ICAO

INTERNATIONAL CIVIL AVIATION ORGANIZATION

Aviation & the Environment

Though its CO_2 and NO_X impact is less than those of other industries and transport sectors, aviation continues to take bold steps toward aggressive targets as its global stakeholders confront the technological and leadership challenges of climate change.

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Vol. 63, Nº 4

THE ICAO JOURNAL
VOLUME 63, NUMBER 4, 2008

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Submissions
The *Journal* encourages submissions from interested individuals, organizations and States wishing to share updates, perspectives or analysis related to global civil aviation. For further information on submission deadlines and planned issue topics for future editions of the ICAO *Journal*, please forward your request to journal@icao.int.

Subscriptions and single copies
Yearly subscription (6 Issues per year) US $40. Single copies available for US $10. For subscription and sales information please contact the ICAO Document Sales Unit,
Tel: +01 (514) 954-8022
E-mail: sales@icao.int

Published in Montreal, Canada. ISSN 0018 8778.

PRINTED BY ICAO

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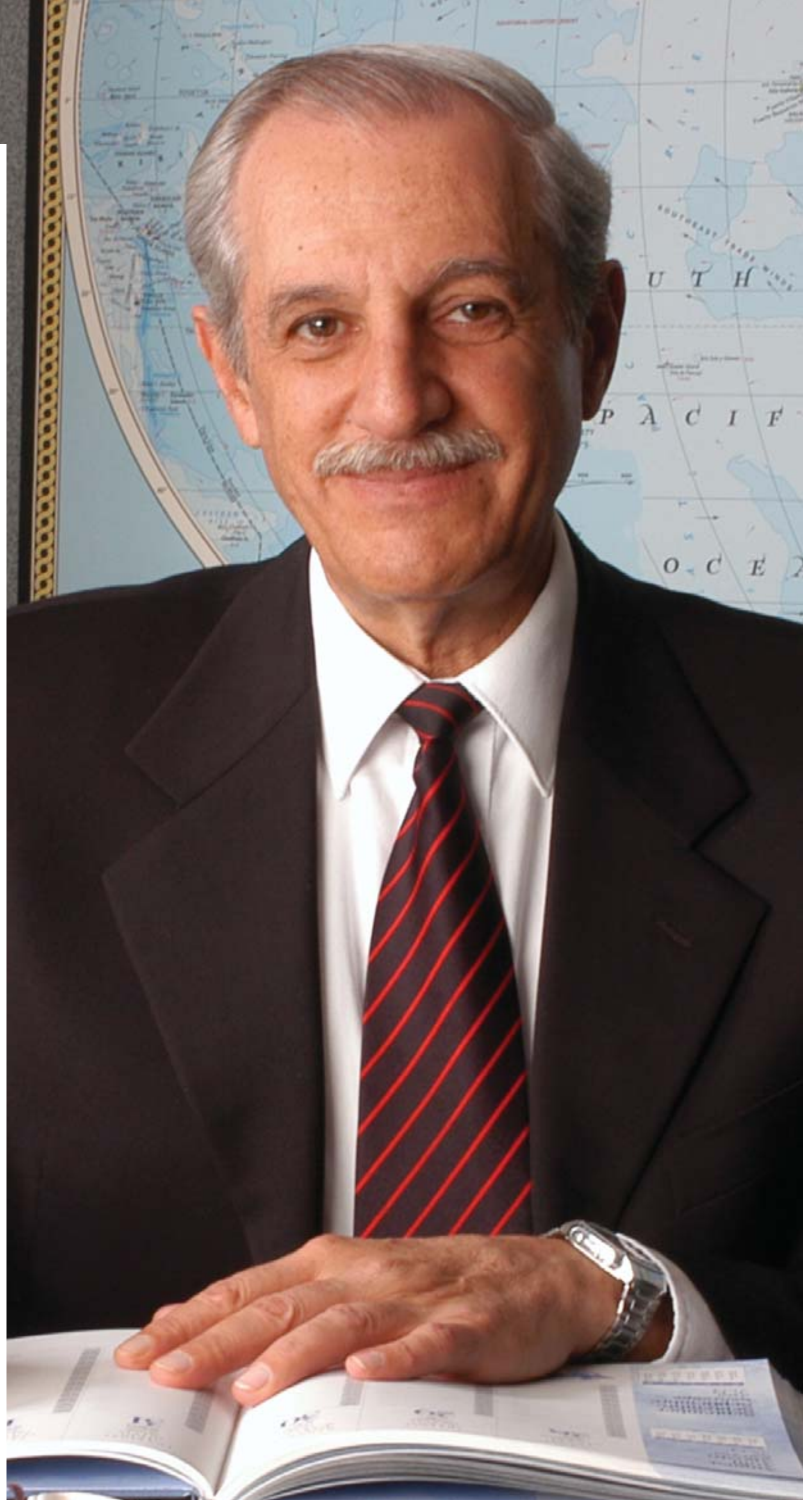
MESSAGE FROM THE PRESIDENT OF THE COUNCIL

Progress Depends on Global Cooperation



Over the years, ICAO has diligently pursued its work in aviation emissions through three main approaches: technology, operations and market-based measures.

The latest initiative is an Aviation and Carbon Markets Workshop which brought together at ICAO, in June, a host of financial, industry and environmental experts to address the challenges involved in tackling aviation emissions and carbon markets. Highlights of the thought-provoking keynote address by UNFCCC Executive Secretary, Mr. Yvo de Boer, is featured in this issue of the *Journal*, while main presentations are available on the ICAO website (www.icao.int).

At the Workshop, ICAO officially launched the ICAO Carbon Calculator, an impartial, transparent and internationally-approved tool to identify the amount of carbon dioxide (CO_2) emissions from a given flight, for use in carbon-offset programmes. The Calculator supports the United Nations (UN) Carbon Neutral Initiative, which calls for all agencies and units of the UN system to determine their total carbon emissions.

Last September, the 36th Session of the ICAO Assembly overwhelmingly endorsed the direction taken and the leadership of ICAO in environmental protection. At the same time, the Assembly recognized the urgent need for more concerted and effective action to reduce the carbon footprint of international aviation.

The same Assembly resolution called on the ICAO Council to form a new Group on International Aviation and Climate Change. Its mandate is to recommend an aggressive ICAO Programme of Action to address climate change, consisting of strategies and measures that States can use to achieve emissions reductions, as well as fuel efficiency goals and means of measuring progress. ICAO will present the proposal at a high-level meeting before the end of 2009.

Meaningful and lasting progress in our collective drive to reduce the impact of carbon emissions on the environment can only be achieved through global cooperation—among the members of the aviation community and with international organizations dedicated to the protection of the environment.

As the attention of the world community is focused more and more on climate change, the need for all out global cooperation is truly essential. ■

Roberto Kobeh González
President, ICAO Council

En Route to Copenhagen: International Aviation Action on Climate Change

By Jane Hupe, Chief, ICAO Environmental Unit, and Secretary for the ICAO Council Committee on Aviation Environmental Protection (CAEP)

Climate change has been characterized as one of the greatest challenges of this century. To address this challenge, it would be essential to reduce and stabilize GHG emissions to a level that does not endanger the global climate and to put in place steps to cope with the inevitable impacts over the coming decades. Negotiations are taking place under the United Nations to identify the best way forward and to define the specific roles of all of those involved in achieving this goal. An effective programme of action to address climate change will need to encompass all countries and activities, while considering their specific needs and respecting their overriding priorities for sustainable development.

Emissions from aviation are part of this equation. The fact that the aviation sector (domestic and international operations) currently accounts for approximately two percent of total CO_2 emissions should not detract from the need for immediate action. This is particularly necessary in the face of expected significant growth in aviation activities in the future.

To address these emissions, however, a clear understanding of the technical, economic, legal and social implications of the various possible measures is necessary, as aviation is a major catalyst of economic development and an important pillar of the achievement of the millennium goals.

Parallel Tracks

Both international aviation and climate change are not restricted to national boundaries. They are global issues and therefore action only makes sense if taken through a concerted approach at the international level. Towards this end, the international community adopted two major Conventions to deal with these subjects: the first one, in 1944, the Convention on International Civil Aviation, also known as the Chicago Convention, and in 1992 (Rio Summit) the United Nations Framework Convention on Climate Change (UNFCCC).

Both of these Conventions have parties from close to 200 States and have, since entering into force, been complemented by other legal instruments taking the form of Annexes, Agreements or Protocols.

In the case of ICAO, Annex 16 to the Chicago Convention deals with Standards and Recommended Practices to address environmental protection (with a volume entirely dedicated to aircraft engine emissions). ICAO has also developed studies, guidance and policies to reduce aviation emissions based on three approaches: reduction of emissions at source through technological innovation (cleaner and more efficient engines and airframes) reduction of emissions through operational measures (e.g. more efficient air traffic management) and through market based measures. Studies identified an open and global emissions trading system as the most efficient market measure to address aviation emissions and ICAO has since developed specific guidance on the matter – ICAO Guidance on the use of Emissions Trading for Aviation (Doc 9885).

The last ICAO Session was held in September 2007 and all Contracting States agreed on a comprehensive plan of action comprised of four major elements:

1) The regular assessment of the impact of aviation on the environment and the continued development of tools for this purpose;
2) The vigorous development of policy options to limit or reduce the environmental impact of aircraft engine emissions and the provision of advice as soon as possible to the Conference of the Parties of UNFCCC on technical solutions and market-based measures;
3) The continued development and updating, through CAEP, of standards and guidance for Contracting States, on the application of measures aimed at reducing or limiting the environmental impact of engine emissions; and
4) The formation of a new group to develop and recommend to ICAO an aggressive Programme of Action on International Aviation and Climate Change. This high-level group, known as GIACC, is composed of senior government officials representative of all ICAO regions, with the equitable participation of developing and developed States. The work of GIACC is done through an inclusive process and will involve consultation with all stakeholders concerned. GIACC held its first meeting February 2008 in Montreal and the most recent one was held in July. In all, four meetings are planned, following which the Council of ICAO will convene a high level meeting to review the Programme of Action recommended by GIACC.

The 36th Session of the ICAO Assembly specifically requested that this high-level meeting be held at a time which would take into account the fact that the 15th meeting of the Conference of the Parties (COP 15) that UNFCCC will hold in December 2009 in Copenhagen.

Regarding the UNFCCC, in December 1997 agreement was reached on the Kyoto Protocol to the Convention. The Kyoto Protocol includes legally binding emission reduction targets for developed countries (Annex I Parties) for the period 2008—2012. Emissions from domestic aviation are included in the total emissions reported and subject to the above targets. Emissions from international aviation are reported separately and are excluded from national totals, hence being excluded from the Kyoto targets. Instead, Article 2.2 of the Kyoto Protocol provides for addressing these emissions working through ICAO.

The Intergovernmental Panel of Climate Change (IPCC), the leading body charged with the responsibility to assess climate change science, published its Fourth Assessment Report in 2007 and brought new momentum to the climate negotiations. The report gave a clear signal that climate change is happening and accelerating, that much of it is caused by the continued and increasing emissions of greenhouse gases from human activities and that it can have severe impacts.

The IPPCC report brought a sense of urgency into the UN climate change negotiations and at the Climate Change Conference in Bali in December 2007, all parties to the UNFCCC agreed on the Bali Road Map to advance ongoing work on key issues. Parties decided to launch formal negotiations on a deal on long-term cooperative action. These negotiations are set to be concluded by the end of 2009 at the Climate Change Conference in Copenhagen, in order to ensure continuity and stability in the current efforts to address climate change.

In a very intrinsic way, ICAO and UNFCCC have set up two separate but parallel streams of activity, which will culminate at the end of 2009. While this is challenging to both organizations, it also provides a unique opportunity for consultation and cooperation. Both organizations are moving in the same general direction, debating similar issues and setting their sights on likewise similar outcomes. It is therefore imperative to strengthen coordination and to join forces to increase the effectiveness of both organizations and identify what needs to be implemented in order to ensure that aviation emissions continue to be addressed effectively in the future. This would be in the best interest of all stakeholders, as matters related to international aviation and to climate change have implications for all parties, independently of their development stage.

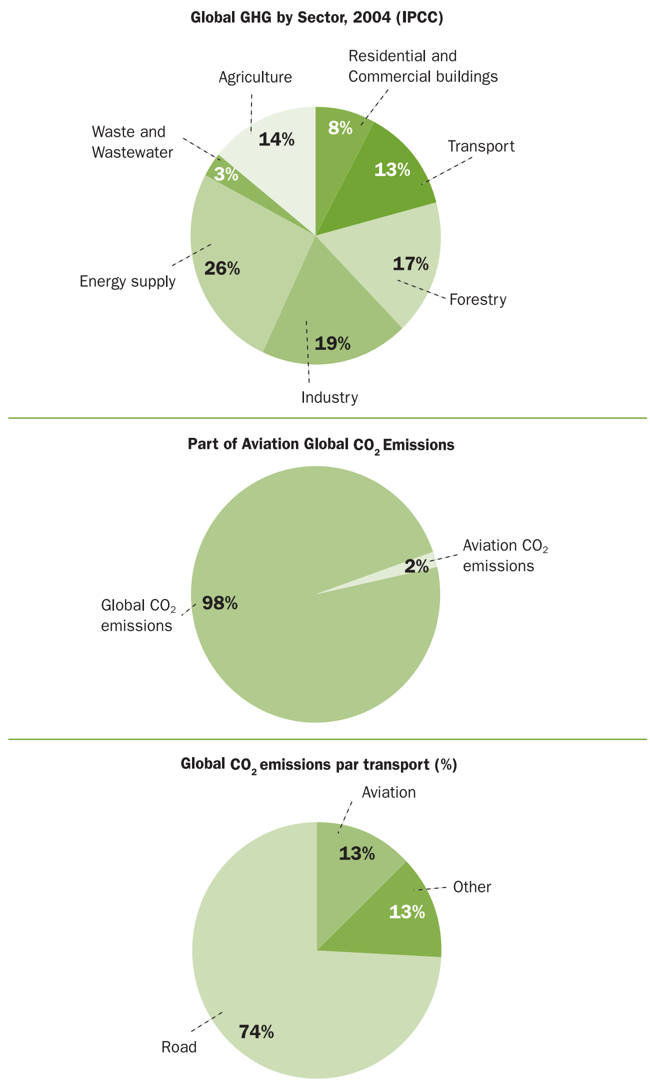
Ongoing Activities and Recent Developments

Since the last Assembly and the inception of the GIACC, the ICAO Council requested the Organization's Committee on Aviation Environmental Protection (CAEP) to prioritize and intensify all activities related to greenhouse gas emissions (GHG). These include assessment of historical and projected GHG emissions, more stringent NO_x standards for aircraft engines, fuel burn goals and metrics, operational measures to reduce global emissions, and market based measures. It also requested CAEP to prioritize input requested by GIACC, so as to meet the deadline of 2009 for the GIACC to develop an ICAO Programme of Action on Aviation Emissions.

ICAO is making progress with the building blocks of the programme and is actively preparing for the second meeting of the GIACC. To ensure that their policy decisions are based on the best available information, ICAO has solicited information from its Contracting States on their aviation GHG emissions. ICAO has also extended an invitation to the UNFCCC Secretariat to participate in the second meeting of the GIACC.

Also, with a view to enable short term action and to ensure that all potential solutions to deal with the growth of aviation emissions are explored, ICAO has developed and recently launched the ICAO Carbon Calculator for use in carbon-offsetting programmes. It is a transparent and internationally-approved web-based tool to identify

Figure 1. Global CO_2 emissions and global Green House Gases (GHG) per sector – Source IPCC 2007



the amount of carbon dioxide (CO_2) emissions from a given flight (available via www.icao.int). The Carbon Calculator responds to the wish of many travelers for a reliable and authoritative method to estimate the carbon footprint of a flight. Only publicly available and verifiable sources of information is used in the calculations *(more details on the calculator can be found on page 11).* The methodology used takes into account a range of variables such as aircraft type, route specific data, passenger load factors and cargo carried. After air travelers calculate the amount of CO_2 they are responsible for, they can choose the programme best suited to offset the impact of their trips on climate change.

ICAO is now exploring the potential of offset programmes in addressing GHG emissions from aviation. Emissions from air travel currently form the bulk of the emissions being offset by individuals through voluntary offset programmes. However, due to the lack of harmonization within these programmes, it is impossible to estimate the volume of emissions currently being offset or to account for them. This and other important market based measures were the focus of the ICAO Workshop on Aviation and Carbon Markets, held in ICAO in June 2008. Its purpose was to establish the current status of carbon markets throughout the world, highlighting areas where aviation is being considered and to stimulate an exchange of views. The programme of the workshop was designed to allow for free-flowing and transparent exchanges with financial, industry and environmental experts. Participants addressed the key issues and challenges the aviation sector will need to address in tackling aviation emissions through the use of carbon markets.

The Challenges Ahead

The challenges ahead should not be under estimated. Although the aviation industry has recorded the substantial benchmark of producing aircraft today that are 70 percent more fuel efficient than 40 years ago, aviation's environmental performance and that of ICAO remain under criticism. This is due partly to the fact that this remarkable technological achievement has not been enough to address the growth in volume of emissions produced by the increasing number of passengers and operations created by the public demand for travel. Thus, while efforts and commitments from many parties require the reduction of emissions to levels below those of 1990, total emissions from international aviation continue to grow.

MAIN MEETINGS OF GIACC AND UNFCCC – FUTURE SCHEDULE GIACC, AWG & AWGLCA

ICAO/GIACC PROCESS		UNFCCC AWG & LCA PROCESS	
GIACC/1	25-27 Feb 2008	AWG5/LCA/1	31 Mar/4 Apr 2008
GIACC/2	14-16 Jul 2008	AWG5/LCA/2	2-13 Jun 2008
GIACC/3	16-18 Feb 2009	AWG6/LCA/3	21-27 Aug 2008
GIACC/4	1-3 Jun 2009	AWG7/LCA/4	1-12 Dec 2008
High Level Meeting in connection with COP/15	To be determined	AWG8/LCA/5	Mar 2009
		AWG9/LCA/6	1-12 Jun 2009
CAEP SG/2	September 2008	AWG10/LCA/7	Aug/Sept 2009
CAEP SG/3	June 2009	AWG11/LCA/8 (COP/15)	30Nov/11 Dec 2009
CAEP/8	February 2010		

Workshops/Informal Groups. For 2009, exact dates and the number of meetings are yet to be decided.

Not having defined a baseline for the sector against which to measure the reduction of emissions, nor a target defining the objective and schedule for future emissions reduction, leads to queries and dissatisfaction from the growing environmental conscientious public. This situation also tend tends to undermine many of the green initiatives of the sector which, with the lack of a baseline scenario to compare to, become characterized as business as usual or are not accounted for.

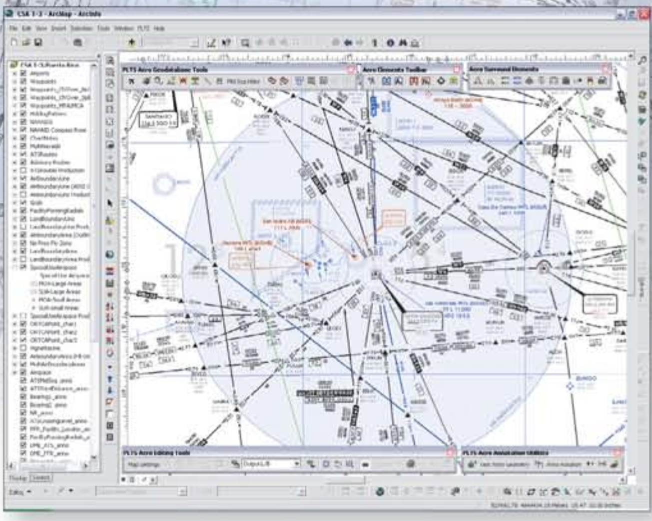
Part of the public concern with the environmental performance of aviation comes from the lack of clarity and accuracy on the information provided by ICAO regarding the current and future growth prospects of aviation emissions. The figures brought to the attention of the public do not convey clearly if they are State or region specific, from international or domestic aviation operations and usually quote non-authoritative sources or methodologies.

Much will be needed in terms of enhancing the outreach activities and defining how international aviation will participate in the next climate change regime. An effective programme of action to address international aviation will need to be based on reliable and authoritative information on current and future estimates of international aviation emissions taking into account realistic scenarios of the global economy. It will also need to include a basket of measures to effectively mitigate the adverse impacts of aviation on the global climate, and will need to include considerations on adaptation, financing and financial flows and technology transfer as key elements in addressing climate change.

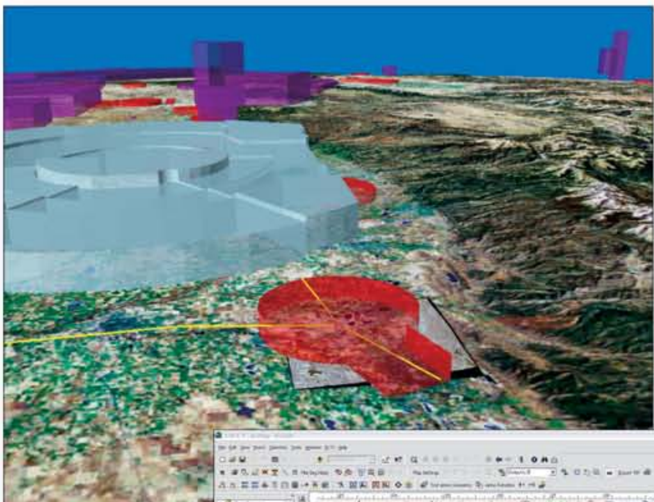
Direct cooperation between the UNFCCC and the ICAO processes will be paramount but effective collaboration must also be encouraged within each of the respective Member States. In many cases, for example, there should be more communication between government authorities responsible for the environment and those responsible for civil aviation, so that the positions and proposals of Member States in international gatherings of ICAO and UNFCCC are better aligned so as to allow a more comprehensive view of a State's policies and programmes. This will ultimately result in a true reflection of the will of the Parties to these processes.

From the schedule shown in Figure 2 *(above)*, it is evident that the work and negotiations in the upcoming year and half will be intense, challenging and highly demanding. We will need to enhance our efforts, be more creative and take note of the spirit of cooperation that's needed to address the challenges that we are facing. We will need to ensure that we keep on the right track and that all the road maps, although taking alternative paths, will converge in Copenhagen. ■

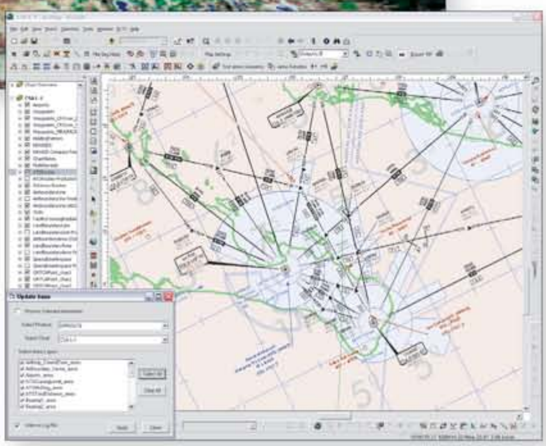
GIS—Modernizing Aeronautical Information Workflow



Maintain current aeronautical information.



3D Visualization



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International Aviation and the Global Environment: How ICAO has Made Climate Change a Priority Issue

Celia Alves Rodrigues, Associate Environmental Officer, and Blandine Ferrier, Junior Professional Officer, ICAO Environmental Unit

The effects of international aviation on the global environment have been a concern to ICAO for nearly 30 years—the first ICAO Standards for aircraft engine emissions were adopted in 1981. To pursue its environmental goal for Climate Change, ICAO has developed and continues to refine Standards and Recommended Practices (SARPs) and guidance material for technological improvements; proper organization of air traffic; and the use of market-based options.

ICAO continues to coordinate its efforts to address climate change with those of other UN bodies such as the United Nations Framework Convention on Climate Change (UNFCCC), the Intergovernmental Panel on Climate Change (IPCC), the UN Environmental Programme (UNEP) and the World Meteorological Organization (WMO).

The Current Situation

It is useful to begin by noting the scale of international aviation emissions in the overall global context. In 1999 IPCC prepared, at ICAO's request and with the Organization's full cooperation, a Special Report on Aviation and the Global Atmosphere. ICAO was also involved in the drafting process of the IPCC Fourth Assessment Report (4AR), which updated the results of the 1999 Special Report. The IPCC 4AR estimated that, in 2005, the total aviation contribution was about 2 percent of globally produced carbon dioxide (CO_2) and about 3 percent of the total radiative forcing by all human activities. As these are aggregate figures for civil, military and other aviation activities, the share of international civil aviation, for only which ICAO is responsible, will therefore be less.

It is pertinent to note that domestic aviation is part of UNFCCC's Annex I Countries' totals, accountable in their national reduction targets. The report also projects that the amount of CO_2 emissions from aviation will grow at around 3 to 4 percent per year. The report states that medium term mitigation of CO_2 emissions from the aviation sector potentially can come from improved fuel efficiency, but such improvements are only expected to partially offset the growth of aviation emissions.

It could perhaps be claimed that these figures are, as a percentage of global totals, not very significant. Despite this, a clear message has been delivered by the scientific community regarding the need for urgent action on climate change from all sectors. Aviation operations necessitate the burning of fossil fuels, and given that the burning of fossil fuels makes a significant contribution to climate change, aviation therefore has a responsibility to take action.

The Work of ICAO

Aircraft engines are required to meet emissions certification Standards adopted by ICAO. Of particular relevance to climate change is the Standard for nitrogen oxides (NO_x), a precursor for ozone, which at higher altitudes affects radiative forcing. There has been a notable reduction in engine NO_x emissions over the last 25 years. The first Standards were adopted in 1981 and those standards most recently agreed are typically more than 40 percent lower.

At the last meeting of ICAO's Committee on Aviation Environmental Protection (CAEP/7, held in early 2007), the Committee received a report from a group of independent experts that it had established on the future prospects for NO_x reduction in the medium (10-year) and long-term (20-year) time frames. This report indicated that further reductions in NO_x of the order

of 40 percent (relative to current values) in the medium and 65 percent in the long term, should be possible—allowing for further increases in the stringency of NO_x standards.

It was cautioned, however, that further improvements would inevitably be increasingly more difficult and costly to achieve. CAEP is currently studying the possibility of increasing the stringency of the current standards based upon the presently available technology and is expected to consider revised Standards at its next meeting in 2010. CAEP is also establishing a similar expert group to study future prospects for reducing fuel consumption, with a view to setting goals as it did for NO_x.

Emissions of CO_2, the major greenhouse gas, are not at present controlled. The setting of ICAO Standards for CO_2 would be very difficult, mainly because of the difficulty of agreeing on a regulatory parameter, but since carbon dioxide production is directly proportional to fuel consumption and in view of the constant pressure on airlines and manufacturers to reduce fuel consumption, it may be that market forces are currently keeping carbon dioxide emissions to the minimum economically possible for the existing traffic demand. In fact, passenger jet aircraft produced today are 70 percent more fuel efficient, on a passenger/km basis, than those produced 40 years ago, and continued improvement is expected.

It must be recognized nevertheless that, in terms of total emissions, these excellent technological gains have been more than offset by the growth in air traffic. In view of the importance of air travel to the world economy, and its continued growth, it is unlikely that this growth will be curtailed in the future and in any case this would be outside the control of ICAO.

As far as the assessment of future emissions effects on the environment and development of control measures are concerned, it is vital to be able to make reliable quantitative estimates of future emissions. For this purpose, it is necessary to have comprehensive models describing future aircraft fleet composition, operating patterns and emissions production. Such models in turn depend on the availability of comprehensive and accurate data describing current fleets and operations. ICAO is uniquely positioned to develop the required models and collect the necessary data and is very active in doing so.

In addition to the technical means available for reducing emissions, ICAO has also been active in a number of other areas, including the reduction of emissions through operational means. A major way of achieving reductions is to shorten flight times and hence fuel consumption by improvements to the air traffic management system. Such improvements have the potential to provide more direct routings for aircraft, as well as reducing the time spent in holding patterns waiting to land or queuing while waiting to depart. Techniques such as continuous descent arrivals, continue to be investigated and current applications indicate significant promise for reducing emissions and noise.

ICAO's main focus, however, is on the Global Air Navigation Plan—the framework currently in place. This plan requires environmental aspects to be taken into account right from the outset, when designing, developing and operating air traffic management systems. Emissions-related aspects of the plan include the flexible use of airspace; air traffic flow management; dynamic and flexible route management; terminal area design and management; aerodrome design and management; and performance based navigation. For example the improved balancing of traffic demand and capacity can lead to reductions in weather- and traffic-induced holding with a consequent reduction in fuel consumption and hence emissions. Similar and possibly more dramatic benefits can be obtained from optimization of route structures and terminal procedures.

Market based measures aimed at reducing emissions are also continuing to receive much attention. Some States and other aviation entities already have in place voluntary schemes for addressing environmental issues through market-based measures. ICAO is assisting in making these measures known to States and organizations who may wish to implement similar schemes. Information for this purpose is posted on the ICAO website. ICAO developed guidance for use by States for incorporating international aviation emissions into voluntary emissions trading schemes that they may wish to put in place. An aspect of this matter yet to be resolved is that of geographic scope, and specifically whether participation in regional schemes should be mandatory or optional for external aircraft operators who fly over or into the regional airspace. This aspect was the subject of intense discussions at the 36th Session of the ICAO Assembly held in October of 2007.

ICAO has recently unveiled a carbon calculator that is an internationally approved, transparent tool for determining the CO_2 emissions attributable to an individual passenger travelling on a specific route segment. It is described as transparent because a user can see the assumptions and methodology used in the calculations. The calculator uses publicly available fuel consumption data. It is intended to be a reference method for making carbon footprint calculations and as a basis for carbon offset schemes. The Calculator is available free of charge on the ICAO website.

In recognition of the importance of global environmental matters to aviation, the 36th Assembly requested the establishment of a regionally representative group of senior government officials to develop an aggressive ICAO plan of action on aviation's contribution to climate change. The group, which became known as the Group on International Aviation and Climate Change (GIACC), held its first meeting in February of 2008.

The mandate of GIACC is broad and requests that its members consider all options available to address aviation's contribution to climate change. These include improvements in aircraft technology and ground based equipment; more efficient operational measures and more extensive use of such measures; improvements in air traffic management to improve efficiency, shorter routes and reduced congestion; the use of market-based measures including positive economic incentives; the deployment of modern, efficient aircraft into the in-service fleet; and any other options which would improve the environmental performance of international civil aviation.

GIACC has been asked specifically to develop an aggressive programme of action based upon consensus and which reflects the shared vision and determination of all Contracting States to deal with climate change. This will involve *inter alia:*

- Developing an implementation framework.
- Identifying a means to measure progress.
- Identifying possible aspirational goals.
- Reporting progress resulting from actions implemented by Contracting States and Stakeholders.

GIACC is meeting again in July 2008 and will report to a full international meeting in order that decisions may be taken at the next Session of the ICAO Assembly in the autumn of 2010.

Conclusion

In summary, it can be seen that ICAO has been actively leading a variety of activities in matters concerning aviation and the environment for many years and will continue this involvement with increased intensity for the foreseeable future. CAEP will continue to address the technical impacts of aircraft noise and emissions by studying policy options on the use of technical and operational solutions, while continuing its consideration of market-based measures. ICAO will also continue to work closely with the UN and associated bodies in an integrated approach that includes not only aviation but also all other emissions producing sectors.

GUIDANCE ON THE USE OF EMISSIONS TRADING FOR AVIATION – (DOC. 9885)

The first edition of the document Guidance on the Use of *Emissions Trading for Aviation* (Doc. 9885) was published in June 2008. This guidance was prepared by CAEP at the request of the ICAO Assembly to provide ICAO Contracting States with advice and practical information they might be able to use when incorporating emissions from international aviation into emissions trading schemes.

The guidance addresses the aviation-specific options for the various elements of trading systems, such as accountable entities, emissions sources and species (gases) to be covered, trading units, base year and targets, allowance distribution, monitoring and reporting, and geographical scope. Since most emissions trading schemes define emissions sources in terms of fixed ground-based installations, the guidance addresses how emissions sources could be defined for aviation and focuses on those aspects of emissions trading that require consideration with respect to aviation-specific issues.

MORE ON THE ICAO CARBON CALCULATOR

The ICAO Carbon Calculator is an unbiased and internationally-approved tool for calculating the amount of carbon dioxide (CO_2) from aircraft engine emissions attributable to a passenger on a given flight for use in carbon-offsetting programmes. Its aim is to be "transparent", meaning that users can read the assumptions and the methodology used to make the calculations. The user only needs to input the origin and destination of their direct through-flights. Where more than one flight is involved, such as for return journeys or a trip with multiple flights, the user will need to enter the city-pairs for each direct through-flight separately. The calculator will then compute the carbon footprint for each individual flight and compute the total for the whole air journey.

For the selected flight, the calculator searches for all the services that are offered on the route and identifies the aircraft types used and their frequency. Each aircraft type is mapped to one of the 50 equivalent aircraft types for which fuel burn, passenger/cargo ratio, seat capacity and load factors have been calculated.

The ICAO Carbon Calculator and further information on its methodology and information sources are available free of charge on the Organization's website (www.icao.int).

Andrew Steinberg: The Five Pillars Approach

*Currently a partner with the law firm of Jones-Day in Washington D.C., **Andrew Steinberg** served as Chief Counsel of the Federal Aviation Administration from 2003 to 2006, and then as Assistant Secretary for Aviation and International Affairs with the U.S. Department of Transportation from 2006 until January 2008. He was appointed to both positions by President Bush and confirmed for the latter by the U.S. Senate.*

ICAO Journal: **Please outline for our readership the impetus behind the five pillars approach and explain why it's the appropriate path for aviation to be proceeding along given the current environmental situation.**

Andrew Steinberg: What we have found in aviation environmental matters over the course of many years is that a variety of approaches—technical, operational, market-oriented and so on—are normally the most effective at producing a long term solution.

Noise reduction is a perfect example of how employing a combination of different tactics can be overwhelmingly successful. The amount of people subjected to aircraft noise has been reduced by about 95 percent over the last 30 years. Though I've seen slightly different percentages in various sources, there is no question industry efforts have been inordinately successful. This success was achieved through improved engines, air frames and flight procedures combined with scientific research, mitigation and market-oriented incentives—such as phasing out nosier aircrafts.

With that success story in mind, the U.S. has therefore taken a multi-faceted approach to the issue of aviation's impact on the environment and climate change. The five pillars we've established include: an improved scientific understanding (particularly of greenhouse gas emissions at higher altitudes—a subject not as well understood as others at present); improved technology such as more efficient engines and airframes; improvements in the operational environment (particularly air traffic management); research into alternative fuels, and; market incentives. Please note that these are not necessarily listed in order of their respective importance.

I'd like to add that one of the things that's very striking about the debate going on right now is that aviation is regarded as being comparable to other industries when there are many significant differences that suggest it requires a unique approach.

Could you please highlight some of those differences?

I think the biggest difference is that fuel is already such a large percentage of the cost of aviation operations—in other words there's already an enormous built in incentive for every operator to reduce their fuel burn. Because of this direct correlation of fuel burn to greenhouse gas emissions, the reductions already being sought in fuel consumption have meant that we've already seen significant reductions in past decades of the aviation industry's aggregate carbon footprint. My guess will be that when you look at 2008 versus 2007 you'll see yet another decline in aviation emissions—certainly, at least, in the U.S.

The second important distinction between aviation and a typical smoke stack industry is that there are no practical and available alternatives to jet fuel available to aviation at this point.

Your last point brings to mind February's fairly high-profile Virgin Atlantic flight from London to Amsterdam with a CF6-powered 747 that ran on a biofuel. Is this where the industry needs to be heading?

There is a lot of good work going on in this area and it all should be encouraged. For instance the U.S. Air Force is also now looking at using drop-in fuels across approximately 50 percent of its fleet in the next decade or so. Today, however, there's still nothing that aviation operators can do other than simply not fly if they wish to avoid using kerosene-based fuel. This remains a very large distinction between the aviation industry and other industries in the present environment.

Another point of distinction is that transportation markets are more complicated than other markets. For example, if you raise the price of fuel through an allowance system or as was proposed in S 1191, the Lieberman-Warner bill[1], the result is going to be either less flying or higher ticket prices. But, with the airlines already operating at an 80 percent load factor a raise in ticket prices may simply create a situation whereby the same or a very similar number of flights are carrying fewer passengers. This solution therefore would be very ineffective at lowering aggregate emission levels.

So we have to be careful then about how we approach this sector. Aviation is a generator and enabler of many disparate forms of significant economic activity, and therefore the health of the industry as a whole needs to be maintained. By simply targeting consumer demand you could end up disabling the aviation system, cause serious economic ramifications society-wide, and in the end simply push passengers into other forms of transportation that could end up raising emissions rather than lowering them. We need to remember that having 200 people take their cars across a short-haul route is not more environmentally friendly than having them take a single aircraft for the same purpose.

Will air traffic management also play an important role?

There's a great deal of potential savings to be had through more efficient air traffic management and we've been, as a nation, struggling for many years to modernize the air traffic control system. We all know the right solution is a satellite-based navigational system with shorter separation of aircraft in trail, and certainly climate change and fuel costs have now become compelling reasons to modernize. In other words, the waste of fuel and the unnecessary creation of greenhouse gas emissions caused by an outmoded air traffic system is a very good reason to change.

Would you say both the economic realities of the oil market and the growing environmental concern are, combined, encouraging the entire airline industry to look at these solutions more seriously?

Yes, there's no question about that. One of the great impetuses toward satellite-based navigation on the part of the airlines is the need to reduce fuel burn. Again, because there's a one-for-one correlation between fuel burn and greenhouse gas emissions, any reduction in fuel consumption benefits the environment. Whatever the motive, the result is very good. There is no justification for a system that requires people to waste fuel.

The position of the U.S. during my tenure at DOT was that we need to focus on some of these operational and technical issues and not just be wedded to so-called market incentives —especially when the cost of fuel is already a big market incentive.

In regards to cap and trade approaches are there any specific elements that you think are counter-productive to making progress in the aviation industry with respect to the environment?

Yes, a lot of them actually. For starters, it's unclear if the EU has the legal right to include international aviation in its existing cap and trade scheme. That's relevant because doing so could end up with us distracted and diverted by litigation rather than focusing on the actual problem. But, beyond that, I think it's very difficult to do this in a way that benefits the environment without doing it on a global rather than regional basis. There are several reasons for that. For example, let's say you're an airline operator and 10 to 15 percent of your flights are from the United States to Europe. Assume it becomes more expensive to fly to Europe because you need to buy allowances from the market for carbon emissions. You may choose to put your more fuel-efficient aircraft on those routes in order to save money, but the option remains open to simply move the less efficient ones to other routes…

It's very hard to control emissions unless everybody participates in all the markets. With a growing domestic aviation industry in China and India, the European proposal only addresses what, over time, will be a declining share of the overall global market. As I said before, in markets where the car provides an alternate means of transportation, the result may actually be an increase in emissions. At least in the United States, it's obvious that the biggest source of emissions to be controlled in transportation is the wasteful use of our cars much more so than what is now being caused by aviation.

In the U.S. we look at aviation as a critical part of our transportation infrastructure. It's no secret that the industry is suffering a lot right now and there are many people who, with the current oil prices, question the industry's economic viability. Any effort to raise operating costs for airlines has the potential to have a calamitous effect. I don't know why we would want to take steps that would knowingly increase operating costs for airlines at this juncture. It may be different in Europe, where there is a much better rail infrastructure.

I, like many other people, believe environmental concern is going to be one of the most challenging issues for aviation for some time to come. I expect there will be serious questions raised and legal challenges ahead, but we need to keep aviation's current effects on the environment in context and try to avoid being distracted by regional squabbles that will do more to promote litigation than they will to serve our global environmental needs. ■

Footnotes:

[1] S 1191 was a Climate Change Bill in the U.S. Senate that would essentially have been a tax on source emissions at the refinery level. This Bill was blocked in the Senate on June 7, 2008.

Striving Toward Meaningful Solutions

Daniel Calleja *has been the* ***Air Transport Director*** *at the* ***European Commission*** *since November 2004. His present responsibilities include the single European aviation market and its broader international components. He successfully negotiated the recent EU-US Open Skies Agreement, is the Chairman of the Air Safety and the Single Sky Committees, and represents the Commission in the SESAR Joint Undertaking. Since April 2008 he is also responsible for EU aviation security matters. Mr. Calleja has been actively involved in a number of roles at the European Commission since 1986.*

ICAO Journal: **Given the results of last year's ICAO Assembly on this issue, have the European Commission's (EC's) plans or expectations, in respect to the implementation of an emissions market that will include aviation, been adjusted or adapted in any way?**

Daniel Calleja: These discussions continue. The EU emissions trading system, as we explained in the assembly at the time, is still a proposal from the Commission. The proposal has been subject to changes by the European Parliament and the Council of Ministers. There are a certain number of amendments among these changes that deal with the international perspective, with a view to accommodating concerns expressed by third countries during the ICAO Assembly.

This is an ongoing process. Like in any democratic system, you have the vote of one House (the Parliament) and then it goes to the other House (the Council of Ministers). So here we have had a first reading vote from the European Parliament, and there has been a decision by the Ministers on a first reading in December. There could be a second vote in July in the European Parliament and then the text will be submitted to the EU Council of Ministers for adoption.

With the proposed cap targets, there is distance between what your environmental committees and your transport committees in the European Parliament are looking for. Has there been any internal movement in the EC toward a more consensual position on aviation emissions?

Internationally, I think everyone agrees that aviation emissions, in absolute terms, are not very significant. We say they are about three percent in absolute figures but it is also important to note that those figures are growing.

Currently the question is: how should the aviation industry contribute to climate change? It's to meet this challenge that the EU proposes a comprehensive approach. We think technology has to play a role and, in this sense, I would say we're very much in agreement with the rest of the world. We think another important component is to provide more infrastructure and resources through programmes and initiatives such as the Single European Sky project or the Atlantic Initiative to Reduce Emissions (AIRE). We are now partnering with the United States specifically in order to take advantage of the best transatlantic paths in terms of emissions. We call this now successfully implemented joint venture "Green Trans-Atlantic Flights." We're also expecting additional results from the Single European Sky Air Traffic Research (SESAR) programme and we already have an agreement in place to collaborate and cooperate with NextGen initiatives in this regard.

In all aspects these are open programmes for the rest of the world to join with us on. The Clean Sky programme is going to be the highest financed EU programme in terms of research and development for the foreseeable future. However, the EU, as a region, differs from other countries because we have already developed an emission-trading scheme —which is now covering 50 percent of our CO_2 emissions for other economic sectors (steel, refineries, electricity, etc.)—and we would like aviation to be a part of it. The rest of the world is not yet as advanced as we are in this respect, and this is one of the difficulties Europe faces as it leads the debate, but we are endeavouring to find solutions that can encompass all operators in line with the ICAO principle of non discrimination.

What role is air traffic management expected to play?

We have calculated that, in general, intra-EU short haul flights are currently

50 kilometres longer than they should be. Air traffic management solutions therefore offer us a great deal of potential for CO_2 savings.

In the coming weeks, the commission intends to put forward measures to achieve the Single European Sky (SES). In the coming months, we will create performance targets and try to unify air traffic management in an effort to accelerate Functional Air Space Blocks. This means several countries will now be pooling their resources to jointly manage their air space. With respect to the complications that inherently arise from issues of sovereignty and airspace this represents a tremendous step forward, and it is only natural given our unique model of regional integration that these solutions should be put in place first in Europe.

The SESAR initiative, representing the technical components of the SES, has now completed its definition phase and will shortly be embarking on the development segment. SESAR is intended to be fully interoperable with NextGen systems and we are ready to engage with any other countries or regions. We think technology can provide very, very significant benefits.

Where do you see the environmental issue headed in the near term?

It is important to note this is an ongoing debate. Europe remains committed to a global solution because we believe that aviation is global. This would be the best outcome. On the other hand, we also feel that if no one acts in a meaningful enough way then it's our duty to put this issue in the center of the discussions and to lead the debate with serious proposals.

Do you feel ICAO is the natural forum to develop a global solution?

Yes, and that's why we are committed the processes that have been launched by ICAO's Group on International Aviation and Climate Change (GIACC). But GIACC has to deliver and, even when it does, its results will then need to be endorsed by the ICAO Council. This represents a challenge in the current environment and there is a lot of work to be done, but we are ready to go in this direction.

We are also ready to revise our system if a more global solution can be agreed. We are open to discussions with third countries and have already begun some with certain States. Australia and New Zealand, for example, are now very committed to discussing environmental issues with the EU. It's very important to engage because, at the end of the day, we need to have a global system or consistent regional systems. As I have said, aviation is global. ■

Measure for Measure

Aggregate CO_2 emissions are only part of what goes into developing an accurate indication of the environmental impact of a given human activity, such as aviation. Dr. Olivier Boucher, Head of the Climate, Chemistry and Ecosystems Team at the Met Office Hadley Centre in the United Kingdom, discusses the scientific background of non-CO_2 multipliers in climate mitigation policies.

__Dr. Olivier Boucher__ was a lead author of the "Special Report on Aviation and the Global Atmosphere" (1999) of the Intergovernmental Panel on Climate Change (IPCC), a lead author of the IPCC Third Assessment Report and a contributing author to the 2002 WMO report on ozone. Dr. Boucher's research interests lie in Earth System modelling, mitigation of climate change, and regional to global air pollution, with a view to be relevant to policy making. His most recent work is on climate metrics to compare the climate effects of short-lived and long-lived atmospheric pollutants.

ICAO Journal: **What it the objective in employing non-CO_2 multipliers when measuring contributions to climate change?**

Dr. Olivier Boucher: It is usual to measure the contribution to climate change in terms of radiative forcing relative to pre-industrial times. Anthropogenic (human-produced) emissions of carbon dioxide (CO_2) were responsible for a radiative forcing of 1.66 Wm^{-2} in 2005, with other long-lived greenhouse gases roughly contributing another 1.0 Wm^{-2}, and short-lived tropospheric ozone, soot aerosols and contrails contributing at least an extra 0.6 Wm^{-2} during that same period. There are also climate change mechanisms that result in negative, but uncertain, radiative forcings. In any case it is clear that climate change is not due to the increase in CO_2 atmospheric concentration alone. The objective of non-CO_2 multipliers is to factor these non-CO_2 climate effects into an equivalent CO_2 only effect.

Which climate metrics are most relevant to measure the non-CO_2 effects?

This depends on the policy question one is trying to answer! Radiative forcing is a measure of the cumulative impact of past emissions. The concept of a Radiative Forcing Index (RFI) finds its origin in the *IPCC Special Report on Aviation and the Global Atmosphere* published in 1999. An RFI of two for aviation means that, as of now, the non-CO_2 climate change mechanisms associated with aviation have more or less doubled the climate warming due to CO_2-only emissions from aviation. As such, it should *not* be used as a multiplier of CO_2 emissions to estimate the total climate impact in the *future* of *today's* emissions from aviation. Global Warming Potentials (GWP) or Global Temperature change Potentials (GTP) provide a better measure of the amount of future global warming expected from the non-CO_2 climate effects. Current estimates of GWP and GTP suggest that the non-CO_2 multiplier for aviation should be smaller than what the RFI suggests if the focus is to stabilize the climate on the time scale of a century. However, as we approach an upper limit for climate change that we do not want to exceed, the "climatic value" of non-CO_2 short-lived species—and therefore the associated non-CO_2 multiplier—will increase sharply.

Is aviation the only sector that should be using a multiplier?

This is a question for policy makers but science can provide some guidance. The mitigation of climate change will be most effective if proposed solutions incorporate all industrial and land use activities. Let us take the example of an emission cap and trade system. It would not be optimal from an economic or a climatic point of view to trade CO_2 emissions on a one-for-one basis between two sectors where the climate contributions from non-CO_2 sources are radically different. In an ideal system the non-CO_2 climate effects should definitely be accounted for, but because the science for short-lived pollutants is less established than for well-mixed greenhouse gases this more comprehensive approach may not be practical to implement in the near-term.

Do you know of any examples of non-CO_2 multipliers in other economic sectors?

To my knowledge multipliers have not been calculated systematically for every economic sector. Some sectors like shipping have a multiplier less than one because of the negative radiative forcing—or climate cooling—associated with aerosol emissions. It is not clear yet how to treat less-than-one multipliers in climate policies because there are also good reasons to reduce aerosol emissions to improve air quality and combat acid rain.

Is a non-CO_2 multiplier the only option?

This is again a question for policy makers and I can only answer from the viewpoint of a climate scientist. We know how the climate system responds both to CO_2 and non-CO_2

climate forcings. It is widely accepted that CO_2 emissions have to be reduced if dangerous climate change is to be avoided, but there is some room to reduce the danger of climate change by decreasing emissions of non-CO_2 species, such as ozone precursors, contrails, or soot particles. In that sense it is desirable that policy instruments also include such sources. For maximum flexibility it can be argued that the non-CO_2 effects should be introduced explicitly in climate policies rather than through simple multipliers. For instance, it might be more effective to minimize the total climate effect of aviation than to minimize its CO_2 climate effect only. However this requires that the right metrics be used to trade CO_2 and non-CO_2 emission reductions. Otherwise such a system could be unfair to some economic sectors and counter productive for climate mitigation.

Are there any new findings since the most recent IPCC Special Report in this area?

A consensus is building up among climate scientists regarding which climate metrics should be used to compare the climate effects of long-lived and short-lived atmospheric pollutants. It is time therefore for climate scientists, the aviation industry and regulators to begin to work more cooperatively in order to minimize the climate impact of aviation. ■

"For maximum flexibility it can be argued that the non-CO_2 effects should be introduced explicitly in climate policies rather than through simple multipliers. For instance, it might be more effective to minimize the total climate effect of aviation than to minimize its CO_2 climate effect only."

ANSPs and the Environment: The Next Steps

There can be few people in aviation who have not become aware in recent years of the concern expressed about the effect of aircraft emissions on climate change. But while the bulk of the criticism has mainly fallen on airlines and airports, ANSPs have remained slightly 'under the radar' because most NGOs and policy makers believe they are neither a major part of the problem nor the solution. But this state of affairs is changing. CANSO assesses the opportunities as policy makers start to realize that air traffic management could be a fertile ground for 'quick wins'.

CANSO has moved environmental issues to the top of its agenda. In 2007 CANSO members agreed an Environmental Code of Practice, which will form the basis of its response to the emissions challenge. It calls for ANSPs *"to recognise the need to deliver air traffic services in ways that mitigate the impact of aircraft operations on the environment"*. In terms of climate change, the Code sets a goal for ANSPs to contribute to the reduction of the impact of greenhouse gas emissions through better understanding the impact of aviation on climate change, and supporting the development of metrics to demonstrate a reduction in impact.

But is that commitment enough? It is clear that many in the aviation world—and, increasingly, many outside it as well—are focusing on ATM as the part of the system with the greatest capacity for a near term step change in performance. In 1999 the IPCC suggested that ATM had an influence over 6-12 percent of global aviation CO_2 emissions, and IATA has called for improvements in airspace design to begin immediately. Phil Stollery, Chairman of CANSO's Environment Workgroup, warns that it will not be easy.

"Recent work by the CANSO environment workgroup to update the IPCC figure suggests that the practical efficiency gains from ATM are lower than the IPCC estimate," began Stollery. "When you place that in the context of increasing traffic of 5 percent p.a., you begin to see the size of the challenge ahead. Much work has gone into trying to realize efficiency gains but with the complexity of a congested airspace and a highly political arena, changes are only able to take place gradually," he noted.

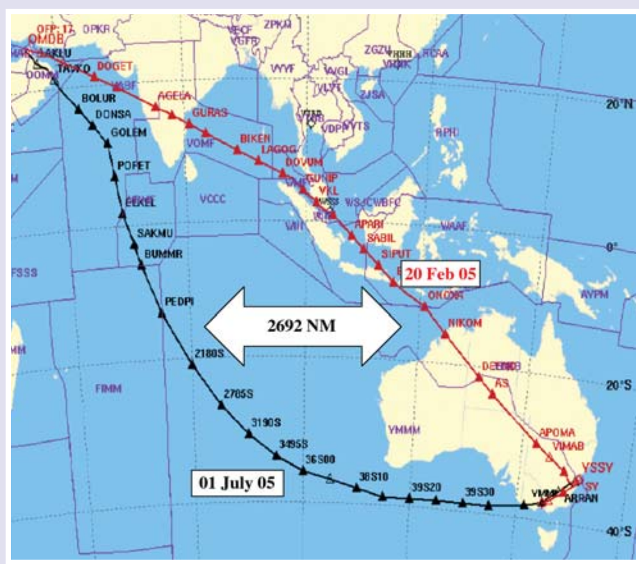
There is evidence to back this stance up. The Performance Review Unit of Eurocontrol recently released a study of the comparative responsibility for airspace reform in Europe. They concluded that 63 percent of route extension (the extra distance flown compared to an absolutely optimized route) was attributable to network design within states, nine percent was attributable to interfaces between States within regional airspace, and 28 percent of route extension was down to interfaces within regional airspace. Exactly how much of this loss of efficiency is related to military designated areas outside the ANSPs control is open to debate, but clearly State politics and bureaucracy have a major role to play.

These wider difficulties have a direct impact on the efforts of ANSPs to make

The CANSO Environmental Workgroup Mission

The CANSO Environment Workgroup promotes the need to deliver air traffic management in ways that mitigate the impact of aircraft operations on the environment. It is therefore committed to the following goals for improving aviation sustainability:

1) To develop metrics and targets for the reduction of environmental impact.
2) To define and advance best practice in environmental management for ANSPs and to promote implementation as widely as possible.
3) To influence environmental policy, regulations and legislation to balance capacity, efficiency and the environment, without compromising safety.
4) To enhance understanding of ATM's environmental impact and mitigation measures.



dramatic improvements in emissions reductions. The most eye-catching recent initiative was the announcement by NATS (the UK ANSP) that it intends to reduce ATM-related emissions per flight by 10 percent by 2020, but the new Head of Environmental and Community Affairs at NATS, Ian Jopson, is keen to point out the challenges his company faces in trying to reach its target.

"Let's be clear, NATS can't do this alone. We'll need to enrol the commitment and engagement of the entire industry, governments and our regulators to make real progress" Jopson commented. "One of the principal problems is that airspace management is not exclusively down to the control of the ANSP. There are political considerations, military requirements, and national boundaries, which all conspire against efficiency in the system".

Jopson notes that in the USA, the NextGen project, designed to help increase efficiency and reduce delays in airspace, has a 12-year timeframe and a multi-billion dollar budget—not to mention no problem commensurate with the small national airspace blocks which are found in Europe. The Single European Sky project is attempting to resolve these complex issues, but political progress has been slow. Despite the political difficulties, there are things that can be done by ANSPs alone.

"Significant gains have already been made, for example with route optimization, RVSM, CDA, the use of Flex Tracks and more direct routing made possible through the Flexible Use of Airspace," continued Phil Stollery. "CANSO members are also working on further initiatives such as more extensive use of 'Collaborative Decision Making.'"

Over long distances of homogenous airspace some innovative work in routing aircraft has resulted in surprising reductions in fuel burn, such as the Flextracks adopted by Airservices Australia *(see map and description on page 18)*. Similar successes are being targeted by the AIRE project, a joint US-EU initiative to reduce emissions on flights across the Atlantic.

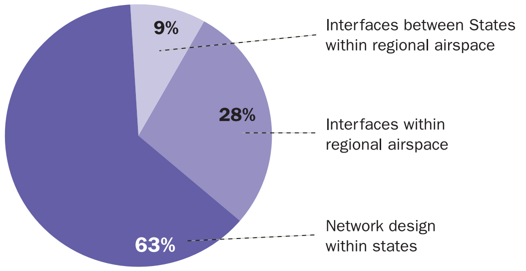
The US Federal Aviation Administration has been looking at a number of projects to reduce emissions, and recently announced changes of the East Coast of the U.S. which, by reducing lateral separation, will save nearly four million tons of CO_2 over a 15-year period. As well as being active in AIRE, it has launched a similar project in the Pacific with Airservices Australia and Airways New Zealand. Called ASPIRE, the project aims to accelerate the development of ATM to reduce the carbon impact of flights to and from the U.S. West Coast. Recent work in the US on CDA has produced a pronounced fuel burn saving, which companies such as UPS, flying out of Louisville, note have an advantage both to the environment *and* the bottom line. At Louisville UPS calculates its new efficient approaches save up to 465 gallons of fuel per landing, which equates to hundreds of thousands of dollars a year *(Editor's note, for more on the UPS initiative please see "Lessons from Louisville", ICAO Journal/Vol. 63, No. 3.).*

FLEX TRACKS

A Flex Track is an air route that allows an aircraft to take advantage of favourable weather conditions, such as jet streams, even if the aircraft subsequently appears to fly miles off course. Even though route length is often extended, fuel (and time) savings can be considerable. In its first Flex Track trial in June 2004 an Emirates flight from Dubai to Sydney achieved a saving of 8408kg of fuel with the flight arriving 43 minutes quicker than the best fixed route.

Route Extension Factors

Route extension refers to the difference between a fully optimized route and what is actually flown by a given aircraft. The table below indicates the primary route extension factors which have been identified by the Performance Review Unit of Eurocontrol:



Back in Europe, LFV (the national ANSP of Sweden) has been leading the way with Continuous Decent Approaches into Stockholm Arlanda airport, where they have announced a venture with Airbus to complement the testing that has been done on a Boeing 737 over the last year and a half. According to the airline SAS, a CDA approach made by one of its Airbus A330s on a flight from Newark in December 2007 saved about 470 kilos of CO_2. In addition, plans are underway to increase the number of European city pairs operating green routes.

But while reduced route length and more efficient approaches and departures are good news for the bottom line of the airlines, and the environment, there is no similar correlation for ANSPs. At the moment the trade-offs between safety, capacity, and optimal environmental performance are not well defined. In theory, shorter routes resulting in fewer charges are actually financially counter-productive for ANSPs, unless the result is higher capacity. As CANSO members continue to bring the environment further up on their agenda, it may be that they need to work with their customers towards an institutional framework that incentivises good environmental performance.

ANSPs have already achieved some significant improvements, but ultimately it will take a step-change in reform, both within ANSPs and their governing states, as well as with their customer partnerships, if the full potential of a seamless sky, with all its environmental promise, is to be realized. ■

Pioneering the Road to a Brighter Future: One Sustainable Plant Source at a Time

By Billy Glover, Managing Director of Environmental Strategy, Boeing Commercial Airplanes

While it was once was inconceivable to think that commercial jetliners might one day be powered by fuels derived from biomass, those beliefs are rapidly turning around in light of oil prices that either hover near or surpass new record levels on a near-daily basis.

Those who follow the economic relationship between globalization and commercial aviation may well recall that travel ebbs and flows within the aviation sector have long been a key indicator of the health of the broader global economy. Today, the state of the global economy is on the verge of sending the aviation industry into a tailspin.

No longer can airlines count on the boost that seasonal travel periods have historically brought. With leisure travelers measuring their expenditures in light of global economic pressures, and businesses increasingly scrutinizing travel budgets, the level of increase in seasonal passenger traffic during the months ahead is anybody's guess. One thing, though, is clear; airlines are warming to the notion of alternative fuels as a way to stem the bite of the escalating price of oil.

Responding to the challenges facing aviation, specifically rising fuel prices and environmental pressures, Boeing has grabbed the alternative fuels mantel and is proactively working across multiple industries to identify sustainable and economically viable new solutions that can help soften the sting of fuel costs being felt throughout the industry, while also looking to lessen aviation's impact on the world's ecosystem.

For Boeing, the commitment to identifying sustainable fuel solutions begins with research and development and ensuring that its own environmental strategy has a clear and precise focus. As we actively address these issues, we must balance the need for new technologies and improved environmental performance, while minimizing disruptions to the flow of people and commerce around the world. Secondly, it's helping people inside and outside of our industry to understand that there essentially are two ways to improve the fuel efficiency and environmental performance of a commercial jetliner—change the design or use of the aircraft *or* change the fuel that goes into the tanks.

The introduction of progressive new aircraft such as the 787 Dreamliner and the 747-8 Intercontinental are poised to deliver significant reductions in noise and fuel emissions, while demonstrating to passengers that aviation is doing its part to not only protect the environment, but also ensure affordable global travel is available to future generations.

But environmental performance isn't simply a by-product of aircraft design; it's a very deliberate effort that has driven us to continually improve fuel efficiency for our customers. That's good business sense, which, in an age of record fuel prices, coincidentally has environmental benefits. For each litre of fuel that isn't burned, it means *not* emitting 3.2 litres of CO_2.

Market-leading airlines such as Virgin Atlantic, Air New Zealand and

Continental have long recognized this and stepped forward to help pursue new fuel solutions for the industry in particular, sustainable next generation biofuels.

In the meantime, energy experts continue to espouse the diminishing discovery of new petroleum-based fuel sources. Some are claiming that we've already reached a point where half or more of the world's crude oil has been consumed, while others predict it will happen around 2030. Regardless of which camp you fall into, alternative fuel options must be identified, tested and implemented many years ahead of peak oil to ensure a smooth and viable transition to sustainable fuel sources. Innovative airlines are helping to pioneer the way forward today.

Plant-based fuel sources derived from sustainable biomass offer a lower carbon footprint and don't compete with food and land resources. These new generations of biofuels—or biojet—offer significant benefits when you consider them over the course of their life cycle.

Plant-based feed stocks absorb CO_2 when they are growing, meaning those fuels that are produced through sustainable growing practices have the ability to reduce the industry's dependence on fossil fuels, while offering a 50-80 percent CO_2 reduction over the course of their lifetime. Of equal importance, the technology is being developed today to ensure that next generation plant-based fuels can be produced in sufficient quantities and at competitive price points compared to where oil prices are headed. That's a tremendous opportunity for an industry that is beginning to witness its airlines' very viability now threatened by rising operating costs that are primarily the result of oil prices.

We've already conducted the first commercial biofuel flight with Virgin Atlantic to prove their technical applicability to commercial aviation and have announced that two more demonstration flights are planned with Air New Zealand and Continental. Going forward we'll focus on the sustainability aspects of potential fuel sources and hold ourselves accountable to the highest standard to ensure fair trade, equitable sourcing and sustainable farming practices are evident throughout the fuel acquisition process.

But solutions take time to develop, and while by our estimates show we're still five to seven years from seeing biofuel solutions become available for commercial use, it's important to know the technological foundation is being established today.

As the approaching summer months invite us outdoors, they also remind us that innovative, bio-based solutions are all around us if we're willing to work together to protect and view them for what they are—potential catalysts of change for the benefit of society and our industry.

While record oil prices will continue to affect business and leisure travel and fleet planning decisions for the foreseeable future, we must continue to work to replace alternative fuel misconceptions with facts, data and innovative technological solutions. Only then can we say that we've effectively avoided the crucial challenge posed by the economic and climate change factors that are now threatening our industry. ■

The Path to a Jet Fuel Alternative: Airbus Initiatives and the Steps Ahead

On February 1, 2008 the Airbus A380 became the first commercial aircraft to fly with a synthetic liquid fuel processed from a Gas To Liquids (GTL) source in a three-hour flight between Filton, UK and Toulouse, France. The A380, today's most fuel-efficient airliner, was powered by Rolls-Royce Trent 900 engines while Shell International Petroleum provided the GTL Jet Fuel. Airbus tests are running in parallel with the agreement signed in November 2007 with Qatar Airways, Qatar Petroleum, Qatar Fuels, Qatar Science & Technology Park, Rolls-Royce and Shell International Petroleum Company to research the potential benefits of synthetic jet fuel processed from gas.

Airbus's activities on research and partnerships for the future production of alternative fuels for aviation are fully integrated into Airbus's eco-efficiency-based strategy. As a consequence, the advantages and potential impacts of alternative fuels are considered from well to wing; i.e. through a complete lifecycle analysis. Short, medium and long term options are considered and both local air quality and global atmosphere effects are being investigated.

Current Options

Alternative fuels offer opportunities, but may require changes in infrastructure, aircraft and/or engine design. In addition, no standard approval process for alternative fuels currently exists.

Aircraft manufacturers are therefore actively involved in different internal, national and international activities aiming at both exploring these opportunities and understanding the potential changes that might be required.

In the medium term, the most promising opportunity consists of finding alternative ways of producing kerosene, i.e. drop-in replacements.

The Fischer-Tropsch-generated synthetic fuels have similar properties to those of traditional kerosene, have superior thermal stability, contain no sulfur and are mixable with conventional fuels. Their properties are not dependant on feedstock type. Although the available stocks of natural gas (for producing synthetic GTL) or coal (for CTL) may be greater than


International Register of Civil Aircraft (IRCA)
Look it up: we know, who this is...
IRCA is a unique world wide database, accessible through intuitive browser based software, that provides details of official administrative information (such as aircraft registrations, owners and operators) and technical information on over 500,000 aircraft.
www.aviation-register.com
The aim of IRCA is to provide public and private bodies with a single source database providing comprehensive details of national aircraft fleets. This allows a global exchange of data in a standardised format promoting the goal of aviation safety.
More than 50 countries, including the USA, currently cooperate with the International Register of Civil Aircraft (IRCA). By having its National fleet represented in the IRCA, an NCAA benefits from worldwide distribution and promotional support of its national register and has access to information on other contributing nations aircraft.
The technical information (Manufacturer – Model Type and Serial Number of aircraft) contained in this database is formatted and standardized in accordance with IACIS developped by CAST/ICAO and adopted by ICAO.
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crude oil, fossil resources are ultimately not renewable and are therefore not considered sustainable.

Biofuels appear attractive in terms of lifecycle CO_2 emissions, primarily since the carbon dioxide absorbed by the plants during their growth could offset a significant part of the emissions released during the fuel combustion. BTL is one of the options in this respect. Biofuel feedstock cost and availability remains an issue that is not yet adequately understood or factorable into a more complete assessment.

Fatty Acid Methyl Ester (FAME) fuels are not suitable for aviation because of their high freezing point, low flash point, low thermal stability, poor energy content, the strong solvent properties of ethanol, and the toxic properties of methanol.

In the longer term, hydrogenated vegetable oils appear to be quite promising—with properties similar to those of conventional fuels but current technology readiness level is low.

Hydrogen remains on the research screen for the very long term. The major challenges with this alternative include the infrastructure needed for its production, distribution and storage.

Hydrogenated Vegetable Oils (HVO) and Biomass To Liquids (BTL) currently appear to be the most environmentally attractive alternative fuels. Airbus decided to focus its research and activities on sustainable second-generation biofuels; i.e. biofuels that do not compete with land or water use for food crops, nor with natural carbon sinks such as rain forests.

Airbus and its Fuel Future

Although these second generation biofuels will not be produced in significant quantities within the next decade or so, Airbus is keen to explore how they might provide up to 30 percent of all commercial aviation jet fuel by 2030.

CLEANER AIRCRAFT FUELS: CURRENT OPTIONS AND POSSIBLE ALTERNATIVES

A conventional jet fuel is derived from crude oil as permitted by the current (2006) major international jet fuel specifications, and is comprised solely of hydrocarbons and/or approved additives. Aircraft and engine design and characteristics are strongly related to the properties of the fuel type being employed. The current range of possible fuel options to be combined with or possibly replace conventional jet fuel is as follows:

Alternative fuels:
An alternative fuel is a fuel that could be considered for use in aviation, but not currently permitted by the major international jet fuel specifications.

Synthetic fuels:
A synthetic fuel is an alternative fuel synthetically produced from hydrocarbon-containing feedstock (e.g. gas, coal, and biomass) via a Fischer-Tropsch (FT) process. This category includes Gas To Liquids (GTL), Coal To Liquids (CTL), and Biomass To Liquids (BTL).

Semi-synthetic fuels:
A semi-synthetic fuel is a blend of a synthetic fuel with a conventional fuel.

Biofuels:
A biofuel is an alternative fuel produced from renewable, biological material. This category includes, for instance, both oxygenates (such as ethanol and vegetable oil Fatty Acid Methyl Ester, also known as FAME), synthetic BTL fuels and Hydrogenated Vegetable Oils (HVO).

Cryogenic fuels:
A cryogenic fuel is an alternative fuel only stable in its liquid state at very low temperatures. This category includes, for instance, Liquid Hydrogen (LH2), which is not considered as a biofuel, since only very small quantities can today be produced by other means than from petrol, coal or nuclear power.

As an illustration, Airbus has teamed with Honeywell Aerospace, UOP (a Honeywell Company), International Aero engines (IAE) and Jet Blue Airways to pursue development of sustainable second-generation hydrogenated vegetable oils for use in commercial aircraft.

In parallel, Airbus is also engaged in partnerships and research activities on GTL fuels, which should be obtainable in the very near future. Fischer-Tropsch (FT) produced alternative fuels have all the same characteristics, independent from the source of the feedstock (CTL, GTL or BTL). While the lifecycle CO_2 emissions from the GTL process are expected to be comparable to conventional fuels, some environmental benefits can be measured in terms of local air quality with GTL compared to conventional jet fuel (very low particulates, no sulfur-related emissions). GTL in this sense can be reasonably considered as a precursor for BTL. In practical terms, it is Airbuses contention that all the technical expertise and experience required on engine, systems and related elements can indeed be built on the GTL foundation and will provide a robust and flexible supply/combustion infrastructure capable of accommodating second generation BTL alternatives when these become available in more significant quantities.

Airbus has defined a global roadmap on alternative fuels, integrating research activities, partnerships, future test flights and cooperation with fuel standard certification authorities in order to act as a catalyst and make alternative fuels, when they become fully sustainable, a reality for aviation. ■

For more information, please connect to http://www.airbus.com/en/corporate/ethics/environment/eco-efficiency/alternative_fuel.html

Engines of Progress

Because fuel burn already plays such an important economic role in the health and viability of the aviation sector, jet engine manufacturers had a built-in incentive to make their products more efficient long before the environment became the pressing concern it is today. As oil now reaches record prices and CO_2 emissions are a more dire concern, manufacturers are responding with even greater innovation and determination. The *Journal* asked GE Aircraft Engines, Rolls-Royce and Pratt & Whitney Canada to update its readership on their plans for our environmental future.

GE AIRCRAFT ENGINES/CFM INTERNATIONAL

Agencies such as ICAO, which regulate airport noise and aircraft emissions, have been implementing more stringent limits for several years now. While leading the charge to lower jet engine emissions, GE is also reducing aircraft noise. A significant part of aircraft noise is created by the propulsion system, and GE is investing in advanced fan designs and components that lower engine noise.

Highlighted below are several present and future GE/CFM engine programmes that are reducing fuel consumption, emissions, and noise.

CFM56 (Snecma and GE)

Recently, CFM has developed new hot-section upgrade kits for the CFM56-3 engines (introduced in 1984) and CFM56-7 engine (introduced in 1997) that power the vast Boeing 737 family. Also, CFM has developed upgrade kits for CFM56-5 engines (introduced in 1996) powering planes in the A320 family.

So far, more than 1,000 CFM56-3 engines have received the advanced upgrade. This package is installed during normal overhaul and provides significant benefits, including up to a 1.6 percent improvement in specific fuel consumption.
In 2007, CFM introduced the CFM56 Tech Insertion production configuration and, to date, more than 1,250 new engines have been delivered. Tech Insertion hardware is also available to upgrade current engines. The full Tech Insertion upgrade kit provides better fuel consumption (as much as one percent over the life of the product), along with longer time on wing, enhanced durability, lower maintenance costs, and the ability to reduce oxides of nitrogen (NO_x) emissions by 15 to 20 percent, which enables CFM to meet the new ICAO CAEP/6 emission regulations that took effect in January 2008.

GE90

First introduced in 1995 on Boeing's early-model 777s, the GE90 provides high thrust with outstanding fuel burn, noise, and emissions characteristics. The GE90 is not only the most fuel-efficient engine in its thrust class, it also enables long-range 777s to fly distances previously achieved only with four-engine aircraft. The world's most powerful engine, the GE90-115B, was introduced in 2002 for long-range 777-300ERs and –200LRs, which achieve 22 percent better fuel efficiency per seat than their closest competitor.

Each year, a fleet of 20 777s powered by GE90-115B engines will emit 177,000 fewer tons of greenhouse gas emissions than if it used the competing airframe requiring four engines. That equals the carbon dioxide absorbed by 43,000 acres of forest, an area more than twice the size of Manhattan. Eliminating those emissions would also be equivalent to removing nearly 25,000 cars from the road for a year.

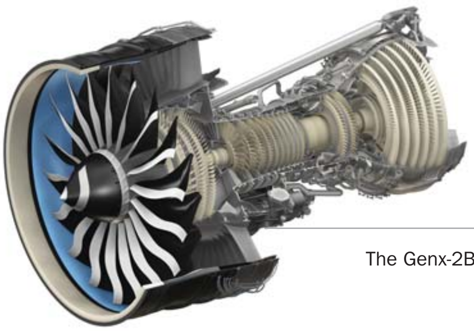
The GE90-115B features composite fan blades with a unique shape that displaces an unprecedented volume of airflow—thus delivering tremendous thrust and excellent fuel efficiency. But this added air volume is created at a slower rotational speed, which in turn produces less noise. On a per-pound-of-thrust basis, this engine ranks as one of the quietest.

Emissions levels are reduced due in great part to an improved combustor. And because the engine is so efficient, it uses less fuel to create each pound of thrust compared to previous generations of aircraft engines. Less fuel burned means less carbon dioxide, a greenhouse gas. The combustor also emits no more than 40 percent of the hydrocarbons that will be allowed by 2008 international standards.

A technician attends to a GE90-115B.

GEnx

The GEnx will power the Boeing 787 and 747-8. It consumes 15 percent less fuel than its predecessor, GE's highly popular CF6 engine, and is the quietest large commercial engine that GE has ever produced. If an airline were to replace 20 of its older 200-to-300 passenger aircraft with next generation jets powered by GEnx engines, it would save nearly $5 million in fuel costs annually.



The Genx-2B Trimetric.

The GEnx engine is the world's only jet engine with both a front fan case and fan blades made of composites, which provide for greater engine durability, weight reduction and lower operating costs. The fan blades utilize composite technology that has performed well on the GE90, with no routine on-wing maintenance required and no in-service issues for more than a decade. The GEnx will operate with 18 fan blades (50 percent fewer than the CF6) at noise levels lower than any other large GE commercial engine. The GEnx also features a new TAPS (Twin-Annular, Pre-Swirl) combustor for efficient fuel mixing prior to ignition.

The result is an engine that produces fewer smog-causing emissions than the maximum allowed by 2008 international standards (94 percent fewer hydrocarbon emissions and 57 percent fewer nitrogen emissions), while consuming at least 15 percent less fuel than the engines they replace.

Advance Technology Programme

Launched in 2005, LEAP56 is CFM International's advanced technology programme focusing on future advances in every part of the engine as well as new engine architecture, exotic materials (such as ceramic matrix composites and super-alloys), and next generation 3-D aerodynamic designs.

Aggressive rig and components tests on several critical enabling technologies are well under way, with core engine tests slated for 2009-2010.

CFM is targeting significant improvements, including 10 to 15 percent lower fuel consumption, and emissions (specifically NO_x) that are 50 percent lower, all compared to today's industry-leading CFM56 engines for the Airbus A320 and Boeing 737 families. Operational benefits are balanced against potentially more stringent noise requirements.

Open Rotor Concepts

GE and the NASA Glenn Research Center will conduct a wind-tunnel test programme to evaluate scale-model, counter rotating fan systems which could be used for "open rotor" jet engine designs targeted to reduce fuel consumption by more than 20 percent over today's conventional turbofan designs.

The GE36, which flew on Boeing 727 and MD-80 aircraft during the 1980s, featured an aft-mounted, open-rotor fan system with two rows of counter rotating composite fan blades. With the enormous efficiency from bypass air created by this fan system, the GE36 engine late in the 1980s demonstrated fuel savings of more than 30 percent, when compared to similar sized turbofan engines with conventional, ducted front fan systems. Snecma was a 35 percent participant on the GE36 programme.

ROLLS-ROYCE

In aerospace, good environmental performance is a key business driver—and much of the research effort at Rolls-Royce is devoted to ensuring its engines meet future environmental targets.

The company pursues programmes that bring near, medium and long-term advances in the main contributory disciplines of emissions and noise under its 'Vision' technology strategy:

- Vision5 includes technologies that exist 'off-the-shelf' and can be applied immediately to new and existing products.
- Vision10 describes a range of technologies currently at the validation stage and likely to be commercially available in approximately 10 years time.
- Vision20 comprises a broad range of emerging or unproven technologies aimed at a future generation of products around the 20-year timeframe and beyond.

For some considerable time, Rolls-Royce has recognized that the industry's rate of growth demands more rapid and radical change, and it embraces the agenda set by the Advisory Council for Aerospace Research in Europe (ACARE) that calls for improvements at twice the historic pace.

One of the first programme to answer ACARE's call was ANTLE (Advanced Near-Term Low Emissions), which was an integral part of our Vision10 strategy. Rolls-Royce led this collaborative, EU-funded programme, and the umbrella EEFAE initiative that included the CLEAN research programme led by MTU.

The engine that resulted from the ANTLE efforts had fewer stages of blading and fewer blades per stage in both the compressor and turbine areas, resulting in a much lower parts count, less complexity, weight reduction and lower cost. Emissions performance was met by a lean-burn combustor designed to halve today's levels of oxides of nitrogen (NO_x).

ANTLE broadly met pre-established objectives to reduce CO_2 by 12 percent, NO_x by 60 per cent, improving reliability by 60 percent, lowering cost of ownership by 20 percent, and time to market and life cycle costs by 30 percent (affordability being a key goal as reflected in the name).

Further environmental progress will come from the VITAL programme, involving more than 50 organizations, including Rolls-Royce. Focusing on the low-pressure section of the engine—and looking at new fan architectures, new compressor concepts and lightweight structures—this €90m programme aims to reduce noise by eight decibels and carbon dioxide emissions by 18 percent.

More obviously focused on noise was SILENCE(R), now concluded after a five-year programme targeting technologies to reduce aircraft noise. For Rolls-Royce, this project—in which Airbus is involved—complemented earlier studies undertaken with Boeing under the banner of the Quiet Technology Demonstrator.

SILENCE(R) engine focus was on advanced intake and acoustic liners, a new low-noise fan, a circumferential 'splitter' in the fan outlet guide vane and a negatively-scarfed intake that directs fan-generated noise upwards rather than towards the ground. Its wider activity has seen active noise control and airframe noise reduction research; large-scale validation involved both ground running (at Rolls-Royce) and flight testing.

Current programmes include EFE (the Environmentally Friendly Engine), which runs through to 2010. Again collaborative, EFE is targeting high-temperature materials, high-efficiency turbine components, low emissions combustion, advanced manufacturing technologies, nacelle aerodynamic performance, engine controls and actuation technologies. This year sees initial testing of the first build standard engine (a heavily modified Trent 1000), followed by six rebuilt engines in total, running at approximately six month intervals.

NEWAC is a four-year, EU-funded programme that aims to provide step-change reductions in CO_2 and NO_x through innovative core configurations using active systems and heat management techniques such as intercooler, recuperator and cooling air cooler. This programme will involve the design and manufacture of components, plus model, rig and core testing.

The recently launched DREAM project is the European engine community's response to increasing pressure (even since the original ACARE goals were published) to reduce CO_2 yet further. The prime objective is to design, integrate and validate new engine concepts to reduce fuel consumption/ CO_2 emissions seven percent beyond the ACARE 2020 targets (recognizing the engine only contributes some of the potential savings and that airframe and aircraft operations have a significant role to play, too).

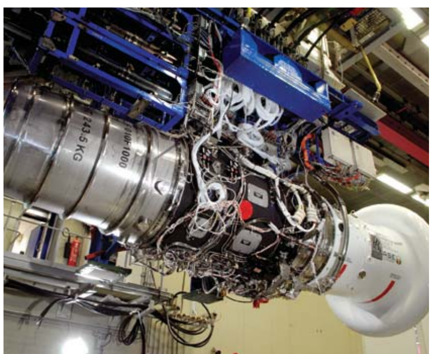
Rolls-Royce continues 'Vision20' research through its network of 29 University Technology Centres (UTCs) spread around the globe. These look at a wide range of fundamental engineering challenges—from noise to aerodynamics and combustion to manufacturing technology—and are of mutual benefit to the company and the universities that undertake real world challenges. They are funded under long-term rolling contracts that provide continuity for the academic research.

One of these, in Genoa, Italy, is studying fuel cell technology. Rolls-Royce has established its own company to develop a solid oxide fuel cell. While it will be many years before fuel cells could be contemplated for aerospace application, it may be in the medium-term future that these highly-efficient and environmentally friendly fuel cell power plants up to around one MW are used to provide electrical power for outlets such as shopping complexes and hospitals.

For more than a decade the company's Trent engine family has been the market leader on new generation wide body jets from Airbus and Boeing, demonstrating significant incremental improvements in environmental performance. The Trent 900 on the A380 will be followed into service by the Trent 1000, certified for the Boeing 787, and will be succeeded in turn by the sixth variant in the series, the Trent XWB, which is the only power plant offered for the A350 XWB.

At a lower slot in the broad Rolls-Royce portfolio, the company's newest entrant is the BR725, selected for the Gulf-stream G650, which has just performed a successful first run at the Rolls-Royce facility in Dahlewitz near Berlin.

The 725 is a more powerful development of the highly successful BR710, currently in service with around 600 top-end corporate jets. The newcomer, however, is more than 4dB quieter, has four percent better specific fuel consumption and shows a 21 percent improvement in NO_x emissions. Initial flight test engines will be delivered to Gulfstream towards the end of this year.



The Rolls-Royce BR725.

Meanwhile, Rolls-Royce is well placed to address opportunities in the 150 seat sector on a broad range of fronts: customer access; airframe integration; advanced engine concepts; technology acquisition and services.

The company has maintained a consistent position that it will continue to evaluate a number of options including advanced two-shaft and three-shaft designs, as well as open rotors. The Rolls-Royce Vision R&T programmes will feed innovative technologies into all future engine designs, including both conventional and open rotor prospects.

Incremental changes to gas turbine technology have yielded improvements in performance and reliability since the advent of the gas turbine, but, alongside improvements in traditional areas, the search for continuous reduction in cost and environmental emissions may require a departure from the boundaries of existing gas turbine architecture.

'More Electric' engines, such as the Trent 1000 for the Boeing 787, feature fewer compressor and turbine stages, and benefit from the elimination of the aircraft pneumatic system, together with significant simplifications in the aircraft-engine interface. Power is produced by generators embedded in the engine and, ultimately, it may be possible to completely remove the engine oil system.

Gas turbine technology, such as that which has made the Trent family so successful, is directly applicable to a power plant for a 250-to-300 seat aircraft flying at or near sonic speeds. Studies suggest that the engine cycle selected for such an application would differ to that which would be chosen for a similarly sized conventional subsonic aircraft, with a greater proportion of the energy being extracted from the core in order to satisfy climb and cruise considerations. This emphasizes the need for lightweight materials and high temperature capability in the compressor and turbine, and provides demanding requirements in terms of noise and emissions.

In years to come, whether airframe makers and customers demand step changes in gas turbine technology or leaps into new directions, it is likely that developments will be driven by a combination of economic and environmental conditions and technical feasibility. Whatever the future brings, the drive to provide value through innovative engineering solutions remains paramount at Rolls-Royce.

PRATT & WHITNEY CANADA

Pratt & Whitney Canada (P&WC) is helping to lead the green evolution in aerospace with a new generation of technologies and environmental stewardship across all facets of its business, outperforming even the most stringent ICAO standards.

Reducing the environmental impact of our products is a core value for P&WC. We are firmly committed to ensuring that our products are designed, produced and operated while minimizing environmental impacts throughout their life cycle.

Leveraging New Technologies

P&WC is leveraging new technologies, championing innovation and working closely with the industry to achieve specific goals.

Ongoing projects encompass:

- *Emissions:* Minimum fuel burn and Technology Affordable Low NO_x (TALON) combustion system for low NO_x.
- *Green Materials:* Materials of concern are avoided in the manufacturing process, many being replaced by safer alternatives and others now under research.
- *Materials:* Improve buy-to-fly ratios, reduce machining waste.
- *Reusability:* Recycling of alloys.
- *Suppliers:* Favouring green suppliers/partners in the supply chain.
- *Green processes,* e.g., reducing alkali cleaners/strippers, machine coolant.
- *Noise,* e.g., modified mixer/tab nozzle & fan case liner.

Today, we are a leader in developing low emission technologies:

- The PW307 is the "greenest" engine in its market, surpassing the most stringent ICAO standards (CAEP 4) for emissions (by 33 percent); our TALON 2 combustor technology also meets Zurich 5 requirements for no surcharges.
- As part of the 10K family demonstrator programme, P&WC have tested the next generation of TALON combustion system that will reduce emissions by up to 50 percent for nitrous oxide and 35 percent for carbon monoxide emissions, and will also achieve low, unburned hydrocarbons and smoke emissions.

The PW307A.

P&WC is also studying the impact of emissions during near-ground operation in the vicinity of airports as well as cruise emissions at higher altitudes. This involves participation in ICAO and other national/international working groups and performing environmental impact studies.

Major Achievements

The revolutionary TALON 2 combustion technology reduces emissions while delivering outstanding performance, durability and operating economics.

Through TALON 2 P&WC has achieved emissions reductions in the last 10 years, as follows:

- Leveraged Pratt & Whitney expertise and advances in low-emissions combustion systems, through TALON design.
- Launched technology demonstrator programme in 1999, for the PW300 engine family, using the PW308 engine core, to exceed ICAO requirements and reach Zurich 5 standard for no landing fee surcharges in specific European areas.
- ATFI core demonstrator, in 2004, was used to continue our progress in low NO_x technology and achieve a further reduction in NO_x for future applications.
- Progress made in recent years in computational fluid dynamics prediction, coupled with advanced fuel injector technology, allowed rapid progress to advance the fuel and air mixing necessary to control burning temperature and NO_x reduction.
- Continuous work has been done to improve cooling efficiency and gain in fuel-to-air mixture homogeneity, and thus gain better control in burning temperatures and NO_x emission.

Advanced cooling schemes and fuel injector concepts have been successfully tested in a sector rig in 2005 to demonstrate the potential to meet the expected ICAO requirements 10 to 15 years out.

These concepts and technologies are serving as a basis for the new-generation 10K pounds thrust engine.

Fuel Efficiency

With respect to fuel efficiency, P&WC has been conducting technology demonstration programmes to develop and test new component technology and materials. This aims to address ever-rising customer demand for engines to be significantly lighter, offer improved fuel consumption and be available at reduced costs.

Our new PW210 turboshaft engine, for example, boasts a significant reduction in fuel consumption over older generation models, offering customers reduced operating costs and lower landing fees at local airports.

In the last five years, P&WC has certified the PW307A, PW615 and PW610, all three of which meet aggressive fuel consumption design targets.

We are also developing new technologies for fuel efficient turboprop engines, which already have a marked advantage in reduced emissions.

Promising Technology

The most promising technologies for NO_x are from ongoing industry efforts to advance combustion systems. Pratt and Whitney Canada is continuing its development of TALON technologies. Up to 50 percent reduction in NO_x compared to original ICAO standards has been demonstrated. These latest technologies are now being incorporated into new engines being developed by P&WC, planned for certification in the 2011–2012 timeframe.

In the longer term, new technologies are being developed for reducing NO_x down to the 80 percent reduction level, benefiting from further combustion and engine performance improvements.

With respect to greenhouse gas emissions, in the short to medium term, improvements to engine fuel burn will significantly contribute to CO_2 reductions. P&WC has embarked on a demonstrator programme to improve fuel burn and NO_x emissions based on component performance improvements and advancement of the thermal management system in small engines.

Use of alternative (bio) fuels is also expected to contribute to greenhouse gas reductions in the long term.

Noise

P&WC's objective is to reduce cumulative noise levels by 10dB over the next 10 years. We are working with Canadian universities and the National Research Council to develop analytical tools for predicting noise levels generated within combustors and exhaust ducts. This project represents the only R&D effort of its type and size in Canada.

In design, we are optimizing engine cycle design for a low-noise signature and our current engine designs meet the most stringent standards (ICAO Stage IV).

Conclusion

As the No. 1 R&D investor in Canada's aerospace sector, P&WC is investing $1.5 billion in R&D and partnering with leading Canadian universities and research centres to continue building on our successes in this important area. ■

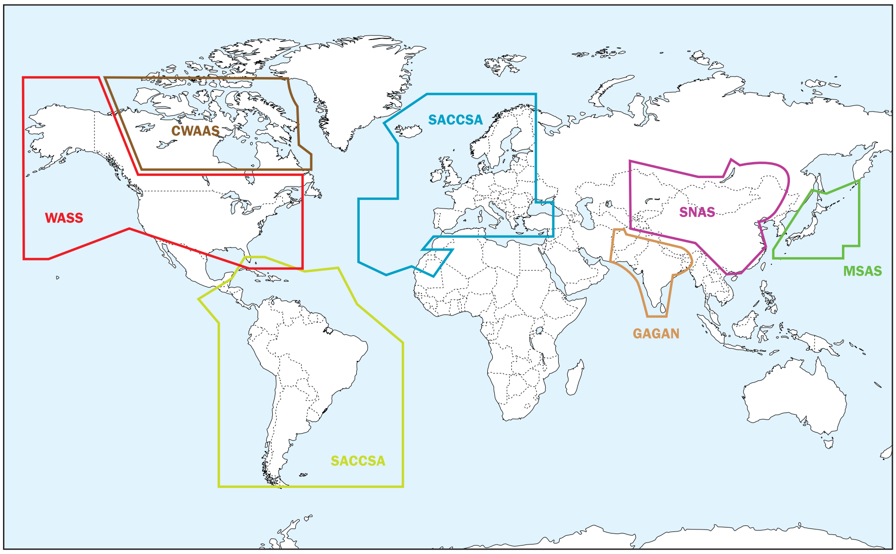
At work on the PW610 and 615.

Environmental Advantages of GNSS in the Aviation Sector

By Luis Andrada Márquez
Chief, GNSS Operations Department
Satellite Navigation Division, Madrid, Spain

Until the 1970s, air navigation was centered on the establishment of rigid routes based on movement from one fixed point to another. These points were fixed by NAVAIDs such as Non-directional Beacons (NDBs), VHF Omni Directional Range (VOR) and Distance Measuring Equipment (DME). The combination of assorted VORs and DME makes it possible to navigate from one point to another without having to pass by a concrete aid. This rendered airspace more flexible and enabled the creation of more direct routes. However, as VOR bearings are of an angular nature and DME suffers from low degrees of precision, it was not possible to truly open up routes and free them from fixed terrestrial elements. This meant that the design of route, departure and arrival procedures were optimized neither in terms of time nor fuel consumption.

Global Navigation Satellite Systems (GNSS) were the great leap forward the industry was looking for, making airspace fully flexible while optimizing routes and arrival and departure procedures. With the current increase in airline fuel prices and the growing alarm regarding greenhouse gas-induced global warming, GNSS has become a key tool providing win-win solutions for operators and environmental stewards. Also important is the emergence of the concepts of Required Navigation Performance (RNP) and Performance-Based Navigation (PBN), which serve to harmonize airborne and navigation system capabilities in order to obtain the maximum performance necessary in any operation.



The different systems which make up GNSS include augmentation mechanisms, both those which are based on Airborne Elements (ABAS) and External Augmentation Systems (SBAS and GBAS). In addition to improving the system's overall precision, these systems provide the basic building blocks for RNP operations. Several SBAS augmentation systems are now being developed, such as WAAS in the United States, EGNOS in Europe, MSAS in Japan, GAGAN in India, and SACCSA in the Caribbean, Central and South American regions.

In order to understand how ABAS and SBAS systems can provide solutions to today's fuel-derived economic and environmental challenges, we need to look at the departure, route, descent and arrival phases individually and asses the challenges each poses.

Departure

A flight's climb phase requires maximum engine power, meaning that even with GNSS assistance departure procedure fuel savings are minimal. However the flexibility, high precision and integrity of GNSS systems makes it possible to design departure procedures which avoid densely populated zones and lower noise impacts. This results in decreased annoyance of local populations and enables less local concerns over improvements such as runway expansion.

En Route

While the use of inertial systems and traditional NAVAIDs has long made it possible to fly optimum routes between two points, GNSS has enabled higher-precision navigation with consistent performance at all points, streamlining aircraft efficiency. The result is reduced separation between aircraft and an improved optimization of a given airspace. This is of particular importance for oceanic or long-haul routes where airlines vie for routes which best enable them to shorten flight times. Separation reduction allows for RNP 5 operations in isolated areas, descents from isolated areas in continental zones, and together with RVSM has made it possible to meet increased traffic needs while maintaining or improving safety levels.

The advent of ADS-B requires highly precise position reporting systems to meet the 10 second alert times now required, necessitating the use of GNSS and SBAS augmentation—although this matter is still currently under discussion.

Descent

Prior to the advent of GNSS and especially ADS-B tools, descents were performed gradually and with small but continuous changes made to the descent path power levels. The introduction of SBAS makes it possible to put the aircraft inside a "tube" which directs it to a given point and level in complete safety. The most obvious application enables an aircraft to perform a descent using minimum power by providing a continuous descent from the route flight level to the touchdown point on a virtual descent path of more than 150 miles. Obviously, this must be done in accordance with control capabilities and airspace restructuring to facilitate these applications, which also have an important impact on aircraft operations.

Arrivals

Fuel efficiency and greenhouse gas emission savings are highest during the arrival phase of a flight. Until now aircraft were required to go toward a point from which the ILS localizer and ILS glide path were intercepted in order to land. The trajectory plots to this point could seem haphazard at times, and different aircraft needed to adjust procedures in accordance with their respective characteristics and type.

The use of GNSS—especially when combined with SBAS and/or GBAS augmentation—makes it possible to establish precise approach paths. This optimizes airspace and reduces the noise footprint, resulting in benefits similar to those enjoyed during departure. It also makes it possible to adapt the procedure to the type of aircraft. This creates the possibility of establishing curved or segmented approaches which allow aircraft to be positioned at the optimum distance from the threshold according to their respective characteristics, which saves approach time. Runway capacity is also increased as lighter and faster aircraft can be placed before bigger aircraft with larger wakes.

Although total savings are clearly difficult to quantify, the combination of continuous descents and advanced, tailored approaches save an estimated and conservative average of five minutes per flight. Such savings would certainly have an impact on a global or regional basis—a saving which is further augmented when IATA's current one-minute initiative is taken into account.

GNSS thus results in reduced times for the various flight procedures and phases, significantly decreasing aggregate fuel consumption. It aids in optimizing power levels, which will significantly reduce greenhouse gas emissions and airline costs. SBAS- and GBAS-compatible GNSS receivers and corresponding FMS programming are required to ensure proper operation with these systems, while ATC services also have to adjust in order to adapt control procedures and airspace structure to the new capacities and the advent of ADS-B. Lastly, the design of SID/STAR procedures need to take into account the new possibilities available in order maximize efficiencies.

SACCSA

SACCSA is the name of Project RLA/03/902, the objective of which is to determine the technical and financial viability of implementing SBAS in the Caribbean and South American (CAR/SAM) region. A system architecture has been established which is adapted to this region. The ionospheric algorithms adapted to obtain minimum APV-I performance levels are now being studied.

These developments would make it possible to incorporate SACCSA into the network of SBAS systems currently in use and/or development in other regions of the world, such as WAAS in the United States, EGNOS in Europe, MSAS in Japan, GAGAN in India and SNAS in China. The resulting world SBAS map would thus look like much as it does in the graphic at the beginning of this article.

This would provide an SBAS system with a high degree of redundancy and integrity throughout wide continental areas of the world.

The initial results of the project have been very encouraging, making it possible to undertake the development of a laboratory model that will enable the real-time study of performance levels needing to be reached by means of the data collected in key locations of the coverage area. This will make it possible to analyze the correct functioning of the ionospheric models developed and the data process elements for SBAS navigation message generation.

This new project phase is to be completed in a 24-month period and it will let us know whether it is feasible to implement the system, giving the CAR/SAM States the necessary tools and information with which to make a decision regarding the implementation of SACCSA. ■

Unmanned but Still Human

By Capt. Thomas Mildenberger and Gideon Ewers, IFALPA

There is a conception that the state of electronics and automation has matured to the extent that the requirement for an onboard human intervention capability has declined such that it is no longer a requirement. This hypothesis is fundamentally flawed. The removal of an onboard pilot does not remove human failure from the safety equation.

This may seem a fairly significant assertion to make since aviation history is littered with the wreckage of accidents of aircraft manned and unmanned that were caused by human failures. How many times have we seen the phrase ‘pilot error’ in accident reports? Of course, deeper analysis often reveals that, while the final link in the chain may have been a human error in the cockpit, in fact the real failure may have been in training or operating procedures and related environments.

In the 1970s, before the days of cockpit resource management, two high profile crashes were the result of crews being distracted by warning lights and the resulting loss of special and situational awareness. More recently there was the loss of a B-Hunter UAV which resulted in the death of a woman on the ground. Analysis of the sequence of events revealed that the operating crew had, as a result of a loss of situational awareness, believed the aircraft to be on the ground and shut down its engine. The human element is therefore just as present in unmanned as manned aircraft.

Let’s take this assertion further. There have been a number of cases where human error has occurred earlier in the chain than the cockpit—for example during maintenance or perhaps even earlier as the result of a coding error by a software engineer during system development.

As an example of the first type of error, in 1995 an Embraer Brasilia operated by Atlantic Southeast Airlines was operating a routine flight when one of the propeller blades on its left engine separated. This led to an extreme imbalance and in turn, caused the affected engine to partially separate from its mounting. The resulting drag rendered the aircraft unable to sustain level flight, and, unable to reach any airport in the vicinity, the crew had no option but to make a forced landing in a farmer's field. Sadly a number of passengers and the aircraft's captain succumbed to the post-landing fire.

Investigation into the crash revealed that the primary cause was human error, but not by the flight crew. In this case the error was attributable to a technician who had worked on the propeller assembly when it had been overhauled some months before. Yet like the pilot errors discussed above the engineer's error proved to be not as a result of negligence, but rather poor training.

Using an example from the NASA space programme of the 1960s, man's first landing on the moon came within seconds of total failure because of a software coding error in the lunar module's guidance computer (incidentally, this example is also a good case for having a human in the cockpit: because of this and other guidance errors Neil Armstrong and Buzz Aldrin flew the approach in manually in the end).

The point here is that these errors and hundreds like them occurred because there is a potential for failure or error in any system. This of course is magnified with system complexity, and in aviation (manned or unmanned) we are dealing with extremely complex equipment and operating environments. Aircraft and equipment that have performed flawlessly for many years will, on occasion, produce failures that will have engineers and other technicians scratching their heads and remarking: "We've never seen THAT before".

Again, these issues could just as easily be found in unmanned as in manned aircraft.

What Can Go Wrong Will Go Wrong

The English have a phrase called Murphy's Law. Murphy's Law states that "what can go wrong, will go wrong". As we have seen, any aircraft or system developed will have flaws as a result of their human element. What can be done to mitigate the effects of Murphy's Law? Clearly, it is important to eradicate as many systemic failures as possible. Naturally, training has a vital role to play in the avoidance of error as does adherence to established and tested operating procedures, but what of the final bulwark against an accident; the ingenuity of the crew?

Let's begin with a caveat: the introduction and use of automatics in manned aviation has done much to improve air safety. In normal flight modes the autopilot will do a far superior job of 'flying' the aircraft, freeing the crew to focus their energies on managing the safe progress of the flight.

However, in the abnormal environment the human pilot comes into their own. As yet, synthesized systems are unable to deal with the rapidly evolving situation that may be the result of major system failure. The main thing that they lack is the ability to learn and reason—even when the cause of the learning is not necessarily reasonable. What is the point in learning a technique that you are 'never' going to use? Surely this is unreasonable?

Take this example of 'unreasonable' learning. Transport category aircraft are designed with multiple failure system redundancy but some failure modes are so radical that they are not possible to resolve. Take, for example, a total hydraulic loss in a large transport aircraft. Surely not a reasonable scenario to train for what with three fully independent systems and the availability of a back-up power source even if all engines were to fail? Think again. When a DC-10 lost all its hydraulics after an uncontained engine failure the crew were able to crash land the aircraft by using differential thrust and in the process saved the lives of 186 passengers and crew.

More recently the crew of a cargo flight hit by a surface to air missile, which caused their aircraft to lose all hydraulics, were able to regain control of the aircraft and land it safely using differential thrust. Perhaps the technique was not taught in the airline's training manual but it happened that the

Captain had, only weeks before, seen a documentary about the DC-10 incident above and applied the lessons he learned from watching the show.

While the events are still under investigation, it is extremely unlikely that the logic of an automatic system would have been able to achieve the successful forced landing by a 777 in January in London.

So it is clear that while undoubtedly automatics have their place in aviation safety, and indeed, it's a vital place, they are at present no match for the flexibility of the human operative's logic.

The Synthetic Element Downside

We often discuss the human factors element in flight safety. As a result, over many years of study, a mass of knowledge has built up which considers human performance, its abilities and limitations. This knowledge base is by no means complete and without flaw—how could it be? The human condition is a very complex one and the data was created with the human element! But even so, it remains a vital and hard won cog in the flight safety machine.

Errors, error causes and error results are explored in the present manned aviation environment to great degree. Much less is understood about errors in unmanned flying and the subject is almost completely unexplored in the field of hardware and software design—which naturally becomes more important when incorporating pilots' abilities into hardware or software.

Errors performed by an operator, pilot or ATC-controller may be 'captured' by a number of methods. Most error types are understood and many of them are alleviated through mitigation means: redundancy; procedures; warning systems; and hardware design elements.

But what about the software-designer? Isn't he or she a human as well as the pilot or controller? Don't they make mistakes like anyone else? To what extent is their working environment explored with respect to the possibility to avoid mistakes? Mistakes that show up much later; probably years later and certainly unexpected...

It is well known how complex the process of proving the robustness of software is against safety-critical failures. Even if it were possible, it is almost beyond financial possibility. The examples of failures of so-called safety critical 'intelligent' software are numerous. Until now, the operator—pilot or ATC-controller—has been used to isolate and capture most of these 'latent' errors. Obviously, in future unpiloted aircraft, a human will be involved somewhere in the chain, depending on the craft's level of achieved autonomy. But whether or not they will be in the right place at the right time and with the right amount of back-up information is an altogether different question.

There are extensive results available from studies on the value and/or importance of information derived from sensory stimuli. UAV pilots experience a partial deprivation of optical cues (their field of vision is limited by the scope of the onboard camera). And that is the good news! Compared with an on board colleague, the UAV pilot in their Ground Control Station (GCS) experiences total deprivation of the senses of sound and smell. In addition, they are unable to experience sensations of jolts or changes in velocity, of temperature or humidity changes—all of which may be early indicators of something amiss with the aircraft.

The onboard pilot will often note an uncommanded change of velocity 'through the seat of their pants' which will trigger a cross check of instruments in order to confirm a deviation ahead of beginning the solution process. They'll smell the smoke from a possible fire or hear the bang of an explosion—cues denied to the remote pilot.

> **"In the non-normal environment the human pilot comes into his or her own. As yet, synthesized systems are unable to deal with the rapidly evolving situation that may be the result of major system failure. The main thing that they lack is the ability to learn and reason—even when the cause of the learning is not necessarily reasonable."**

Like his cockpit counterpart, the UAV pilot suffers from all the shortcomings of being a human being yet is further denied the ability to use all their faculties to analyze and deal with an abnormal situation. As a result, they are hampered in the ability to use the upside of the human element because, as asserted earlier, it remains true that the human brain is yet to be matched operating in an ambiguous or unknown situation.

Generally speaking therefore, it might be this incredible flexibility of the human brain that is the ultimate tool in keeping aviation safe. ■

UNFCCC VIEWPOINT

Bringing Aviation Into Climate Change Agreements

Mr. Yvo de Boer, Executive Secretary
United Nations Framework Convention on Climate Change

Last year saw an incredible build-up of momentum, and a real jolt to societies around the globe, with the publishing of the Fourth Assessment Report by the Intergovernmental Panel on Climate Change. The Report proved beyond doubt that climate change is happening, that it is accelerating, and that much of it is caused by the continued and increasing emissions of greenhouse gases from human activities.

It also showed that—if we fail to come to grips with it—climate change will have devastating effects on economies, societies and eco-systems throughout the world, especially in developing countries. Not acting on climate change now will cost us dearly in the future.

This clear signal from science called for an equally clear answer from the political arena. At the UN Climate Change Conference in Bali last year, governments recognized that the world needs firmer international action on climate change. A two-year process was kicked off on the basis of this shared realization and these negotiations are set to be concluded in Copenhagen by the end of 2009.

The aim needs to be nothing less than a deal on stronger international climate change action that matches up to the crystal clear signal that we have all heard from the scientific community. This means that the rise in greenhouse gas emissions needs to be **stopped** over the next 10 to 15 years, and that global emissions need to be dramatically cut back by at least 50 percent by 2050.

All of the current trends now apparent from the transportation sector, however, fly in the face of what science tells us is needed. Between 1990 and 2004, emissions from transport-related activities grew a significant 25 percent based on aggregate accumulations. Of all the different categories within the transport sector, aviation accounted for the biggest share of this increase, with emissions from aircraft fuel burn having increased 50 percent since 1990. Bearing in mind the growth in international trade and travel, it is projected that this increase will continue over the coming decades.

As we all know, the emissions from international transport, including international aviation, currently do not fall under the Kyoto Protocol. The question therefore becomes: "How is international aviation going to contribute to the Copenhagen deal?" More specifically the industry needs to address to what extent any advances will be possible without a cap-and-trade approach. I am personally convinced that a carbon market represents the most promising option for aviation to cut back its emissions in a cost-efficient way.

One of the greatest achievements of the Kyoto Protocol is that it has put in place an incredibly valuable architecture—one that for the first time in history puts a price on carbon. It also provides an architecture that enables governments and businesses to seek out the most cost-effective options for reducing emissions on the global market through the use of three market-based mechanisms: emissions trading, joint implementation and the clean development mechanism.

The best news perhaps is that the carbon market works. In 2007 it was already worth $64 billion (US)—more than double its size in 2006. The Clean Development Mechanism accounted for $13 billion of this amount by allowing industrialized businesses to invest in low emissions projects in developing countries. These initiatives encourage ecologically-sound growth in these countries while at the same time helping developed countries to meet their commitments in a cost-effective way.

Through a 2 percent levy on CDM projects, the carbon market also feeds the Adaptation Fund, generating resources that are desperately needed to help developing countries adapt to the unavoidable impacts of climate change. Under a scenario with ambitious targets for industrialized countries, the CDM has the potential of spurring $100 billion (US) annually for green growth and adaptation in the developing world.

We are all aware of the criticism that the carbon market engenders and I admit that there might still be some imperfections which need to be addressed. But not putting a price on carbon would be an irresponsible continuation of the biggest market imperfection ever.

The world cannot solve the climate change challenge without the participation of international aviation. Especially now, in the run up to a new climate change deal in Copenhagen, it is crucial that discussions in ICAO and those in the UNFCCC are closely linked. I am confident that, through ICAO's unique mechanisms, aviation's leaders will rise to meet the call to action represented by the Copenhagen process. I encourage all States and stakeholders to strongly consider how a carbon market can help global aviation to set and achieve consensual and meaningful emissions control objectives. ■