THE U.S. STRATEGY FOR TACKLING AVIATION CLIMATE IMPACTS

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Abstract

The effects of aircraft emissions on the current and projected climate of our planet may be the most serious long term environmental issue facing the aviation industry. The climate impact drivers are increasingly urgent, with actions (e.g. cap and trade schemes, CO_2 emissions standards) to mitigate impacts are being introduced or contemplated throughout the world.

The elements of the U.S. strategy to reduce aviation's climate impacts are: better scientific understanding and integrated analyses; clean and energy efficient aircraft technologies; aviation alternative fuels; clean and energy efficient operational procedures; and policy, environmental standards and market-based options. Goals include mid term carbon neutral growth and long term absolute reductions.

1. Introduction

Aviation contributes more than $1.2 trillion each year to the U.S. economy and supplies more than 1 million high paying jobs. Aviation moves people and products all over the globe -- quickly and safely. Aviation contributes to our quality of life -- allowing us to visit friends and relatives, to travel, to experience new places, and to connect the regions of the world. However, these benefits are accompanied by noise and emissions and their environmental impacts. Aviation emissions affect surface air quality and earth's climate. Aviation contributes ~3% of global CO_2 emissions; this contribution may grow to 5% by 2050 [1].

For sustained mobility, aviation must have a reliable, affordable, and environmentally-sound energy supply as well as an effective and balanced approach to simultaneously address aviation noise, air quality, and climate change impacts in an integrated and cost-beneficial manner. Despite the current market volatility, the long-term trajectory of aviation growth has not changed. The effects of aircraft emissions on the current and projected climate of our planet may be the most serious long term environmental issue facing the aviation industry. The climate impact drivers are increasingly urgent, with actions (e.g. cap and trade schemes, CO_2 emissions standards) to mitigate impacts being introduced or contemplated throughout the world.

The U.S. is pursuing an ambitious strategy to tackle aviation's climate impacts. Goals include at least 2% overall system efficiency improvements per year, carbon neutral growth from a 2005 baseline by 2020 and absolute reductions in greenhouse gas emissions by 2050. However, emissions reductions cannot be tackled in isolation from other environmental impacts. There are not only environmental tradeoffs and interdependencies, but also economic consequences associated with each solution designed to mitigate environmental impacts. There is a need for a multi-faceted approach as there is not one solution that can alone address all aviation environmental concerns. Given the parallelism between the expected long-term growth of the aviation system and the associated environmental impacts, well-informed optimal and cost-beneficial solutions are needed to deliver an energy efficient and environmentally friendly aviation system. Also, there are different levels of benefits that can be realized from various solution sets despite similar dedicated levels of effort and resources.

Under the auspices of its efforts to develop the Next Generation Air Transportation System (NextGen), the U.S. has adopted a five-pillar strategy to effectively address aviation environmental impacts. In an iterative manner, this strategy is designed to characterize issues and problems, develop well informed solutions and manage these solutions to meet environmental targets in a verifiable manner. The elements of this five-pillar strategy are: (1) better scientific understanding and integrated noise, emissions, and fuel efficiency analyses; (2) advancement of clean, quiet, and energy efficient aircraft technologies; (3) development and demonstration of sustainable aviation alternative fuels; (4) development and implementation of clean, quiet, and energy efficient operational procedures; and finally (5) policy, environmental standards and market-based options. A conceptual depiction of how each of these strategies could contribute toward meeting the mid and long term goals is shown in Fig. 1.

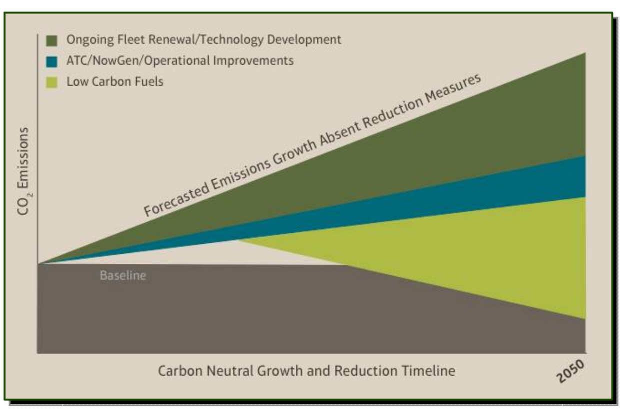

Fig. 1: Conceptual Strategy for Tackling Climate Impacts of Aviation.

This paper outlines progress on each strategy toward meeting the environmental goals.

2. Better Scientific Understanding and Environmental Analysis

Characterization of the problem and comprehensive analysis of tradeoffs and interdependencies of aviation as an integrated system is critical so that appropriate targets for environmental goals and well informed cost-beneficial solutions can be developed and implemented. Even though noise and emissions originate from the same aircraft source, their related environmental and human welfare impacts are distinctly different. There are also various levels of uncertainties associated with each impact. Therefore, it is important to characterize these impacts and develop corresponding metrics, including approaches to interrelate various impacts.

Aviation climate impact is the area of fastest growing concern and largest uncertainty. The Federal Aviation Administration (FAA), with support from the U.S. Global Change Research Program and its participating federal agencies (National Aeronautics and Space Administration (NASA), National Oceanic and Atmospheric Administration (NOAA), Environmental Protection Agency (EPA) and Department of Energy (DOE)) has developed the Aviation Climate Change Research Initiative (ACCRI) with a goal to advance scientific understanding for well-informed decision-making. The ACCRI program is designed to understand and quantify regional and global climate impacts of aircraft emissions with quantified uncertainties for current and projected aviation scenarios under changing atmospheric conditions. Another key focus of ACCRI is to develop and evaluate metrics relating various non-CO_2 climate impacts as well as impacts of CO_2.

With scientific input from national and international aviation climate change experts, as discussed in the ACCRI "Way Forward" report and subject specific White Papers [2], the

ACCRI program embarked on the next step of its activities. Under a multi-year program, eight teams of international researchers were recently selected through a competitive process in the Fall of 2009 to support aviation climate change research, which will be used to inform decision-making. The FAA formed an ACCRI Consortium by linking ACCRI and Partnership for AiR Transportation Noise and Emissions Reduction (PARTNER) climate research activities. PARTNER is a leading aviation cooperative research organization and a Center of Excellence sponsored by FAA, NASA and Transport Canada. Currently, the ACCRI Consortium consists of 47 research experts from 25 national and international institutes conducting 10 aviation climate research projects.

The thrust of the ACCRI program is distinctly different from that of other climate impact studies involving aviation. The scope of the ACCRI Consortium spans a range of activities which include laboratory measurements, atmospheric observation data analyses, atmospheric and climate simulations using chemical transport and general circulation models, and model-data intercomparison analyses. The ACCRI program will assess the aviation climate impacts within the interactive atmospheric modeling system framework considering dynamical, radiative, chemical and microphysical feedbacks. These feedbacks modify not only the magnitude of aviation climate impacts but also those due to background atmosphere.

In addition to ACCRI, the FAA and PARTNER continue to develop a comprehensive suite of models, comprising of the Environmental Design Space (EDS), the Aviation Environmental Design Tool (AEDT) and the Aviation Portfolio Management Tool (APMT). The Tool Suite is shown in Fig. 2 and described in more detail at the FAA website [3]. These tools are being used to evaluate existing and expected future advanced aircraft technologies, develop reliable estimates of full flight fuel burn, develop inventories of aviation noise and emissions at the source level, and perform integrated analysis of aviation environmental impacts.

The Emissions Prediction and Policy Analysis (EPPA) tool for aviation is also added to this Tools Suite. The EPPA model was developed by Massachusetts Institute of Technology to provide projections of world economic development and emissions along with analysis of proposed emissions control measures. Currently, it is being modified for aviation specific analyses.

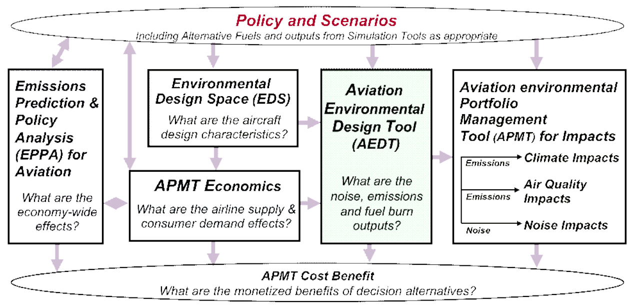

Fig. 2: Schematic of FAA/NASA/TC Tool Suite

For the first time, the AEDT was used to develop an integrated inventory of noise and emissions at the source level in support of the work program of the International Civil Aviation Organization Committee on Aviation Environmental Protection (ICAO/CAEP). The U.S. used the Tool Suite to better inform its position on appropriate levels of stringency for nitrogen oxide (NOx) emissions considered at the 8th meeting of CAEP in February, 2010. In addition, these aviation environmental analysis tools are being used to conduct environmental analyses for NextGen and to support research on emerging aircraft technologies.

Comprehensive assessment is integral to the development of these tools not only for transparency, but also to establish confidence in performance, credibility, and operational efficiency. Once fully mature, the integrated suite of these tools will be capable of characterizing and quantifying environmental impacts of aviation, including noise and emissions, on health and welfare, industry and consumer costs. Moreover, these tools will also assess the associated environmental benefits resulting under different policy, technology, operational, environmental standards and market-based scenarios. Ultimately, we are advancing understanding, and applying the best knowledge to seek solutions now.

3. Advancement of Aircraft Technologies

Progressive advances in engine and airframe technologies have traditionally been instrumental in reducing the aircraft noise and emissions at the source level and increasing aircraft fuel consumption efficiency. To accelerate maturation of promising clean, quiet, and energy efficient aircraft technologies from Technology Readiness Levels (TRL) 3-4 to TRL 6-7, the FAA has recently launched the multi-year Continuous Lower Energy, Emissions, and Noise (CLEEN) technology program.

The CLEEN program approach uses previously successful government/industry partnering efforts as a model, such as the Boeing Quiet Technology Demonstrator (QTD) programs. Selected airframe and engine noise reduction technologies, some of which were funded by the FAA through NASA, were flight tested under the QTD and QTD2 programs in the early 2000s. Technologies demonstrated under the QTD programs have been incorporated into Boeing product designs, including the 787, significantly reducing the time to commercialize the technology.

The CLEEN program focuses on maturing and demonstrating aircraft and alternative jet fuel technologies to accelerate commercialization of these technologies into current and future aircraft.

Specifically, CLEEN goals include:
1) Developing and demonstrating certifiable technologies that:

- Reduce aircraft fuel burn by 33% relative to current subsonic aircraft technology;
- Reduce nitrogen oxide (NOx) emissions by 60%, over the ICAO standard adopted in 2004 (CAEP/6);
- Reduce cumulative noise levels by 32 decibels, relative to Stage 4 standards.

2) Determining the suitability of new technology for engine and aircraft retrofit to accelerate penetration into the commercial fleet.

The CLEEN program is also developing and demonstrating use of “drop in” alternative fuels in aircraft systems and quantifying their environmental benefits. These are discussed in the next section.

The goals of the CLEEN program are consistent with the near–term (less than five years) U.S. National Aeronautics Research and Development Plan goals for environment and energy [4]. This effort is complemented by NASA’s technology programs, most notably the recently launched Environmentally Responsible Aviation (ERA) project.

This year the FAA awarded five-year agreements to Boeing, General Electric, Honeywell, Pratt & Whitney and Rolls-Royce. These companies will match or exceed all Federal dollars in this cost-sharing program. The total Federal investment is expected to be $125 million, making the total expected overall value of efforts at least $250 million.

Fig. 3: Sampling of CLEEN Technologies

Technologies to be developed and demonstrated under CLEEN include lighter and more efficient gas turbine engine components, low NOx combustor, noise reducing engine nozzles, adaptable wing trailing-edges, open rotor and geared turbofan engines, advanced onboard flight management systems for optimized flight trajectories, and sustainable alternative aviation fuels.

The FAA will review technology assessments conducted by the CLEEN companies as the selected technologies are demonstrated. In addition, the U.S. Government will conduct independent assessments of CLEEN technologies using the EDS modeling tool. CLEEN technologies will be modeled within EDS on representative aircraft classes to estimate reductions in fuel burn, emissions and noise, and assess fleet-wide impacts. Significant interactions among the technologies will also be evaluated. This approach should identify the best technology combinations to meet CLEEN goals.

Some of the technologies being pursued under CLEEN are closer to commercialization than others. Once technologies are demonstrated in a full-scale engine test and/or flight test, companies will continue technology development. They may insert technology into new products that are already planned for entry into service or prepare the technology for retrofit on aircraft already in service. Not all technologies developed under CLEEN will be suitable for retrofit, but Government and industry will identify those most suitable. Some CLEEN technologies are expected to be commercialized beginning in 2015 and continuing through 2017. Application of some technologies will only be possible in the next generation engines and/or aircraft, the timing of which will be driven by market demand.

4. Sustainable Aviation Alternative Fuels

Sustainable alternative fuels development and deployment offer prospects for enabling environmental improvements, energy security and economic stability for aviation. Other improvements in aircraft/engine technology, operational procedures, and enhancements in the national airspace system (NAS) alone will not be sufficient to allow us to achieve our goal of carbon neutral growth by 2020 and further reductions by 2050. Breakthroughs in sustainable alternative aviation fuels are key to meeting this goal.

The FAA, the Aerospace Industries Association (AIA), the Air Transport Association of America (ATA), and the Airport Council International-North America (ACI-NA) have jointly formed the Commercial Aviation Alternative Fuels Initiative (CAAFI, www.caafi.org). CAAFI seeks energy security and environmental sustainability for aviation by promoting the development of alternative fuel options that offer equivalent levels of safety and compare favorably with petroleum-based jet fuel both on cost and environmental footprint. CAAFI, as a coordination forum for aviation alternative fuels activities, represents a global public/private coalition of all leading stakeholders in the field of aviation working to build relationships, share and collect data, identify resources, and direct research, development and deployment of alternative jet fuels.

CAAFI participants advance alternative jet fuels via collaborative work on four panels:

(1) Research and Development -- accelerates efforts to advance feedstock and conversion processes to increase the range of fuel options, reduce cost, and increase quality;

(2) Environment -- ensures environmental sustainability of alternative jet fuels via quantification of "well to wake" greenhouse gas lifecycle and air quality impacts;

(3) Business and Economics -- enables aviation as a "first mover" user of alternative fuels by supporting production and deployment of new fuels; and

(4) Certification and Qualification -- enables supply of alternative jet fuels by expediting new fuel certification.

CAAFI and all four panels meet multiple times annually to address critical needs essential to the development and deployment of alternative fuels in aviation and update discipline specific roadmaps which serve as a means of communication among stakeholders.

The FAA is presently funding a number of projects through PARTNER to characterize the emissions of alternative fueled engines and auxiliary power units, to investigate greenhouse gas life-cycle analysis for a range of alternative fuels, and to explore options for "drop-in" and "renewable" aviation alternative fuels and their production outlook. [5, 6] Generally, all alternative fuel options examined appear to reduce particulate matter emissions – which are responsible for the majority of human health impacts attributable to aviation emissions. Renewable options that use oil, sugar or cellulose from plants may dramatically reduce life-cycle CO_2 emissions, depending on processing approaches and land use considerations.

As noted above, the CLEEN program also comprises a component focused on advancing alternative aviation fuels including support for qualification and certification, engine and flight demonstrations and environmental analysis.

The CAAFI Certification and Qualification team is focused on quantifying and certifying aviation alternative fuels, particularly "drop in" candidates that can replace existing petroleum derived jet fuels with no equipment modification. CAAFI leadership helped facilitate the new ASTM International synthetic fuel standard, D7566, "Aviation Turbine Fuel Containing Synthesized Hydrocarbons". This initial version of the specification enables commercial use of fuels from the Fischer-Tropsch (FT) process up to 50 percent blended with conventional Jet A fuel. FT fuels can be generated from a variety of feedstocks, including biomass, natural gas, coal and combinations thereof. The FT approval will be followed by the approvals of hydroprocessed renewable Jet (HRJ), also known as Bio-SPK, and other sustainable alternatives as data from technical evaluations is obtained. CAAFI partner The Boeing Company delivered an ASTM required research report on the HRJ fuels in December 2009. This report, and other data being gathered, will support the incorporation of HRJ fuels into the ASTM D7566 specification by 2011. Other fuels are expected to follow.

Commercialization of sustainable alternative fuels is challenged by both feedstock supply and a dearth of investment capital. The CAAFI Research & Development team is working with the U.S. Department of Agriculture to develop a Feedstock Readiness Level (FeRL) tool that can be used to communicate the stage of development, availability and sustainability of various biofuel feedstocks. This tool will complement CAAFI's previously developed Fuel Readiness Level (FRL) gated risk management scale that applies technology readiness level (TRL) and manufacturing readiness level scales commonly in use by NASA, industry and the Department of Defense (DoD) to alternative jet fuels. The FRL is useful shorthand for communicating the stage of development and risk areas for specific alternative jet fuel options to researchers, fuel users and investors. [7]

In early February 2010 the White House Biofuels Interagency Working Group – co-chaired by the Secretaries of the United States Department of Agriculture (USDA), DOE, and EPA Administrator -- released "Growing America's Fuel" a report that, among other things, recognized the importance and priority of aviation biofuels as an element of a new U.S. Government strategy for meeting or exceeding the country's biofuel targets. The report recommends a concerted effort to secure purchasing commitments from the military and airline sector to stimulate biofuel production. In March 2010, DoD's Defense Energy Support Center and the Air Transport Association of America responded with the signing of a Strategic Alliance for alternative jet fuel purchasing. This collaboration, combined with detailed fuel purchasing negotiations currently underway between a number of alternative fuel producers and airlines, has created a robust signal to the market of the intent of the aviation sector to be a primary purchaser of sustainable alternative fuels.

5. More Efficient Air Traffic Management

Improvements in aviation operational procedures may offer near term ways to meet aviation environmental and energy efficiency goals. The development and integration of clean and quiet operational procedures will foster a more efficient air space system and reduce fuel use while reducing noise and emissions.

The FAA is working with national and international stakeholders to coordinate and advance aviation environmental and energy efficient operational procedures and initiatives. The scope of the effort is gate-to-gate (surface optimization, departure/arrival, en-route, and oceanic), and the goal is a more systematic approach to address critical environmental operations research needs and development of a research plan. To date, the FAA has sponsored research and demonstrations in each of the flight segments identified above. The Operations Research Roadmap will focus on near-term exploration and significant demonstration of clean and quiet operational procedures. [8]

The FAA continues to support efforts to implement Continuous Descent Arrival/ Optimal Profile Descent (CDA/OPD) or Tailored Arrivals procedures at both high and low density airports beyond LAX, ATL, MIA, Louisville, Phoenix and Salt Lake City airports. In particular, CDA procedure has been implemented at the Charleston (CHS) International Airport. The estimated per flight fuel savings for a full tailored arrival is on average 617kg.

Efficiencies beyond terminal operations are also being pursued to include surface traffic movements and en route operations management. For example, under the International Air Traffic Interoperability (IATI) program comprising of Atlantic Interoperability Initiative for Reduced Emissions (AIRE) and the Asia and South Pacific Initiative to Reduce Emissions (ASPIRE), demonstrations are being expanded to investigate and demonstrate potential efficiency enhancements. Additional investments will further explore and demonstrate new capabilities. Coordinated decision-making through comprehensive automated systems communication/data networking of surface movement/en route/terminal domains will be vital for total “gate-to-gate” fuel efficiency. Additional international partners and participants are being added to realize the environmental and performance benefits under both AIRE and ASPIRE initiatives.

The efforts are showing real savings. A Boeing 777 flying from Auckland to San Francisco using CDA burned approximately 1,200 gallons less fuel. A Boeing 747 flying from Sydney to San Francisco saved approximately 1,600 gallons of fuel. Fuel savings directly translate to CO_2 savings. The ASPIRE demos showed the potential to reduce CO_2 emissions by 1.8K metric tons, which is about the equivalent of removing 336 passenger cars from the roads.

6. Market Based Measures and Environmental Standards

Penetration of advanced technologies and sustainable alternative fuels and better management of the air space system along with implementation of improved environmentally efficient procedures provide an effective basket of measures to meet aviation environmental goals and a secure energy future. However, market-based measures, noise and emissions specific environmental standards and regulatory policies are also important considerations.

As the fifth and final pillar of its environmental strategy, the U.S. is currently engaged in analyzing the effectiveness of various market and regulatory-based policy options. We are working through ICAO/CAEP to establish an aircraft CO_2 standard. This was the highest priority identified at the 8^{th} meeting of CAEP in February 2010. Though challenging, we are focusing our resources and working diligently with international partners to meet the challenge to establish this standard by 2013. For example, the FAA is supporting a project through PARTNER to investigate possible metrics for aircraft CO_2 standards [9].

The FAA is also supporting research through PARTNER to investigate various aspects of Cap and Trade as a market and regulatory option to limit aviation related greenhouse gas emissions within the context of emissions from all other anthropogenic sources. This project will develop methods to examine policies designed to limit greenhouse gas emissions and to estimate their effects on aviation economics and on emissions from aircraft. This study applies APMT and the EPPA model for underlying analyses.

Implementation, management, and verification of environmental mitigation solutions are all critical to ensure maximum intended benefits are realized to meet environmental goals and targets. Therefore, the FAA is developing and implementing a NextGen Aviation Environmental Management System (EMS). NextGen EMS is necessary to quantify impacts, measure progress towards meeting the aviation environmental goals and targets and to enable mitigation solutions and ensure their effectiveness.

7. Summary

The U.S. places great value on economic development to provide the greatest opportunities to all our citizens and the citizens of every country – and aviation is critical to this development. Our President, our Secretary of Transportation and our FAA Administrator also place environmental performance as a national priority. We believe that it is possible to do both. For example renewable energy and green technologies are key to simultaneously addressing the co-issues of climate change, energy security, global economic development, poverty, employment, sustainability and achieving the Millenium Development Goals.

The programs we have in place will allow us to achieve NextGen environmental and mobility goals. Given the complexity of aviation as an integrated system with associated tradeoffs and interdependencies, there is no single solution to mitigating aviation's climate impacts. Therefore, the U.S. is pursuing a mix of solutions ranging from advanced quiet, clean, and energy efficient aircraft technologies and alternative jet fuels, to implementation of environmentally-friendly operational procedures and market measures. All of these solutions are needed to mitigate aviation environmental impacts.

8. Contact Author Email Address

For further information about the topics presented herein, the reader is directed to the email below:

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