How Green could Tomorrow's Aircraft be?

Climate Change, Environment and Aviation

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I am greatly honoured to be asked to give the 14th Govind Ballabh Pant Memorial Lecture at this Institute. This Institute is located in a beautiful part of our country in the foothills of the Himalayas – a location where preservation of the environment must be a major issue. I would like to take this opportunity to discuss one aspect of a question that has become a major global issue, especially in the last few years: I refer to the possibility of climate change and its impact on the world. As an aerospace scientist I would like to look at what impact recent studies on climate change have made or are going to make on aviation. Although civil aviation now contributes only about 2½% of the green house gas emissions that the atmosphere is experiencing, flying activities are set to grow especially in Asia, and the emissions they are responsible for in relation to climate change will undoubtedly affect the future of aviation.

But before looking at the impacts on aviation perhaps I should say a few words about climate change itself.

1 THE SCIENTIFIC PROBLEM OF CLIMATE CHANGE

The idea that an increase in carbon dioxide levels might actually affect climate has been scientifically known for long, and dates back to the work of the Swedish chemist Arrhenius in the late 19th century. But it was only around 1990 that a serious global collaborative effort on assessing the scientific problem of possible climate change and its likely impact were undertaken. We must on this occasion honour the pioneering efforts of such scientists as Sir John Houghton who began studies on climate change at a time when it was not taken seriously by the large majority of scientists, let alone political or economic leaders.

A key role in this effort has been played by the Intergovernmental Panel on Climate Change (IPCC), which shared the Nobel Prize last year with Mr Al Gore. An enormous amount of scientific research on the problem has now been carried out, and it is greatly to the credit of the IPCC that this has been done with extraordinary transparency and with the participation of a very large number of scientists from all parts of the world. The documents produced by IPCC once every five years or so have often involved 500 to 1000 scientists: every word in the document is reviewed and re-reviewed to make sure that the words used truly reflect the inevitable uncertainty in climate prediction, at the same time making the best possible estimates given today's scientific understanding of the effect of the projected GHG emissions on climate. From one point of view the uncertainty may not seem all that small. For example the predicted range of global temperature increase for a doubling of the carbon dioxide emission is quoted as 2-4.5° C, but even larger temperature increases cannot be ruled out. One interesting feature of the IPCC reports is that while the evidence for possible climate change has continued to become stronger, the range of uncertainties in the predicted temperature change has remained more or less the same. This intriguing feature of the prediction appears to be related to the positive feedback mechanisms that are responsible for the predicted change. Roe and Baker (2007 Science 318:629-632) have recently pointed out that dramatic changes in physical processes are not necessary for dramatic changes in climate sensitivity. If the changes in the processes are all in the same direction then increased sensitivity can result. To give an analogy, an accident may occur with a fairly large number of causes – none of them acting alone would cause the accident, but they can 'conspire', especially when they are all in an adverse direction, to result in the extraordinary accident. Many such instances are known, especially in the history of aerospace technology, and seem to be responsible for what is often called Murphy's law – namely that if anything can go wrong it will.

It is often asked how it is possible to even attempt to predict the climate, say hundred years from now, when we cannot predict rainfall even five days from now (sometimes not even over the next couple of days). However the nature of the climate prediction problem is different from that of the weather prediction problem. The dynamical factors that influence our climate over long periods of time are cumulative in nature, which makes it possible to discern trends even when accurate prediction at a given point and given time may not be feasible. To take an extreme instance, the skill in predicting the monsoons in India still remains poor, nevertheless we are virtually certain that it will rain next year. In his famous study in the 1960s Edward Lorenz introduced the concept of what came to be called chaos, and the inherent limits on the predictability of weather as a chaotic system. Predictions of climate are also subject to uncertainties, but because the dynamical factors are different the cumulative

uncertainties do not translate from the short term to the long term in some unambiguous way.

2 THERE ARE ETHICAL ISSUES

Whatever the uncertainties are regarding climate prediction, one thing is clear, namely that the problem we are now facing is global. Emissions of carbon dioxide in one part of the world are distributed across the globe by atmospheric circulation, which in turn may affect oceanic circulation as well. It is therefore entirely possible, and indeed very likely, that emissions in one part of the world affect climate in remotely distant parts of the world. Furthermore it is quite likely that all parts of the world will not necessarily suffer because of climate change. For example if temperature goes up, Antarctica or Siberia may suddenly grow habitable and more productive, agriculturally and in many other ways. Such changes have indeed occurred in the climatic history of our planet. Therefore not everybody is necessarily a loser. Furthermore some parts of the world – in our case the industrial world in particular – has been responsible for much of the carbon dioxide and other green house gas emissions that are now changing our climate. So, to put the question very bluntly, who should pay for the costs of climate change? Should the whole world have to bear the expense? Should the nations that are responsible for enhanced green house gas emissions be held to account on that ground? What about those emerging (really re-emerging) economies like India and China whose green house gas emissions are rapidly increasing, and may well become major contributors in the coming decades?

Furthermore, even if we can take immediate action on climate change its effect will not be felt for another few decades. It is not easy to foresee what might happen through that waiting period. There might for example be new technologies that will generate energy in completely environment-friendly ways. One likely candidate for such a source of energy, especially in India, is solar. I estimate that an area of the order of 100 km x 100 km – say in a part of the country like Rajasthan, is capable of delivering all the energy that India needs today at an efficiency of 10%, which is quite well achievable by today's technologies (projects in the research laboratories have already achieved about 40% efficiency). India has a very weak programme in solar energy, largely on the grounds that it is too expensive (which today is true). However oil prices are going up now, and it is entirely likely that in ten years time solar energy will be very competitive. Would it not be worthwhile for India to make a major investment in the development of solar technologies which, apart from being environment-friendly, could have many implications for our energy security?

The ethical issues come in because the time scales involved in climate change span several human generations. Any decision made today is a decision made for the next future generations. It is also a decision made where the sum of money invested in climate change-related projects will not be available for other causes. To be specific, let us consider the important work carried out by a committee chaired by (Sir) Nicholas Stern for the UK Government. This study considers in detail the economic consequences of climate change, as well as the economic policies on action that should be taken right now. Its major conclusion is that there is still time to avoid the worst of climate change if strong action can be taken now on a global scale. The Stern review estimates are based on the outputs of the different climate models and on the economic models that they have themselves used. The review concludes that if the world does not act the overall costs would be equivalent to not less than at least 5% of global GDP. If the wider range of risks is considered, it could be as much as 20% of GDP. On the other hand the cost of reducing green house gas emissions to avoid the worst impact of climate change, according to the Stern review, would be around 1% of global GDP each year, i.e. at current levels of the GDP of the world about US $ 45 B per year. So Mr Stern is recommending an expenditure of about US $ 45 B per year on climate change. This figure must be compared with the investments needed to provide 80% of rural population in Africa with access to water and sanitation by 2015; the costs are US $ 1.3 B per year. So how do we balance exactly where the money is to be invested, and whether the money should be used to prevent the effects of climate change or to prevent starvation and conflict in the world today?

The problem of taking action in the event of uncertainties is an ancient issue. It is a problem that has been considered at length by philosophers and poets for thousands of years. In India it is famously the central problem that for example the Bhagavad Gita and Mahabharata tackle. So was the war in Kuruksetra justified? In the Gita Krishna gives a variety of arguments on why the war was necessary. At the end of the war Yudhisthira says that if he knew that the war was going be so terrible, he would not have fought it at all. Nevertheless, in spite of the uncertainties of the effect of such major action, there are times when – I think this is the crucial point –the likely costs of not acting are far higher than the uncertainties involved in the effects of the action taken. If spending 1% GDP can save us through 5-10% of it later on, I think a large part of mankind would agree that spending 1% is worthwhile. It is in this sense that I think action on climate change has to be taken. The increasing convergence among different nations of the world on the necessity for action is I think a consequence of the perceived costs of inaction. And when we look at those costs we have to allow for the probability of catastrophic change or, as is often said in popular discussion of the subject, the possibility of reaching a tipping point past which the climate reaches a new equilibrium, which would be vastly different from the one that we have been used to. Once again the

history of global climate change suggests that the temperature rise that is now being talked about is similar to change that have occurred on earlier occasions and led to extraordinary changes in the climate of the planet.

3 AVIATION AND GHG EMISSIONS

In the last year or two there has been a tremendous interest in making aviation greener. The total contribution that global flying activities make to CO_2 in the atmosphere is of the order of 2-3% (AWST 26 May 08:64). This is actually a small fraction of the total, but to understand the growing concern about climate change in aviation circles it is necessary to appreciate the general scene today.

The most striking feature is that the centre of gravity of civil aviation is shifting eastwards. China and India are likely to make huge demands on the aircraft industry of the world. Airbus and Boeing are expected to deliver a staggering 1200 commercial aircraft per year for several years to come. The number of trips per capita in China and India still remain small, so the scope for expansion is huge. In particular domestic travel in these two large countries is bound to grow. In India we find that airports are congested, because they were built a time when flying was only for an extremely small section of the population. Given the expected growth in Asia the total air traffic in the world seems bound to increase in coming years.

From the position not too long ago when 70% of global civilian air traffic was within, out of or to the United States, we are rapidly moving to a position where North America, Europe and Asia will have roughly equal shares of air traffic in the world.

The other major characteristic of aviation that has become evident especially during the past year is the steep rise in the prices of oil. Fuel prices have tripled over the last four years. Aviation jet fuel, which cost $ 2 per gallon in May 2007, doubled to $ 4 per gallon in May 2008 at New York. Most airlines in the world (and virtually all airlines in India) are now making huge losses. This is of course partly due to the fact that oil is no longer cheap, but there are other reasons. Anticipating a boom huge investments have been made in new airlines in India and elsewhere, in Asia in particular, and the resulting competition has forced airlines to charge unreasonably low fares in spite of the increase in the price of oil. Furthermore, both the aircraft designs in use and the operating practices of the airlines reflect a global cheap-oil economy.

So the rise in oil prices and the fear of global climate change have suddenly made sustainable green aviation a matter of great urgency. The Green Aviation Forum is going to meet on 23 September 2008 in Madrid. Given these circumstances, we can ask what options do we have for making aviation greener? We can look at the action needed as demanding protection of the environment while maximizing the social and economic benefits of such action. This involves the airlines, the airports, air traffic management and the designers and manufacturers. Among these the quickest benefits are likely to come through air traffic management and airline operating practices. Those who fly in India know that air-space congestion is now very common at our airports. Travelling to Delhi from Mumbai or Bangalore, waiting for half-an-hour in the skies after reaching the destination is not at all uncommon – i.e. some 20% of the total time, and the fuel burnt during that time, is wasted trying to land. A similar loss occurs when one waits for take-off. Furthermore there are low-fuel options available for the take-off trajectory, but these are generally not adopted by the airlines in order to save time. The same thing is true of cruise. While some reduction in speed would save fuel, current airline practices prefer to fly faster rather than to save fuel.

Similarly there are practices in air traffic management that can cut down fuel costs. For example Europe is wrestling with the problem of integrating a variety of national air traffic management practices that characterize it now into something centrally agreed into a set of practices that save fuel, time and money.

Interestingly, although the airline industry as a whole is losing money, the world is not without airlines that are making money as well. In general in both North America and Europe the low-fare carriers have done better than the big legacy airlines, and have continued to make profits while some of the bigger airlines have even been on the verge of bankruptcy. Even among the bigger airlines some have done well, like the Air France-KLM combine and Lufthansa. There are therefore measures that airlines can take that can render them economically profitable even under the present difficult conditions.

If air traffic continues to grow, especially in Asia, new and bigger airports will be needed. If we want to make a significant change in physical connectivity in India we need many more airports, and some of them in what we have till now considered to be small towns. Even the industrialized nations need bigger airports and are taking action to establish them. Germany recently constructed a new airport in Munich. The British want to expand Heathrow with a third run-way but the environmentalists have been making vigorous protests against it.

A long term gain can only come from newer aircraft designs. One major initiative concerns the possible use of alternative fuels. This has the twin advantages of fighting against oil prices and offering stronger protection of the environment. Among the candidates for such alternative fuels are synthetic fuel using a gas-to-liquid process, already tested by Airbus (37% GPF to 63% Jet A1). Boeing is experimenting with biomass-to-liquid fuel. South African Airways have been flying for many years with synthetic coal-to-liquid jet fuel. The American Society for Testing Materials has recently approved 100% synthetic jet fuel for aircraft engine use. Although gas-to-liquid fuel does not reduce CO_2 emissions, it does reduce particulates. Qatar Airways is going to use 5-GT Balance by 2009. Many airlines would probably change fairly quickly to such new fuels if appropriate standards for the fuels were approved by the different national regulatory agencies. Here again action by an international standards agency would greatly help.

Meanwhile biofuels including hydrogenated vegetable oils are already being considered by industries like Airbus. Such oils have a smaller carbon footprint because they are less energy intensive in manufacturing. Airlines in India must start experimenting with bio-fuels from Pongamia and Jetropha.

The other big change could be a return to the use of turboprop aircraft or such modern alternatives as open rotors. Turboprops were fairly common in India till about twenty years ago, when the HS748 and the Fokker Friendship were familiar at our airports. But over the last few decades most turboprops have disappeared from the skies of the world, partly because they were slower and partly also because they were seen as noisier and less comfortable than jet aircraft. However the ATR is now flying on regional routes in India, and more modern designs could make the turboprop an attractive proposition. NAL has begun designing a 70 passenger turboprop aircraft known as the RTA-70.

Apart from these initiatives better aerodynamic designs and the use of several drag reducing agencies including riblets, compliant surfaces, micro-jets, boundary layer suction etc., which are known to be technologically feasible, have till now not been pursued with vigour because of operational complexity or because the returns on investments were not commensurate. These arguments however are becoming irrelevant as oil prices have gone up substantially. Lighter structures made of carbon fibre would also save fuel. The newer civilian aircraft are beginning to use more carbon than aluminium. So there has been a silent revolution in the materials that are used in the airframe.

Dirigibles are also beginning to make a come back. A company called World Wide Aeros in the US is designing what it calls airscraft which uses gas buoyancy and thrust vector control in addition to some aerodynamic lift on a specific niche in the aviation market. It will fly at 12,000 ft with 28 passengers at a cruise speed of 120 km and a range 3100 nautical miles. It may turn out to be particularly attractive as a cargo aircraft.

But all of these schemes will operate only if aviation becomes a sustainable activity. Among the measures being devised to research environment-friendly technologies is the scheme of the European community, which wants Airbus to pursue the target of halving CO_2 – by 2020. There is the Emissions Trading Scheme, in which operators who emit less CO_2 into the atmosphere will be able to 'sell' their performance to airlines which are not so environment friendly. In other words, 'carbon credits' can be bought and sold. Such measures can provide effective economical incentives that will help develop new technology and will also result in progress in these matters.

4 CONCLUSION

In conclusion, it is necessary to take action on climate change in spite of the uncertainties associated with prediction of climate. Among the many courses of action, major initiatives are needed to encourage solar and biomass-based energy sources. This needs promotion of R&D and the institution of economic incentives to develop alternate sources of energy. Although aviation contributes less than 3% of the CO_2 in the skies, there are active programmes to promote green aviation, because the boom in the re-emerging Asian markets can enhance global GHG emissions. These programmes are likely to help in controlling climate change to some extent.