating maximum lift effects as investigated in EUROLIFT (I), the vortex dominating effects play a major role in determining maximum lift for a full 3D aircraft configuration with pylon and nacelles.

| Project details | |
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| **Project Reference:** 502896 | **Contract Type:** Specific Targeted Research Project |
| **Start Date:** 2004-01-01 | **End Date:** 2007-06-30 |
| **Duration:** 42 months | **Project Status:** Execution |
| **Project Cost:** 7.33 million euro | **Project Funding:** 3.74 million euro |

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| **Participant Organisation:** INSTITUTO NACIONAL DE TECNICA AEROESPACIAL | **Country:** SPAIN |
| **Participant Organisation:** DASSAULT AVIATION S.A. | **Country:** FRANCE |
| **Participant Organisation:** ICAROS COMPUTING LTD | **Country:** GREECE |
| **Participant Organisation:** ALENIA AERONAUTICA SPA | **Country:** ITALY |
| **Participant Organisation:** AIRBUS UK LIMITED | **Country:** UNITED KINGDOM |
| **Participant Organisation:** AIRBUS FRANCE SAS | **Country:** FRANCE |
| **Participant Organisation:** AIRBUS DEUTSCHLAND GMBH | **Country:** GERMANY |
| **Participant Organisation:** SWEDISH DEFENCE RESEARCH AGENCY | **Country:** SWEDEN |
| **Participant Organisation:** IBK INGENIEURBUERO DR KRETZSCHMAR | **Country:** GERMANY |
| **Participant Organisation:** CENTRO ITALIANO RICERCHE AEROSPAZIALI SCPA | **Country:** ITALY |
| **Participant Organisation:** AIRBUS UK LIMITED | **Country:** UNITED KINGDOM |
| **Participant Organisation:** EUROPEAN TRANSONIC WINDTUNNEL GMBH | **Country:** GERMANY |
| **Participant Organisation:** OFFICE NATIONAL D'ETUDES ET DE RECHERCHES AEROSPATIALES | **Country:** FRANCE |
| **Participant Organisation:** DASSAULT AVIATION S.A. | **Country:** FRANCE |
| **Participant Organisation:** AIRBUS DEUTSCHLAND GMBH | **Country:** GERMANY |
| **Participant Organisation:** AIRBUS FRANCE SAS | **Country:** FRANCE |
| **Participant Organisation:** ICAROS | **Country:** GREECE |

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| COMPUTING LTD | |
| **Participant Organisation:** INSTITUTO NACIONAL DE TECNICA AEROESPACIAL | **Country:** SPAIN |
| **Participant Organisation:** STICHTING NATIONAAL LUCHT- EN RUIMTEVAART LABORATORIUM | **Country:** NETHERLANDS |
| **Participant Organisation:** SWEDISH DEFENCE RESEARCH AGENCY | **Country:** SWEDEN |
| **Participant Organisation:** IBK INGENIEURBUERO DR KRETZSCHMAR | **Country:** GERMANY |
| **Participant Organisation:** CENTRO ITALIANO RICERCHE AEROSPAZIALI SCPA | **Country:** ITALY |
| **Participant Organisation:** OFFICE NATIONAL D'ETUDES ET DE RECHERCHES AEROSPATIALES | **Country:** FRANCE |
| **Participant Organisation:** EUROPEAN TRANSONIC WINDTUNNEL GMBH | **Country:** GERMANY |
| **Participant Organisation:** STICHTING NATIONAAL LUCHT- EN RUIMTEVAART LABORATORIUM | **Country:** NETHERLANDS |
| **Participant Organisation:** ALENIA AERONAUTICA SPA | **Country:** ITALY |

**HISAC**

**Environmentally-friendly High-Speed Aircraft**

**Action Line:** AERO-2003-1.3.2.5 Multidisciplinary approach to an environmentally acceptable small size supersonic transport aircraft

| **Co-ordinator** | |
|---|---|
| **Contact Person:**<br>Name: PARNIS, Patrick | **Organisation:**<br>DASSAULT AVIATION<br>DGT/DPR<br>9 Rond-Point des Champs-Elysées Marcel Dassault<br>FRANCE |

Business productivity would benefit from a significant reduction in air travel time, especially for long- haul flights. The main objective of the HISAC project is to establish the technical feasibility of an environmentally-compliant, supersonic, small-size transport aircraft (S4TA), through a MultiDisciplinary Optimisation (MDO) approach and focused technological improvements.

The HISAC partners have chosen the following avenue:
Translation of the environmental objectives into quantified design criteria applicable to an

S4TA;
Adaptation of numerical models and tools essential to the multidisciplinary design process;
Development and validation of the most critical aircraft and engine technologies;
Establishment of rules and methods to solve key technology integration issues, through shape design ; and
Application of MDO methods, using the results of the above, to obtain:
aircraft specifications compliant with environmental objectives, exploring a broad range of configurations; quantified trade-offs between aircraft performance and environmental constraints H.ISAC will provide achievable specifications for an environmentally-compliant and economically- viable, small- size supersonic transport aircraft ;
Recommendations for future supersonic environmental regulations (community noise, emissions, sonic boom);
Enabling technologies, and a road-map for their further maturation and validation, up to a future Proof Of Concept .

The 37 partners of HISAC consortium come from 13 different countries, including one from Poland and four from Russia.

Major aircraft manufacturers (Dassault Aviation, Alenia, EADS-M, Sukhoi (SCA) and engine manufacturers (Snecma, Rolls Royce, Volvo, CIAM) associated with 5 SMEs represent the industrial backbone of the consortium. Eleven research centres and 9 universities will lead the scientific activities.

The total budget is around Euro 26 million, with 46% allocated to the Research Centres.

| **Project details** | |
|---|---|
| **Project Reference:** 516132 | **Contract Type:** Integrated Project |
| **Start Date:** 2005-05-01 | **End Date:** 2009-04-30 |
| **Duration:** 48 months | **Project Status:** Execution |
| **Project Cost:** 26.05 million euro | **Project Funding:** 14.25 million euro |

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|---|---|
| **Participant Organisation:** SNECMA | **Country:** FRANCE |
| **Participant Organisation:** EADS DEUTSCHLAND GMBH | **Country:** GERMANY |
| **Participant Organisation:** AIRCRAFT DEVELOPMENT AND SYSTEMS ENGINEERING B.V. | **Country:** NETHERLANDS |
| **Participant Organisation:** INSTITUTE OF THEORETICAL & APPLIED MECHANICS | **Country:** RUSSIAN FEDERATION |
| **Participant Organisation:** ALENIA AERONAUTICA S.P.A. | **Country:** ITALY |
| **Participant Organisation:** UNIVERSITY OF SOUTHAMPTON | **Country:** UNITED KINGDOM |
| **Participant Organisation:** CFS ENGINEERING SA | **Country:** SWITZERLAND |
| **Participant Organisation:** DEUTSCHES ZENTRUM FUER LUFT-UND RAUMFAHRT E.V. | **Country:** GERMANY |

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|---|---|
| **Participant Organisation:** NATIONAL TECHNICAL UNIVERSITY OF ATHENS | **Country:** GREECE |
| **Participant Organisation:** SUKHOI CIVIL AIRCRAFT | **Country:** RUSSIAN FEDERATION |
| **Participant Organisation:** UNIVERSITA DI NAPOLI FEDERICO II | **Country:** ITALY |
| **Participant Organisation:** THE PROVOST, FELLOWS AND SCHOLARS OF THE COLLEGE OF THE HOLY AND UNDIVIDED TRINITY OF QUEEN ELIZABETH NEAR DUBLIN | **Country:** IRELAND |
| **Participant Organisation:** KUNGLIGA TEKNISKA HÖGSKOLAN | **Country:** SWEDEN |
| **Participant Organisation:** NUMERICAL MECHANICS APPLICATION INTERNATIONAL | **Country:** BELGIUM |
| **Participant Organisation:** ENGIN SOFT TECNOLOGIE PER L'OTTIMIZZAZIONE SRL | **Country:** ITALY |
| **Participant Organisation:** CHALMERS TEKNISKA HOEGSKOLA AB | **Country:** SWEDEN |
| **Participant Organisation:** SNECMA MOTEURS | **Country:** FRANCE |
| **Participant Organisation:** INTEGRATED AEROSPACE SCIENCES CORPORATION (INASCO) | **Country:** GREECE |
| **Participant Organisation:** ROLLS-ROYCE PLC | **Country:** UNITED KINGDOM |
| **Participant Organisation:** CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE | **Country:** FRANCE |
| **Participant Organisation:** THE EUROPEAN ORGANISATION FOR THE SAFETY AND AIR NAVIGATION | **Country:** BELGIUM |
| **Participant Organisation:** INSTITUT NATIONAL DE RECHERCHE EN INFORMATIQUE ET AUTOMATIQUE | **Country:** FRANCE |
| **Participant Organisation:** SONACA S.A. | **Country:** BELGIUM |
| **Participant Organisation:** STICHTING NATIONAAL LUCHT EN RUIMTEVAARTLABORATORIUM | **Country:** NETHERLANDS |
| **Participant Organisation:** ECOLE CENTRALE DE LYON | **Country:** FRANCE |
| **Participant Organisation:** CRANFIELD UNIVERSITY | **Country:** UNITED KINGDOM |
| **Participant Organisation:** VOLVO AERO CORPORATION | **Country:** SWEDEN |

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| **Participant Organisation:** SENER INGENIERIA Y SISTEMAS | **Country:** SPAIN |
| **Participant Organisation:** OFFICE NATIONAL D'ETUDES ET DE RECHERCHES AEROSPATIALES | **Country:** FRANCE |
| **Participant Organisation:** INGENIEURBUERO DR. KRETZSCHMAR | **Country:** GERMANY |
| **Participant Organisation:** AIRCRAFT RESEARCH ASSOCIATION LTD | **Country:** UNITED KINGDOM |
| **Participant Organisation:** ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE | **Country:** SWITZERLAND |
| **Participant Organisation:** RUAG AEROSPACE | **Country:** SWITZERLAND |
| **Participant Organisation:** INSTYTUT LOTNICTWA | **Country:** POLAND |
| **Participant Organisation:** CENTRAL INSTITUTE OF AVIATION MOTORS | **Country:** RUSSIAN FEDERATION |
| **Participant Organisation:** FEDERAL STATE UNITARY ENTERPRISE CENTRAL AEROHYDRODYNAMIC INSTITUTE | **Country:** RUSSIAN FEDERATION |
| **Participant Organisation:** SWEDISH DEFENCE RESEARCH AGENCY | **Country:** SWEDEN |

**AIDA**

**Aggressive Intermediate Duct Aerodynamics for Competitive and Environmentally--Friendly Jet Engines (AIDA)**

| **Coordinator** | |
|---|---|
| **Contact Person:**<br>Name: BARALON, Stéphane<br>Tel: +46-52-093771<br>Fax: +46-52-098521 | **Organisation:**<br>VOLVO AERO CORPORATION AB<br>Aerothermodynamics Engines<br>SWEDEN |

All the aero engine manufacturers of Europe, 3 research institutes and 5 universities have joined their expertise and resources in the project AIDA to reach beyond the current state-of-the-art in aero engine intermediate duct design. The AIDA project will strengthen the competitiveness of the European aero engine manufacturers and improve the environment, which are 2 objectives of the priority 4 "Aeronautics and Space" of the 6th framework programme, through the achievement of the technical objectives given below:

Improved understanding of the flow physics in aggressive intermediate ducts-system integration; Knowledge of how aggressive ducts interact with neighbouring components;

* New advanced vane-duct integration concepts for optimised engine layouts;

* Development and tests of very aggressive intermediate ducts;

* Establishment of validated analysis methods and CFD Best Practice Guidelines for duct flows;

* Tests and modelling of novel passive separation control devices for super-aggressive ducts;

* Development of new numerical optimisation techniques for intermediate ducts;

* Establishment of design rules and a validation database for aggressive intermediate ducts.

The short-term to long-term exploitation of these technical achievements will benefit European aeronautics and the environment through the use of a new generation of engines, which will lead to: 2% reduction in fuel burn through 1-2% reduction in engine weight & length and 0.5% and 1.5 % increase in compressor and turbine efficiency, respectively ;

New, low, engine noise levels through the use of ultra-high-by-pass-ratio jet engine configurations - 2.5 % better operating margin for long-haul aircraft through reduced fuel burn together with 5% and 70% reduction of aero engine development costs and time-to-market, respectively. The project hinges upon 6 technical work packages with clearly-defined milestones and deliverables and one management work package.

| **Project details** | |
|---|---|
| **Project Reference:** 502836 | **Contract Type:** Specific Targeted Research Project |
| **Start Date:** 2004-01-13 | **End Date:** 2008-02-01 |
| **Duration:** 49 months | **Project Status:** Execution |
| **Project Cost:** 8.22 million euro | **Project Funding:** 5.61 million euro |

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| **Participant Organisation:** TECHNISCHE UNIVERSITAET GRAZ | **Country:** AUSTRIA |
| **Participant Organisation:** LOUGHBOROUGH UNIVERSITY | **Country:** UNITED KINGDOM |
| **Participant Organisation:** THE CHANCELLOR, MASTERS AND SCHOLARS OF THE UNIVERSITY OF CAMBRIDGE | **Country:** UNITED KINGDOM |
| **Participant Organisation:** ROLLS ROYCE PLC | **Country:** UNITED KINGDOM |
| **Participant Organisation:** MTU AERO ENGINES GMBH | **Country:** GERMANY |
| **Participant Organisation:** AVIO S.P.A. | **Country:** ITALY |
| **Participant Organisation:** TURBOMECA SA | **Country:** FRANCE |
| **Participant Organisation:** INDUSTRIA DE TURBOPROPULSORES SA | **Country:** SPAIN |
| **Participant Organisation:** OFFICE NATIONAL D'ETUDES ET DE | **Country:** FRANCE |

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|---|---|
| RECHERCHES AEROSPATIALES | |
| **Participant Organisation:** SNECMA MOTEURS SA | **Country:** FRANCE |
| **Participant Organisation:** CHALMERS TEKNISKA HOGSKOLA AB | **Country:** SWEDEN |
| **Participant Organisation:** UNIVERSITA DEGLI STUDI DI GENOVA | **Country:** ITALY |
| **Participant Organisation:** SWEDISH DEFENCE RESEARCH AGENCY | **Country:** SWEDEN |
| **Participant Organisation:** ROLLS-ROYCE DEUTSCHLAND LTD&CO KG | **Country:** GERMANY |
| **Participant Organisation:** DEUTSCHES ZENTRUM FÜR LUFT- UND RAUMFAHRT E.V. | **Country:** GERMANY |

## Appendix three – report author biographies

**Simon Michell** worked for many years as managing editor at the Jane's Information Group, with responsibility for titles such as *Jane's ATC and Jane's All the World's Aircraft* and is the founder editor of *Jane's Aircraft Upgrades*. He is currently editor of the Eurocontrol Yearbook, which focuses on the future of sustainable air traffic development. Simon has also worked as a business analyst focusing on European defence and aerospace companies and has written articles for various magazines including *Jane's Airport Review, International Defence Review* and *Le Bourget Today*.

**Ian Lowden** has 25 years' experience in the air transport industry, including 15 as a consultant. He provides advice in the areas of business planning, policy and regulation to many airlines, airports, financial bodies and industry suppliers. Ian Lowden is a regular advisor to some of the most progressive and dynamic organisations in aviation and is now managing director of RDG Solutions, a niche aviation consultancy, based in Manchester, UK. He makes frequent conference presentations and is a regular lecturer on air transport industry short courses at the University of Westminster.

**Philip Butterworth-Hayes** has over 20 years experience as an aerospace consultant and writer. He is the current editor of Jane's Aircraft Component Manufacturers and director of communications at the Civil Air Navigation Services Organisation. He has been the lead consultant in a large number of studies for clients as diverse as the United States Air Force and Imperial College London.

His work for Jane's Information Group has encompassed the production of market analysis products for the ATM industry, the aviation environmental sector and the civil aircraft market. He writes on airline issues for The Wall Street Journal and since 1992 has been the European Correspondent for Aerospace America, the journal of the American Institute for Aeronautics and Astronautics (AIAA).

He has also edited a number of yearbooks for clients such as Airbus and the UVS International.

A former editor of Interavia Aerospace Review and Airports International he has also been an aviation consultant to BBC Television and Time-Life books.

Philip Butterworth-Hayes is a Honours graduate of the University of Hull, UK, and began his career as a lecturer at higher education institutes in the Middle East before returning to the UK to write on road transport issues for a number of specialist publications. In 1987 he was appointed Managing Editor, Jane's Transport Press/Jane's Air Transport Press and managed the following titles: Jane's Urban Transport Systems, Jane's World Railways, Jane's High Speed Marine Craft and Air Cushioned Vehicles, Jane's Airport Equipment, Jane's Merchant Ships, Jane's Airports and Handling Agents.

**Rainer Vogel** has worked for 25 years in the media and advertising industries. Starting as International Sales Manager for Flugrevue he has managed his own publishing company for the last 12 years. Through this company he has co-published a newsletter FlugPost and Luft-und Raumfahrt, a monthly magazine, and represented international publishers such as Interavia, and International Defence Review. He also spent eight years in the television industry where he became CEO of several German television channels. Rainer has a proven track record in building and running media companies. Since 2001 Rainer has worked as contract publisher, editing and producing a monthly German-language magazine. Rainer Vogel has also been trained as journalist.