Report to the United States Congress

AVIATION AND THE ENVIRONMENT

A National Vision Statement, Framework for Goals and Recommended Actions

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Alan Schein/CORBIS

1.0 Executive Summary

Aviation is a critical part of our national economy, providing for the movement of people and goods throughout the world, enabling our economic growth. In the last 35 years there has been a six-fold increase in the mobility provided by the U.S. air transportation system. At the same time there has been a 60% improvement in aircraft fuel efficiency and a 95% reduction in the number of people impacted by aircraft noise.

Despite this progress, and despite aviation's relatively small environmental impact in the United States, *there is a compelling and urgent need to address the environmental effects of air transportation.* Because of strong growth in demand, emissions of some pollutants from aviation are increasing against a background of emissions reductions from many other sources. In addition, progress on noise reduction has slowed. Millions of people are adversely affected by these side effects of aviation. As a result of these factors and the rising value being placed on environmental quality, there are increasing constraints on the mobility, economic vitality and security of the nation. Airport expansion plans have been delayed or canceled due to concerns over local air quality, water quality and community noise impacts. Military readiness is challenged by restrictions on operations. These effects are anticipated to grow as the economy and demand for air transportation grow. If not addressed, environmental impacts may well be the fundamental constraint on air transportation growth in the 21st century.

Immediate action is required to address the interdependent challenges of aviation noise, local air quality and climate impacts. Environmental impacts may be the fundamental constraint on air transportation growth in the 21st century.

The concerns extend well beyond American shores. For example, within the European Union (EU) the climate impacts of aviation are identified as the most significant adverse impact of aviation, in contrast to the United States and many other nations where air quality and noise are the current focus of attention. As a result, there are increasing EU calls for regulation—trading, taxes and charges, demand management and reduced reliance on aviation—even though there is large uncertainty in the understanding of the climate effects of aircraft and appropriate means to mitigate these effects. Despite the importance of this issue, the United States does not have a significant research program to assess the potential impacts of aviation on climate. This may put the United States at a disadvantage in evaluating technological, operational and policy options, and in negotiating appropriate regulations and standards with other nations. The international concerns will continue to grow with the strong increase in air transportation demand anticipated for Asia.

Immediate, focused action is required to address the interdependent challenges of aviation noise, local air quality and climate impacts. Not acting, as stated above, will not only affect millions of Americans living near airports but will adversely impact the vitality and security of our nation. A national vision and strategic plan of action are required.

This document reports the results of a study mandated by the United States Congress in December 2003 as part of the *Vision 100–Century of Aviation Reauthorization Act* (H.R. 2115, Public Law 108-176). Section 321 of the legislation mandates that the Secretary of Transportation, in consultation with the Administrator of the National Aeronautics and Space Administration, shall conduct a study of ways to reduce aircraft noise and emissions and to increase aircraft fuel efficiency. Fifty-nine stakeholders from 38 organizations spanning the aerospace industry, the National Aeronautics and Space Administration (NASA), Federal Aviation Administration (FAA), the Environmental Protection Agency (EPA), the Department of Commerce (DOC), the Department of Defense (DoD), academia, local government and community activists, participated in formulating the recommendations in this study.

Collectively, the stakeholders who participated in this study propose the following National Vision for Aviation and the Environment:

A National Vision for Aviation and the Environment:

In 2025, significant health and welfare impacts of aviation community noise and local air quality emissions will be reduced in absolute terms, notwithstanding the anticipated growth in aviation. Uncertainties regarding both the contribution of aviation to climate change, and the impacts of aviation particulate matter and hazardous air pollutants, will be reduced to levels that enable appropriate action. Through broad inclusion and sustained commitment among all stakeholders, the US aerospace enterprise will be the global leader in researching, developing and implementing technological, operational and policy initiatives that jointly address mobility and environmental needs.

Reducing significant aviation environmental impacts in absolute terms is a challenging goal, especially when considered in light of the projected growth in aviation traffic. While in some areas absolute reductions are already being achieved (e.g., the reduction in the number of people exposed to significant levels of aircraft noise), these reductions will be difficult to sustain as traffic grows. Further, there are areas (such as NOx emissions) where technological improvements and operational procedures combined have not been enough to offset the increase in emissions associated with traffic growth. Accordingly, the vision statement is aspirational. To achieve the vision, immediate and sustained public and private commitment to investment, experimentation, communication, feedback and learning at local, regional, national and international levels is required. Such action will provide both near-term and long-term benefits. Throughout the process of realizing this vision, there must be careful attention to fostering distributed leadership, responsibility and burdens among all stakeholders. A plan of action to bring this vision to reality is the main thrust of this report. Development of the Next Generation Air Transportation System (NGATS) offers an opportunity to implement the recommendations made in this report; the plan for NGATS should address both the funding sources and levels required to do so.

Within the United States there are hundreds of organizations and groups (federal, state, local, aerospace industry, and community groups) whose principal focus is aviation noise and emissions. The participants are dedicated to their charge and, when focused, can be very effective in bringing about change. However, in general, the activities of these organizations are not well coordinated, and acting independently they are not likely to alter our national path in a substantive manner. To become more effective, organizations must better coordinate their activities. The development of a new paradigm for organizational interaction and coordination at the national level emerged from the study as one of the most important opportunities for improving the nation's capability to jointly address mobility and environmental needs.

Recommendation 1: Communication and Coordination

A federal interagency group should be established for coordinating governmental action to reduce the negative impacts of aviation on local air quality, noise, and climate change. The group should have representation from the FAA, NASA, EPA, DoD, DOT, DOC, and DOI, and should be chaired by a representative from the FAA. The group should be formed within the Joint Planning and Development Office (JPDO). It should promote public-private partnerships with industry. This new interagency group should also be responsible for fostering a network of community forums to promote communication, idea exchange and joint action. These community forums should be given representation at the highest level in the interagency coordinating group. This coordinating group should build upon existing interagency efforts, but not be bound by them. The group should operate in a coordinated fashion with relevant committees and oversight groups in Congress. The group should be responsible for strategic planning and for coordinating the member agencies to achieve the national goals for aviation and the environment.

The benefits of aviation, as well as its effects on the environment, result from a complex system of interdependent technologies, operations, policies and market conditions. In addition, there is great uncertainty in evaluating potential impacts, particularly the health effects of some aviation emissions and the role of aviation in climate change. Policy and research investment options related to aviation and the environment are currently considered within narrowly-focused contexts (e.g., only noise, only local air quality, only climate change), and the full economic effects, and health and welfare impacts of these options are not considered. Actions in one domain can produce unintended negative consequences in another.

Recommendation 2: Tools and Metrics

The nation should develop more effective metrics and tools to assess and communicate aviation's environmental effects. The metrics should better represent the human health and welfare impacts of aviation. The tools should incorporate the best scientific understanding, and be able to put aviation's impact in context with that of other sources. The tools should enable integrated environmental and economic cost/benefit analysis of policies and research and development activities so that it is possible to:

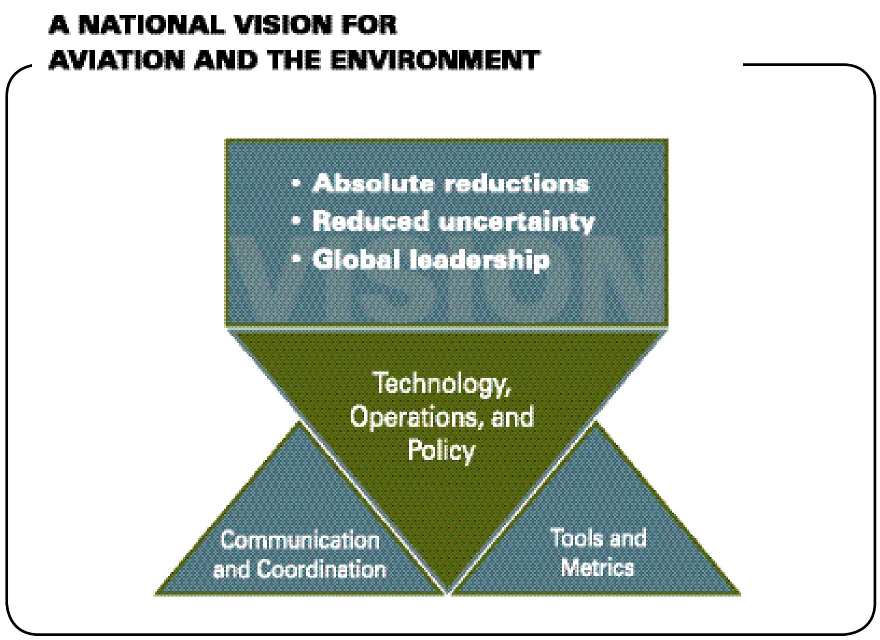
- evaluate potential benefits of research initiatives including source reduction technologies and operational advancements
- assess the effects of environmental constraints on national airspace system expansion
- account for airline economics and affordability in evaluating regulatory and research opportunities
- assess the impacts on communities of policy and operational decisions
- understand aviation's environmental effects individually and relative to one another (air quality, noise and climate) in terms of both damage costs and mitigation costs

These tools should be useful at local, regional, national and international levels — enabling experimentation and feedback at all of these levels.

There is no single technological or operational solution to resolve the conflict between goals for aviation and the environment. Yet there are many emerging operational, technological and policy options that can support a balanced approach to reducing the environmental impacts of aviation. Many are already being pursued within FAA, NASA and industry.

Recommendation 3: Technology, Operations and Policy

The nation should vigorously pursue a balanced approach towards the development of operational, technological and policy options to reduce the unfavorable impacts of aviation. Because they offer near-term improvements, priority should be given to developing and implementing improved operational procedures for both noise and emissions reduction that satisfy safety requirements. Innovative market and land-use options should be evaluated and implemented for mid-term improvements. For the long-term, but commencing immediately, integrated programs should be strengthened to bring economically reasonable advanced technologies to levels of development that allow more rapid insertion into aircraft and engines. Strategic decisions about what options to pursue should be considered within the interagency coordinating group and informed by improved metrics and tools.



This image depicts the relationship between the recommended actions and the National Vision for Aviation and the Environment. Technology, Operations and Policy represent a balanced approach to addressing aviation mobility and environmental needs. These are placed in an inverted triangle to signify that the balance is dependent on the supporting elements of Communication and Coordination, and Tools and Metrics. It is only with all three of these elements in place that the National Vision of absolute reductions, reduced uncertainty and global leadership will be achieved.

2.0 Overview of the Study and Organization of the Document

A study of ways to reduce aviation noise and emissions was mandated by the United States Congress in the *Vision 100–Century of Aviation Reauthorization Act* (H.R. 2115, Public Law 108-176, Section 321). Appendix A contains the full text of the relevant section of the legislation. The mandate asks for consideration of operational, infrastructure, and technological changes or improvements to mitigate the environmental effects of aviation. Based on the legislation language and consultations with FAA, NASA, the Aviation Subcommittee of the House Committee on Transportation and Infrastructure, and the Space and Aeronautics Subcommittee of the House Committee on Science, goals for this study were defined that are broader, but inclusive of the requirements of P.L. 108-176, Sec. 321. In particular, we sought:

- to develop a shared vision of national goals for addressing aircraft noise and emissions
- to develop actionable recommendations by consulting stakeholders and examining and learning from the results of past activities on aviation and the environment
- to recommend a sustainable implementation plan to achieve the stated goals

The study was conducted by the Partnership for AiR Transportation Noise and Emissions Reduction (PARTNER), an FAA/NASA/Transport Canada-sponsored Center of Excellence (COE), on behalf of FAA and NASA, with participation from governmental organizations, academia, industry groups and community groups.

We began the study by synthesizing key findings and themes from 35 prior studies (Appendix C contains a list of these studies). We also interviewed 43 individuals in 18 different organizations to better understand stakeholder perspectives and interests (Appendix D contains a list of the people we interviewed). The information we collected was summarized and communicated to the study participants in advance of the first of two combined stakeholder meetings. Forty-five people from 31 organizations attended the first meeting. After the meeting, a draft report was developed and circulated; it generated detailed comments from 16 organizations. A revised draft was circulated in advance of a second stakeholder meeting. Forty-eight people from 32 organizations attended the second meeting. Following the second stakeholder meeting, another revised draft report was circulated. The report generated additional comments from 18 organizations. These comments are reflected in this final report. Appendix E contains a list of people who attended the two stakeholder sessions.

During the study it became apparent that significant opportunities for long-term environmental improvements exist beyond the domains of advanced technology and operations, in particular through better interagency coordination, and through the development of more effective tools and metrics. Therefore, following the judgment of the study team and the participating stakeholders, we have placed less emphasis on a detailed review of advanced technological and operation opportunities than indicated in the language of the legislation.

This document is the final report resulting from the study. It is divided into six sections. Sections 1 and 2 are the Executive Summary and an overview of the study. Section 3 provides a brief review of the relationship between aviation and the environment. Sections 4, 5 and 6 propose a National Vision for Aviation and the Environment, a Framework for Goals, and Recommended Actions, respectively.


Martin Jones; Ecoscene/CORBIS

3.0 Aviation and the Environment

In this section we briefly review the relationship between aviation and the environment, including what is known about community noise impacts (Section 3.1), air quality impacts (Section 3.2) and climate impacts (Section 3.3), the interdependencies between these effects and opportunities to address them (Section 3.4), constraints on mobility, economy and national security (Section 3.5) and interactions between governmental and other organizational structures to address these impacts (Section 3.6). This section was developed using themes synthesized from 35 prior studies (Appendix C contains a complete listing), and interviews with 43 individuals in 18 different organizations held prior to the stakeholder meetings. (Appendix D contains a complete listing.)

Taken together, these studies and interviews present a compelling case for urgent national action to address the environmental effects of air transportation. Aviation is a critical part of our national economy, providing for the movement of people and goods throughout the world, enabling our economic growth. Despite dramatic progress in reducing the environmental effects of aviation, and despite the relatively small contribution that aviation currently makes to environmental impacts in the United States, environmental concerns are strong and growing.

Organizations must better coordinate their activities to address the growing challenges of aviation and the environment.

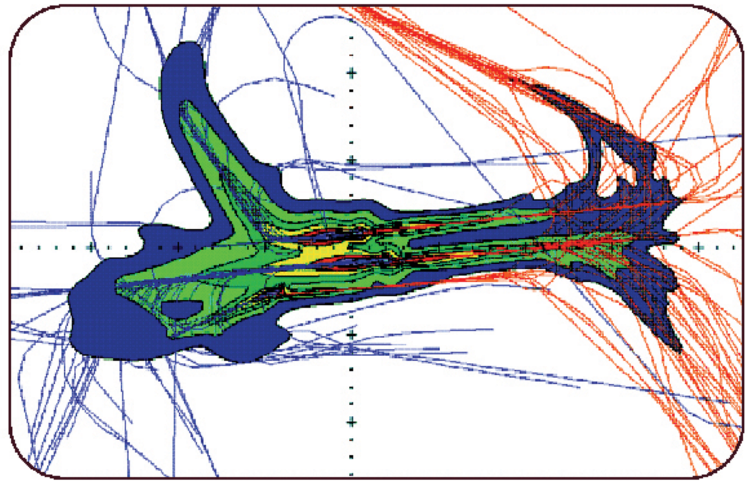
As a result of growth in air transportation, emissions of many pollutants from aviation activity are increasing against a background of reductions from many other sources. In addition, progress on noise reduction has slowed. Although it depends on the metric used, estimates suggest that millions of people are adversely affected by these side effects of aviation. Because of these factors and the rising value placed on environmental quality, there are increasing constraints on the mobility, economic vitality and security of the nation. Airport expansion plans have been delayed and canceled due to local air quality, water quality and community noise impacts [GAO 2000c]. Military readiness is increasingly challenged by restrictions on operations [Waitz 2003]. These effects are anticipated to grow as the economy and demand for air transportation grow. Indeed, as highlighted by the National Science and Technology Council [NSTC 1999], and later by the National Research Council [NRC 2002], if they are not addressed, environmental constraints may impose the fundamental limit on the growth of our air transportation system in the 21st century.

The United States is not the only force in this arena: non-U.S. concerns and regulatory actions are increasingly setting conditions for the world's airlines and manufacturers. For example, within the European Union the climate effects of aviation are identified as the most significant adverse impact of aviation, exceeding the importance of local air quality and noise impacts that are the current focus of attention in the United States and many other nations. As a result, there are increasing calls for regulation: trading, taxes and charges, demand management and reduced reliance on aviation. However, there is considerable uncertainty in assessing the climate effects of aircraft and determining appropriate means to mitigate these effects. Despite the importance of this issue, the United States does not have a significant research program to assess the potential impacts of aviation on climate. This must be remedied to enable strong U.S. participation in international forums and continued competitiveness in world markets. The international concerns will continue to grow with the strong increase in air transportation demand anticipated for Asia.

Within the United States there are hundreds of organizations and groups (federal, state, local, aerospace industry and community groups) whose principal focus is aviation noise and emissions. The participants are dedicated to their charge and when focused can be very effective in bringing about change. However, in general, the activities of these organizations are not well coordinated and acting singly they are not likely to alter our national path in a substantive manner. To become more effective these organizations must better coordinate their activities to address the growing challenge of aviation and the environment. This change, the development of a new paradigm for organizational interaction and coordination at the national level, emerged from the study as one of the most important opportunities for improvement. Both requirements and incentives for coordinated action should be considered.

With greater coordination, many opportunities for long-term environmental improvements can be realized. A critical requirement to capitalize on these opportunities is the development of better metrics and tools for assessing interdependent impacts, and options for addressing them. The tools currently used to estimate the costs and benefits of proposed improvements do not effectively address either the strong interdependencies between actions or the full economic consequences of different choices. Once they are developed, these tools should be used to assess the many opportunities for long-term environmental improvements that exist in the domains of technology, operations, and policy. Most of these opportunities are being pursued in some form, but most are not sufficiently funded to promote rapid change.

We discuss in the following sections the specific connections between aviation and the environment. We focus on community noise, local air quality and climate change. We do not review the literature on water quality. However, this is also an important environmental impact; water quality issues are limiting several airport expansion projects. Water quality issues must also be addressed in the future.



The FAA Integrated Noise Model (INM) is the principal tool used around the world for assessing the noise of aircraft around airports. Shown here are contours of day-night noise level (blue = 55dB-65dB, green = 65dB-75dB) and departure and arrival flight tracks (blue and red respectively) for a major international airport.

3.1 Noise

There has been a 95% reduction in the number of people affected by aircraft noise in the United States in the last 35 years. This dramatic reduction was realized in terms of the number of people living in areas above 65dB Day-Night Noise Level (DNL, a weighted measure of the noise impact for multiple flights over a period of time), where greater than 12% of the population may be highly annoyed, and also in terms of the number people living in areas above 55dB DNL, where greater than 3% of the population may be highly annoyed [NRC 2002, FICON 1992]. Note that the FAA identifies 65dB DNL as the threshold for the federal funding of noise mitigation. While current FAA policy recognizes that impacts below 65dB DNL may be evaluated, federal funds for mitigation cannot be applied to these impacts. The reductions in the number of people exposed to aircraft noise were realized during a period of six-fold growth in mobility through major technological advances such as the introduction of high bypass ratio engines that provided both noise reductions and fuel burn savings [NRC 2002]. The improvements were promoted by new certification standards and a forced phase-out of 55% of the older, louder fleet as a result of the Airport Noise and Capacity Act of 1990 (ANCA). The phase-out was estimated to have cost the industry approximately $5B (as determined using an FAA methodology that incorporated generally reasonable assumptions; other estimates are higher) [GAO 2001].

Nonetheless, aircraft noise remains a significant problem and it is anticipated to grow. In 2000, approximately 0.5 million people in the United States lived in areas with noise levels above 65dB DNL. In 2000, approximately 5 million people in the United States lived in areas with noise levels above 55dB DNL. There has been a further 10% reduction in the number of people impacted since 2000 due to the earlier than expected retirement of certain aircraft in light of the economic downturn and the events of 9/11, and the continuing reduced traffic in the U.S. system compared to 2000 [ICAO 2004].

Such dramatic improvements are not expected to be realized in the future. The environmental impact of aircraft noise is projected to remain roughly constant in the United States for the next several years and then increase as air travel growth outpaces expected technological and operational advancements [NRC 2002]. Continuing increases in noise impact are expected for Europe and Asia. In addition, new concerns are emerging such as the audibility of aircraft noise in certain areas of national parks and low frequency noise impacts around airports. There are also growing efforts to develop supersonic business jets with sonic boom signatures that may be acceptable for flight over populated areas.

A balanced approach is necessary: the greatest near-term opportunities exist with operational procedures, reductions in source noise are required for the long-term, policies to encourage appropriate land use will be required throughout.

While federal and industry investments can be applied to reduce aircraft noise, it is local authorities that control land-use decisions near airports. There are many examples where federal land-use guidance designed to mitigate impacts has not been followed by local authorities, and this has exacerbated the problem [GAO 2001]. Even when airports are relocated to areas that were once sparsely-populated (e.g., Dallas/Fort Worth International Airport, Naval Air Landing Field Fentress, and Denver International Airport), problems eventually appear as local decisions lead to increased land-use near the airfield. While some communities have taken active roles in addressing land-use issues near airports (e.g., through establishing building codes and guidelines for sound insulation of new homes, and by providing interactive tools and property locators to enable communities to better understand noise levels in particular locations), a disconnect remains between federal aviation policy and local land-use decision-making.

The current situation is that aircraft noise is the single most significant local objection to airport expansion and construction [AERO 2002]. As the national aerospace system becomes increasingly capacity-constrained it will be ever more important to remove the limits introduced by community noise impacts. Recognizing the strong role that advanced technology and operations can play in addressing this issue, the National Research Council (NRC) recommended that the federal government shift some funding from local abatement (approximately $0.5B/year is currently spent for sound insulation and land purchases around airports) to noise reduction research and technology [NRC 2002]. This money would be used, in part, to enable NASA to develop noise reduction technologies to a technology-readiness-level (TRL) of 6 so they can be more readily adopted by industry [NRC 2002]. However, airports see these mitigation funds as an essential part of addressing near term issues and maintaining positive relations with communities. In addition, some airports have effectively used these funds for land purchases in an effort to reduce future concerns. A compromise on this issue was reflected in the Administration's proposal for FAA's 2003 Reauthorization that included a provision for allowing the use of $20M per year from the Airport Improvement Program (AIP) noise set-aside fund for aviation noise and emissions research. This proposal received broad support across the stakeholders, but it will take legislative action to enact it.

There is much potential for technological and operational improvements to reduce aircraft noise as reflected in the plans of government research organizations both in the United States and abroad. By 2020, the European Union hopes to reduce perceived noise from new aircraft to one-half of the average levels in 2001 [ACARE 2001]. NASA plans to develop technology that could enable a 50% reduction in the effective perceived noise level (EPNdB, a measure of single event noise closely related to human annoyance) for a new aircraft relative to the 1997 state-of-the-art by 2007 and reductions of a factor of four beyond 2007. The NASA plan considers improvements to airframes, engines and terminal area operations [NASA 2003]. The National Research Council recognized NASA's noise reduction goals as technically feasible, but saw the level of funding for federal research programs as too low to achieve the current goals on schedule or to remove noise as an impediment to the growth of aviation [NRC 2002]. Research within the FAA currently focuses on the development of better metrics and tools to assess aviation noise impacts, and on the development and implementation of operational procedures to mitigate aviation noise [FAA 2004b]. It is widely recognized that a balanced approach is necessary, with the greatest near-term opportunities existing with operational procedures, and reductions in source noise (airframes and engines) being required in the long-term for further reductions. Continuing policy efforts to encourage appropriate land use will be required throughout.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3.2 Local Air Quality

Although noise is the primary environmental constraint on airport operations and expansion, many airports either put local air quality concerns on equal footing with noise or anticipate they will be on equal footing soon [GAO 2000c]. Emissions of nitrogen oxides (NOx), carbon monoxide (CO), unburned hydrocarbons (UHC) and particulate matter (PM) from a variety of airport sources contribute to local air quality deterioration, resulting in human health and welfare impacts. Nationally, local air quality has steadily improved as a result of the Clean Air Act, which has led to reductions in pollution from most sources

Although aviation is a small overall contributor to local air quality impacts, some aircraft emissions are growing against a background of generally decreasing emissions from other sources.

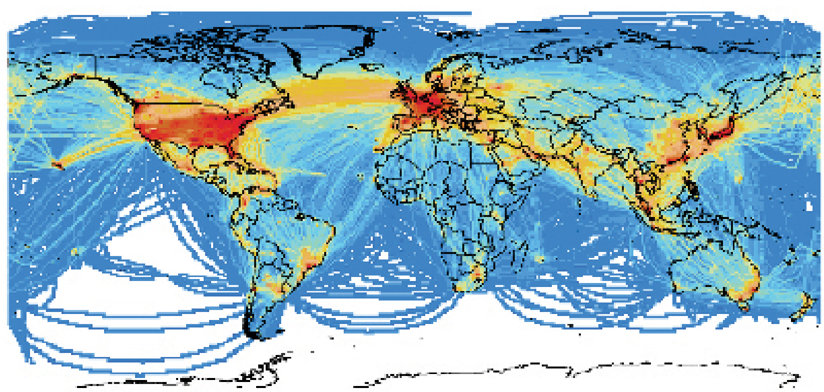
[EPA 1999a, EPA 2001]. However, many of the technologies employed for land-based sources are not applicable to aircraft because of the more severe weight, volume and safety constraints. Thus, although aviation is a small overall contributor to local air quality impacts, some aircraft emissions are growing against a background of generally decreasing emissions from other sources.

Historically, the most difficult of the pollutants to control for aviation has been NOx. Aviation operations below 3000 feet contribute 0.4% to the total national NOx inventory. Forty-one of the 50 largest airports are in ozone non-attainment or maintenance areas. In serious and extreme status non-attainment areas, the airport contribution to the area NOx inventory ranges from 0.7% to 6.1% with an average of less than 2% [FAA 2004a]. The contribution of aviation to NOx emissions around airports is expected to grow [EPA 1999b].

There are physical and chemical phenomena that make it more challenging to reduce NOx emissions from aircraft engines that employ high temperatures and pressures to reduce fuel consumption. However, there are alternatives for reducing NOx that do not require trade-offs with fuel efficiency; improvements in combustor technology and airframe aerodynamics and weight have led to reductions in NOx emissions without negative effects on fuel efficiency. Over the last 35 years fuel burn per passenger-mile has been reduced by 60%. Two-thirds of this reduction has been due to improvement in engine technology with the rest due to improvements in aerodynamics, weight and operations [Lee 2000]. Continuation of ongoing technology research is expected to reduce fuel consumption at a slower rate—about 1% per year over the next 15 to 20 years—with more opportunities for improvement in airframes than engines [Lee 2001, IPCC 1999]. However, the demand for air transportation is expected to increase 3% to 5% per year [NRC 2002]. Low emissions technology and operations must therefore make up the difference to avoid increased pollutant emissions from aircraft.

There are many opportunities for technological and operational improvements to reduce emissions of NOx, UHC, CO and PM. These options for reducing emissions present major engineering, safety and cost challenges that must be overcome before they can be implemented in the fleet. Research programs in the United States and Europe have been developed to address these challenges. By 2020, the European community hopes to make an 80% reduction in NOx emissions [ACARE 2001]. By 2007, NASA plans to develop technology to reduce NOx emissions of new aircraft by 70% from 1996 International Civil Aviation Organization (ICAO) standards with additional plans to further reduce NOx by one-third of the remainder beyond 2007. These reductions will focus on engine developments [NASA 2003]. NASA has already demonstrated TRL 4 technology for a 67% reduction in NOx emissions below 1996 standards [NASA 2003]. However, the National Research Council determined that NASA funding is insufficient to reach the specified milestones for reducing NOx emissions on schedule [NRC 2002]. There are also several promising operational opportunities for reducing fuel burn and emissions such as single-engine taxi, modified takeoff and landing procedures, and modernization of the air traffic management system to reduce enroute and ground delays. Less attention has been given to these in national research plans, but increased focus is warranted because they may enable relatively near-term reductions.

Two areas of increasing importance and high uncertainty relating to local air quality have emerged for aviation in the last decade. The first is fine particulate matter (PM). On a per-pound basis, the mortality and morbidity costs of PM are several hundred times greater than those resulting from emissions of NOx [EPA 1999a]. While the EPA has introduced increasingly stringent national ambient air quality standards for particulate matter, there are currently no uniformly accepted methods for measuring both the PM and PM precursors from aviation. The aviation community is thus challenged first to measure and characterize the pollutants, then to assess the impact of the pollutants, and finally to adopt strategies to reduce them if warranted. Airports are required to address conformity and other requirements as part of expansion or improvement projects, so mitigating actions may be required, even though there is little understanding of aviation PM, its health impacts, and the relationship with aviation technology and operations. FAA, NASA, EPA, industry and academic institutions have joined together to develop a National Roadmap for Aviation Particulate Matter Research [FAA 2004b] to outline the efforts required in this area.



This output from the FAA System for assessing Aviation's Global Emissions (SAGE) shows the world-wide distribution of aircraft carbon dioxide emissions for 2000. SAGE calculates aircraft emissions on a flight-by-flight basis as a function of aircraft type and detailed flight profile information. The results can be used to assess the impact of various mitigation strategies on fuel burn and emissions at airport, regional and global levels.

The second emerging local air quality concern is the potential for aviation to contribute hazardous air pollutants (HAPS) to local environments. In recent airport environmental assessments, HAPS reviews have figured more prominently [see e.g., Oakland 2003]. In these recent cases HAPS associated with emissions from the airport were not found to produce significant health impacts. However, the estimates of HAPS emissions used in these reviews were developed using measurements from 35-year-old engine technology because no other data were available. Here again, the aviation community is challenged to first measure and characterize the emissions and then to adopt strategies to address them if warranted [FAA 2003b]. Current plans are not sufficient to meet this need. As a result, more airports may find themselves in the difficult position of being required to pursue mitigation measures without the benefit of the proper tools to measure and characterize the pollutants and assess the potential impacts.

3.3 Climate Change

The topic of greatest uncertainty and contention is the climate change impact of aircraft. In Europe, this is considered the single most important environmental impact from aviation [SBAC 2001], while in the United States many still regard it as less important and less urgent than community noise and local air quality. It is a fact that aircraft emit chemical species and produce physical effects (like condensation trails, or contrails) that most scientists believe affect climate. Scientific assessments also suggest that the resulting chemical and physical effects due to aviation are such that aviation may have a disproportionate effect on climate per unit of fuel burned when compared to terrestrial sources.

In 1999, a special aviation study, conducted by the Intergovernmental Panel on Climate Change (IPCC) estimated that aviation was responsible for approximately 3.5% of the anthropogenic forcing of the climate in 1992. These estimates reflect a finding that per unit of fuel burned, radiative forcing from aircraft is expected to be approximately double that of land-based use of hydrocarbon fuels [IPCC 1999]. Since the IPCC study, the scientific understanding of some of the chemical and physical effects (particularly contrails and the cirrus clouds they may induce) has evolved. A recent report by the UK Royal Commission on Environmental Protection (RCEP) stated that the net effect of contrail and aviation-induced cirrus is expected to be three to four times the radiative forcing due to the CO_2 emitted from aircraft, although further changes in these estimates are likely [RCEP 2002]. If the estimates are correct and the aviation growth projections used by the IPCC are realized, aviation may be responsible for between 3% and 15% of anthropogenic forcing of climate change by 2050 [IPCC 1999].

The topic of greatest uncertainty and contention is the climate change impact of aircraft. There are currently no major U.S. research programs to address this.

Because of the uncertainty in understanding the impacts of aviation on climate, appropriate technological, operational and policy options for mitigation are also uncertain. As a result most mitigation options currently being pursued focus on reducing fuel burn. However, as noted in Section 3.4, it is possible that this is not the most effective strategy for reducing aviation's contribution to climate change. Further, although fuel use per passenger-mile has been reduced by 60% in the last 35 years, most projections suggest a slower rate of improvement in the next 15 to 20 years—about 1% per year [Lee 2001, IPCC 1999]—falling short of the expected growth in demand. NASA has a five-year goal to deliver technologies (at a technology-readiness-level of 6) needed to reduce CO_2 emissions of new aircraft by 25%. However, significant challenges will remain to demonstrate technological feasibility and economic reasonableness such that these concepts can be employed in the fleet. As a result, it may take an additional 5 to 15 years and significant industrial investment before these NASA technologies can be introduced into new aircraft.

Within Europe, public and governmental positions increasingly point towards a desire to regulate the climate impacts of aircraft. The RCEP noted that without regulatory control, the rapid growth of air transport will proceed in fundamental contradiction to the British government's stated goal of sustainable development. Recently, The Guardian newspaper wrote that the British prime minister said, "… he would push the EU to curb emissions from aircraft, which by 2030 could represent a quarter of Britain's total contribution to global warming. Britain would argue strongly for aviation to be brought within the next phase of an EU emissions trading scheme. It would set a cap on emissions and require companies increasing output to 'buy' unused capacity from elsewhere." (The Guardian, p. 9, September 14, 2004).

Ying Liu/CORBIS

While the United States has increased investment to reduce uncertainty in climate change impacts generally, there are currently no major research programs in the United States to evaluate the unique climate impacts of aviation [NASA 2003]. This may put the United States at a disadvantage in evaluating technology and policy options, and in negotiating appropriate regulations and standards with other nations. It could also lead to reliance on data put forth by others who may favor curtailing aviation activity to mitigate environmental impacts, despite its significant contribution to the economy.

3.4 Interdependencies

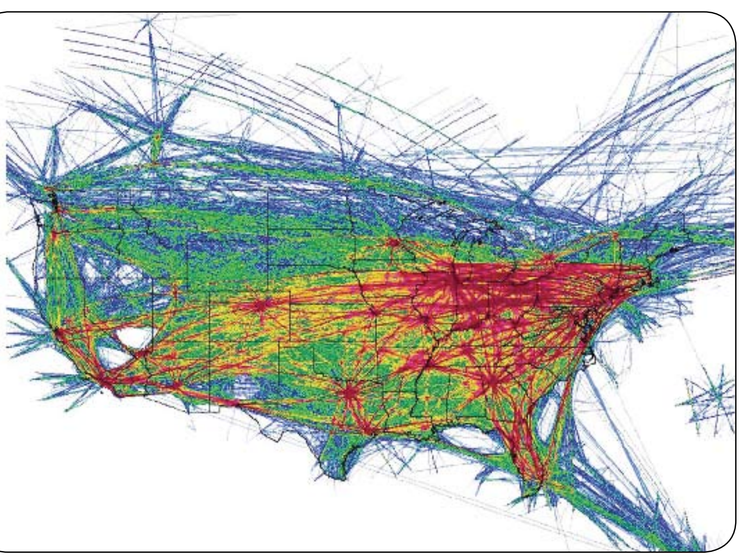
Action to address impacts in one domain can have negative impacts in other domains.

Noise, local air quality and climate effects of aviation result from an interdependent set of technologies and operations, so that action to address impacts in one domain can have negative impacts in other domains. For example, both operational and technological measures to reduce noise can result in greater fuel burn, thus increasing aviation's impact on climate change and local air quality [SBAC 2001]. Emissions interrelationships make it difficult to modify engine design as a mitigation strategy since they force a trade-off among individual pollutants as well as between emissions and noise [FAA 2004a]. To date, interdependencies between various policy, technological and operational options and the full economic consequences of these options have not been appropriately assessed.

The NRC has recommended that government and industry invest in comprehensive interdisciplinary studies that quantify the marginal costs of environmental protection policies [NRC 2002]. Such investments are now being made. Over the next six years the FAA and NASA plan to invest $10M per year to develop a comprehensive framework of aviation environmental analytical tools and methodologies to assess interdependencies between noise, emissions, and economic performance to more effectively analyze the full costs and benefits of proposed actions [FAA 2004b]. These tools will be critical for informing decisions on new noise and emissions standards, potential phase-outs of portions of the fleet and potential cruise emissions standards. They are also required to define appropriate research and development investments for technological and operational opportunities for reducing noise and emissions. These tools can offer significant leverage because of the billions of dollars invested in developing and operating aircraft. The development of such tools will be a major step forward for the nation.

3.5 Mobility, Economy and National Security

Aviation enables economic growth. The Presidential Commission on the Future of Aerospace found that the superior mobility afforded the United States by air transportation is a major national asset and a competitive advantage, but United States dominance in aerospace is eroding [AERO 2002]. The Air Transport Association estimated that the total direct, indirect and induced impact of commercial aviation exceeded $800B and 10 million jobs in 2000, representing 8% of the United States gross domestic product [ATA 2004]. From 1978 through 2001, the number of passenger boardings grew from slightly over 300 million to over 600 million annually. United States businesses also shipped more by air: from 1978 to 2001, air freight ton miles grew from 6 million to over 20 million annually. From 1978 through 2003, revenue passenger-kilometers flown by large certificated air carriers increased by a factor of 2.8 to approximately one trillion passenger-kilometers per year [DOT 2004]. At the same time airline ticket prices have fallen approximately 50% in real terms (adjusted for inflation) since 1978 [ATA 2004].



U.S. Air traffic for a 24-hour period taken from the FAA Enhanced Traffic Management System (ETMS) which integrates data from FAA air traffic control radar.

Large carrier traffic in the United States and international passenger traffic are both expected to continue to grow, with international markets growing faster than domestic markets (4.7% versus 3.5% annually) over the next 12 years [FAA 2004b]. At the same time, restructuring of large legacy carriers and the growth of low-cost carriers is anticipated — low-cost carriers and regional and commuter carriers could account for more than half of all domestic passengers by 2015. Forecasts for air cargo and general aviation indicate growth as well [FAA 2004c].

The United States national air transportation system is not sufficient to accommodate this growth. Five of the top 35 U.S. airports were in need of additional capacity in 2003; 15 of the top 35 airports are projected to need additional capacity by 2013. If improvements proposed in the FAA Operational Evolution Plan (OEP) do not take place, the number of airports requiring additional capacity in 2013 increases to 26 of the top 35 airports. Further, even with these capacity expansions, new airports may have to be built to satisfy demand projections in many metropolitan areas [DOT 2004].

Environmental issues caused airport officials to cancel or indefinitely postpone expansion projects at 12 of the 50 busiest U.S. airports in the last 10 years [GAO 2000c]. The dominant concern was noise, followed by water quality and then local air quality. In the future, noise and local air quality are expected to be the most significant concerns.

Aviation is an enabler for economic growth. Environmental issues caused airport officials to cancel or indefinitely postpone expansion projects at 12 of the 50 busiest U.S. airports in the last 10 years.

Although the situation is different for military aviation, similar challenges exist. Increasing impacts on national security have been recognized due to constraints on the deployment and combat readiness of the airborne services, particularly as related to limitations on the realism of training activities [Waitz 2003]. While commercial aviation has grown, military aviation has experienced reductions in fleet size and number of operations over the last 50 years. However, technological and operational improvements in noise and emissions for military aircraft have been more challenging to achieve because of the mission requirements for these vehicles. Nonetheless, because of the decreasing number of operations, military aviation has been responsible for a small and decreasing fraction of total fossil fuel use in the United States (approximately 0.5% of total U.S. fuel use in 2000). Further, when averaged nationally, contributions to local air quality impacts and community noise have also decreased from 1990 to 2000. However, since base closures were largely responsible for these reductions, the impacts at any given installation may not reflect overall trends. Thus, community noise and air quality are expected to be a growing concern for military aviation due to increasing urbanization, and increasing public and regulatory attention.

3.6 Interactions between Government, Industry and Other Groups

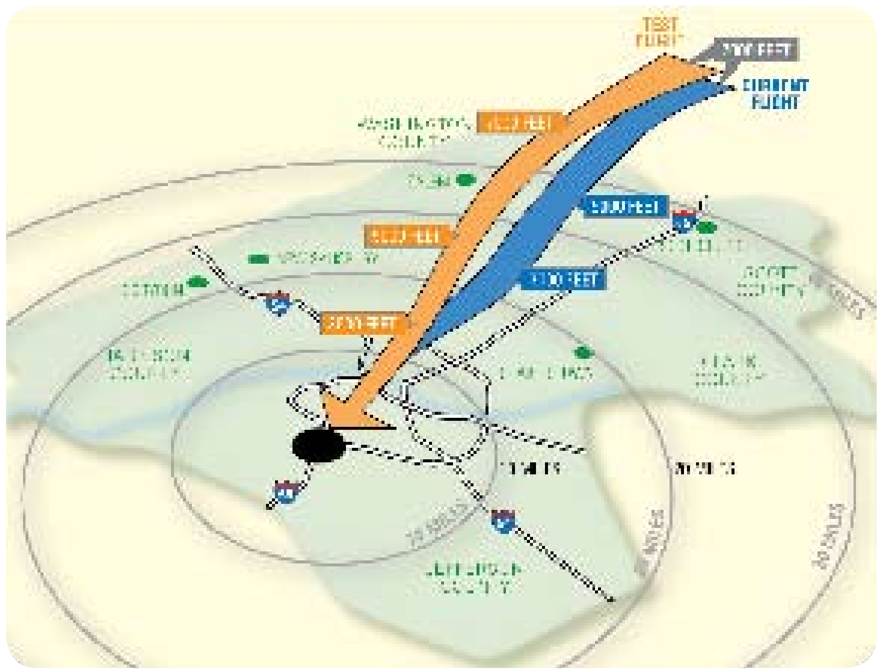
A distinct difference exists between the approaches of Europe and the United States to address the challenges described above. Europe has plans and programs focused on making it the global aeronautics leader by jointly satisfying aviation safety, environment and mobility demands by 2020 [ACARE 2001]. The Advisory Council for Aeronautics Research in Europe (ACARE) was formed to coordinate the positions of international institutions that support the aerospace industry and to launch and approve a Strategic Research Agenda and update it every two years [ACARE 2001]. AERONET was established as a platform for aviation emissions issues in Europe where the different stakeholders can meet, communicate and cooperate in a well-organized and systematic way [AERONET 2000]. As Europe has moved to act in a coordinated fashion, several studies and reports have encouraged independent European action on charges and economic instruments to address noise, air quality and climate change, outside of the ICAO framework [SBAC 2001, RCEP 2002]. Taxes, demand management and modal shift have been recommended to curb growth and impacts [RCEP 2002]. The foundation for these recommendations is the belief that current levels of air traffic cause major environmental costs that will grow unless economic instruments are instituted to curb them [SDC 2003]. These recommendations reflect the very different context within Europe relative to infrastructure (greater availability of rail) and governmental policies to address environmental costs.

These activities are moving the nation in the right direction, but at a pace that far lags the burgeoning need.

Less coordinated action is apparent within the United States, but there have been several recent activities. The General Accounting Office (GAO) has called for the creation of a national strategic framework for local air quality emissions [GAO 2003]. The Presidential Commission on the Future of Aerospace found that U.S. government functions in a vertical manner in different organizations, whereas national problems cut across organizations and need horizontal integration [AERO 2002]. In response to these and other drivers, the FAA, NASA, DOT, DOC, DoD, Homeland Security, and the Office of Science and Technology Policy (OSTP) recently became part of the Joint Planning and Development Office (JPDO), an organization created by a mandate in the *Vision 100–Century of Aviation Reauthorization Act* (P.L. 108-176). The JPDO has been formed to create and carry out an integrated national plan that sets goals and aligns missions across government to ensure that the United States stays at the forefront of aviation and meets the demands of the future [JPDO 2004]. One of JPDO's eight strategic thrusts is "to reduce noise, emissions, and fuel consumption and balance aviation's environmental impact with other societal objectives." The EPA has regulatory authority over aviation emissions under the Clean Air Act. A concern is thus the lack of EPA participation thus far in the JPDO [JPDO 2004]. The recent agreement by the EPA to participate in the JPDO is a positive step forward that will further the ability of the office to effectively pursue environmental objectives.

There are also growing cross-agency research programs. For example, FAA, NASA, and Transport Canada have jointly sponsored a Center of Excellence called Partnership for AiR Transportation Noise and Emissions Reduction (PARTNER) to address issues of aviation and the environment by utilizing the resources available in academia and industry [FAA 2004b].

These activities are moving the nation in the right direction, but at a pace that far lags the burgeoning need. When we asked the stakeholders to describe prior successes and failures, communication and coordination between organizations was the key enabling or disabling factor in all of the examples they offered. Examples were given of poor coordination among NASA, FAA, EPA and the National Park Service and of poor coordination between groups within agencies.



Standard flight paths, such as the one at Louisville (shown in blue) involve a series of stepped descents. New continuous descent approach procedures, collaboratively developed by an FAA/NASA/industry/academia team, have been shown reduce noise impacts by keeping aircraft higher, longer. They have also been shown to reduce fuel burn and emissions of local air quality pollutants. (Illustration © The [Louisville] Courier Journal.)

Conversely, past successes all bridged boundaries between various groups and organizations. Perhaps the most prominent example is the Aircraft Noise and Capacity Act of 1990 (ANCA) described earlier. This was a negotiated legislative response involving all stakeholders that led to the incorporation of NASA and industry technology into the fleet faster than it otherwise would have been, producing substantial reductions in community noise along with reductions in per mile fuel burn and per mile emissions. A key compromise involved enacting federal guidelines for communities in setting local aircraft noise limits and restrictions, while requiring airlines, at a cost of $5B or more, to phase-out noisier (Stage 2) aircraft under a proscribed timetable. Another example was the Federal Interagency Committee on Noise (FICON) that produced a report in the early 1990s covering policy, technical and legal issues. The study endorsed supplemental metrics and reinforced methods for DNL levels. It led to more clarity on how to assess certain noise impacts, and it reduced tensions between stakeholders. The NASA Atmospheric Effects of Aviation Program (AEAP) was considered to be a successful example of the NASA Science Directorate working with the NASA Aeronautics Directorate on basic research focused on a specific problem with participation from EPA, FAA, academia and industry. Although widely regarded as successful, lack of sustained long-term funding led to cancellation of the program, and the research community that was developed around the program dissipated.

At the community level, provisions in the *Vision 100–Century of Aviation Reauthorization Act* (P.L. 108-176, and CFR part 150, Airport Noise Compatibility Planning) are seen as effective in the way they tie funding to better communication between communities and airports. There are also isolated examples of effective forums for engaging the community. The O'Hare Noise Compatibility Commission and the San Francisco International Airport/ Community Roundtable each include multiple stakeholders working together in ongoing forums with local political leadership and airport management support. The relationships that have emerged among industry, towns, cities, counties, schools, airports, and airlines have made these forums successful. They are recognized nationally as effective examples of intergovernmental cooperation regarding aviation noise impacts and mitigation efforts in affected communities. Stakeholders feel they are part of a process that encourages continuing growth in the quality of life of local residents and the economy.

In summary, a key finding of this study is that promoting greater coordination and communication among stakeholders presents a major opportunity for improving the nation's ability to jointly address mobility and environmental needs.

Courtesy Alaska Airlines

4.0 A National Vision For Aviation and the Environment

The consensus of the stakeholders who participated in this study is that immediate, focused action is required within the United States to jointly address the interdependent challenges of aviation noise, local air quality and climate impacts. For this, a national vision and strategic plan of action are required.

The stakeholders who participated come from 38 organizations that span the aerospace industry, NASA, FAA, EPA, DOC, DoD, academia, local government and community activists. When they were asked to define a vision for success, some diverging views were expressed, but there were many more elements in common among the stakeholders. This enabled them to identify a national vision that they all support and recommend for action.

Collectively, the stakeholders who participated in this study propose the following *National Vision for Aviation and the Environment:*

A National Vision for Aviation and the Environment:
In 2025, significant health and welfare impacts of aviation community noise and local air quality emissions will be reduced in absolute terms, notwithstanding the anticipated growth in aviation. Uncertainties regarding both the contribution of aviation to climate change, and the impacts of aviation particulate matter and hazardous air pollutants, will be reduced to levels that enable appropriate action. Through broad inclusion and sustained commitment among all stakeholders, the US aerospace enterprise will be the global leader in researching, developing and implementing technological, operational and policy initiatives that jointly address mobility and environmental needs.

Reducing significant aviation environmental impacts in absolute terms is a challenging goal, especially when considered in light of the projected growth in aviation traffic. While in some areas absolute reductions are already being achieved (e.g., a reduction in the number of people exposed to significant levels of aircraft noise), these reductions will be difficult to sustain as traffic grows. Further, there are areas (such as NOx emissions) where technology and operational measures combined have not been sufficient to offset the increase in emissions associated with traffic growth. Accordingly, the vision statement is aspirational. To achieve the vision, immediate and sustained public and private commitment to investment, experimentation, communication, feedback and learning at local, regional, national and international levels is required. Immediate action will provide both near-term and long-term benefits. Throughout the process of realizing this vision, there must be careful attention to fostering distributed leadership, responsibility and burdens among all stakeholders.

In drafting this vision, specific attention was given to separating issues for which the impacts are sufficiently well understood such that action is appropriate, from those for which uncertainty is high and research must be done to reduce uncertainty before it is appropriate to define specific actions. Community noise and local air quality impacts due to NOx, CO, and UHC were considered to be actionable now. Impacts of aviation PM, HAPS and aviation climate effects require further research to understand the effects and the relationship to aviation technology and operations. However, in light of growing national and international requirements to assess and mitigate these impacts, expeditious action is urgently required.

Further, our use of "significant" in the first paragraph of the vision statement is meant to signal a specific regulatory threshold for consideration. It is beyond the scope of this report to define these levels of significance, but we look to the relevant agencies to define and amend these thresholds as necessary. For example, the U.S. EPA defines thresholds for attainment of national ambient air quality standards and thresholds of significance for health effects of hazardous air pollutants. These should be taken into account in considering whether action should be taken to mitigate these effects of aviation.

Alan Schein Photography/CORBIS

5.0 A Framework for National Goals

A set of clear, measurable goals for long-term environmental improvement is necessary to support the National Vision. Within the limited scope of this study, we did not address such goals. However, we offer the following as a potential framework for their development. One of the first activities of the federal interagency group for aviation and the environment that we propose in Section 6.1 should be to develop and finalize these goals. In doing so, the following guidelines should be considered.

We have divided these guidelines into three parts: recommendations on the process of defining and reviewing the national goals, recommendations on the metrics (i.e., how progress will be measured), and recommendations on the goals themselves.

5.1 Processes

- The metrics and goals should be developed through an open, inclusive process involving a broad cross-section of stakeholders.
- The goals and metrics should be related to representative examples to enable communication with non-experts.
- As part of the process for establishing the goals, a schedule for periodic review of both metrics and goals should be established. When improved metrics are developed, they may merit incorporation. If conditions change, and when uncertainty regarding impacts improves, the goals may need to be revised.
- A periodic process should be established for assessing progress against the goals and communicating that progress to the stakeholders.

5.2 Metrics

- The goals should incorporate the best available metrics. When there is concern that the metrics do not accurately reflect the health and welfare impacts, it is important to move forward with existing metrics, but also to plan specific actions for improving the metrics.
- To measure progress relative to the national vision, metrics should be defined based upon specific health and welfare endpoints (e.g., quantitative health and welfare risks due to local air quality impacts of aviation).
- However, supplemental metrics involving quantities of pollutant or efficiency metrics could be used to relate the national goals to other significant policy or regulatory benchmarks.
- For areas where there is considerable uncertainty as to aviation's effects (e.g., climate change, HAPS and PM), the metric employed should be the uncertainty in assessing impacts. This will enable specific quantitative goals to be set with regard to reductions in uncertainty (e.g., reduce uncertainty in the climate change impacts of aviation from ±100% to ±25% over 10 years).

5.3 Goals

- The goals should be both meaningful (accurately representing the national vision for absolute reductions in significant impacts), and achievable (with due consideration for economic reasonableness and technological feasibility).
- The goals should be established in a framework that allows for consideration of interdependencies. For example, the goals could be formulated as ranges, rather than single values, to reflect the interdependent nature of the environmental impacts of aviation and the range of approaches that may be employed to mitigate them; progress in one domain may limit progress in another.
- The goals should clearly define a threshold level for significance as referenced in the National Vision Statement ("In 2025, *significant* health and welfare impacts … will be reduced in absolute terms").
- The goals should specify the baseline against which change will be measured.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6.0 Recommended Actions

The following recommendations have been constructed from the prior studies, from comments in the various stakeholder interviews and from activities during the combined stakeholder meetings.

To achieve the National Vision for Aviation and the Environment, three actions are recommended. The goal of the first is to promote coordination and communication among stakeholders. The second addresses the development of more effective tools and metrics for guiding policy decisions and for planning research investments. The third focuses on specific technological, operational and policy options to support a balanced approach to long-term environmental improvements. While the third recommendation is the most important in terms of directly addressing the needs, it will not be successful unless the first two recommendations are implemented in parallel. Below each recommendation we briefly review current activities and suggest an implementation plan for responding to the recommendation. The Next Generation Air Transport System plan should address both the funding sources and levels necessary to implement the recommendations made in this report.

6.1 Recommendation 1: Coordination and Communication

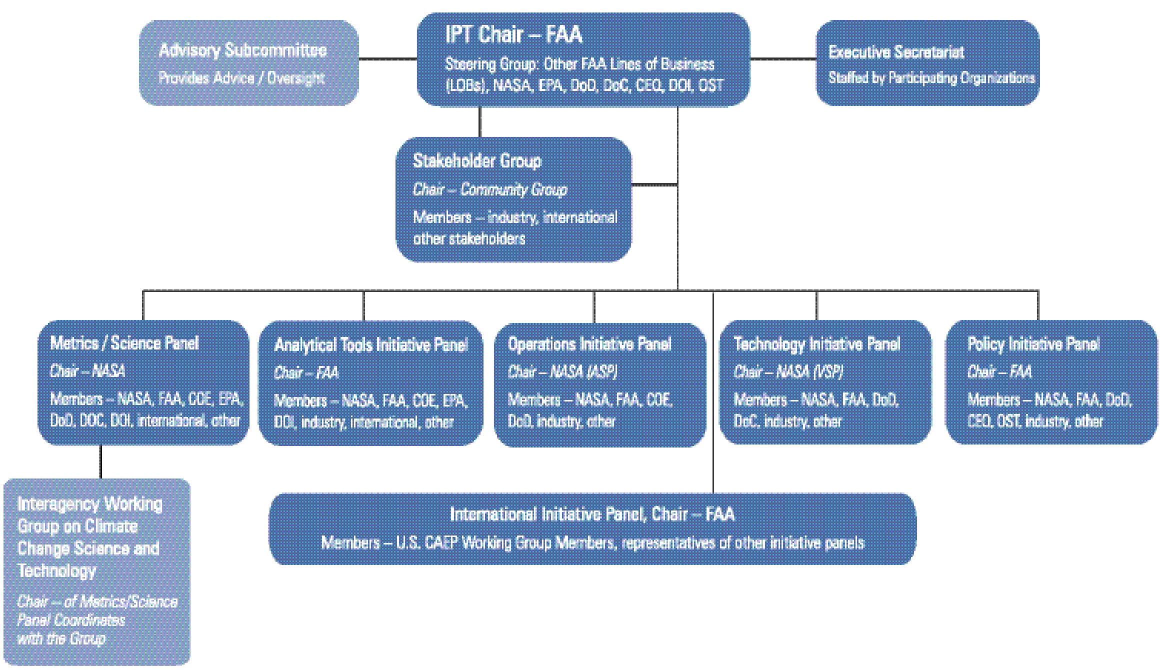
A federal interagency group should be established for coordinating governmental action to reduce the negative impacts of aviation on local air quality, noise, and climate change. The group should have representation from the FAA, NASA, EPA, DoD, DOT, DOC, and DOI, and should be chaired by a representative from the FAA. The group should be formed within the Joint Planning and Development Office (JPDO). It should promote public-private partnerships with industry. This new interagency group should also be responsible for fostering a network of community forums to promote communication, idea exchange and joint action. These community forums should be given representation at the highest level in the interagency coordinating group. This coordinating group should build upon existing interagency efforts, but not be bound by them. The group should operate in a coordinated fashion with relevant committees and oversight groups in Congress. The group should be responsible for strategic planning and for coordinating the member agencies to achieve the national goals for aviation and the environment.

An Integrated Product Team (IPT) such as that being developed within the JPDO, is an appropriate structure for implementing this recommendation. Guidance for establishing the IPT follows:

- The IPT must be staffed and funded at levels that will allow effective and sustained progress on addressing aircraft noise and emissions issues
- Lead agencies and functions within agencies must be subject to appropriate checks and balances, as reflected in the IPT governance structure and operations
- The IPT must develop effective mechanisms for alignment with industry research and development, as well as airline operational practices
- The IPT must establish mechanisms to ensure that its efforts are addressing the interests of relevant stakeholders and building sufficient levels of trust and communication
- The IPT leadership must have authority over their respective agency resources

The relevant agencies should enter into a Memorandum of Understanding that will describe their roles and responsibilities, resources, and other administrative matters. Under the IPT Steering Group, there should be panels associated with the various strategies, as well as an overarching stakeholders panel. The Steering Group should meet regularly for an in-depth review of all initiatives. A suggested structure for the IPT and associated panels is shown below.

Suggested Structure for the Aviation Environmental IPT and associated groups and panels.



6.2 Recommendation 2: Tools and Metrics

The nation should develop more effective metrics and tools to assess and communicate aviation's environmental effects. The metrics should better represent the human health and welfare impacts. The tools should incorporate the best scientific understanding, and be able to put aviation's impact in context with that of other sources. The tools should enable integrated environmental and economic cost/benefit analysis of policies and research and development activities so that it is possible to:

- evaluate potential benefits of research initiatives including source reduction technologies and operational advancements
- assess the effects of environmental constraints on national airspace system expansion
- account for airline economics and affordability in evaluating regulatory and research opportunities
- assess the impacts on communities of policy and operational decisions
- understand aviation's environmental effects individually and relative to one another (air quality, noise and climate) in terms of both damage costs and mitigation costs

These tools should be useful at local, regional, national and international levels — enabling experimentation and feedback at all of these levels.

The plan for implementing this recommendation should include the following program elements.

6.2.1 Aviation Environmental Design Tool and Aviation Portfolio Management Tool

FAA and NASA are investing approximately $10M per year for the next six years to jointly create new analytical tools to better understand the relationship between noise and emissions and different types of emissions, as well as to analyze the full costs and benefits of different technological, operational and policy options for mitigation. These tools are directly aligned with Recommendation 2 and will be a major step forward for the nation when complete. Future analytical tools should provide for: 1) the incorporation of more effective metrics for assessing health and welfare impacts, as well as industry and regional economic effects; 2) more effective validation of the suite of tools; and 3) more rapid extension of the tools for application to local analysis. Also, coordination should be sought between these efforts and research within NASA to assess the environmental benefits of air traffic management system modernization.

6.2.2 Earth System Observations, Modeling and Analysis

The nation must pursue a research program to assess the unique impacts of aviation on climate, weather and local air quality. A focused research program similar to the Atmospheric Effects of Aviation Program (AEAP) that was supported by NASA as an element of the high-speed civil transport and subsonic aviation programs should be developed. This new program should integrate atmospheric observations with local, regional and global modeling to reduce the uncertainty in the understanding of aviation's climate, weather and local air quality impacts, and to reduce the uncertainty in the relationship between these impacts and technological and operational options for mitigation. An improved understanding of aviation climate, weather and local air quality effects is necessary to ensure investments in aircraft technology and operations are effective.

6.2.3 Characterization of Aviation Air Toxics and Particulate Matter

FAA, NASA and DoD are investing approximately $5M per year to develop techniques to measure hazardous air pollutants (air toxics) and particulate matter from aviation, to collect data to quantify the emissions for the current fleet, to perform research to understand the effects of engine design and operations, to inform stakeholders of the impact of aircraft emissions and their contribution to local air quality, and to develop simplified models for technical and policy decisions. Future work should consider ways: 1) to obtain data for a wider range of aircraft and decrease reliance on approximations; 2) to accelerate the development of methods for measuring particulate matter from both commercial and military aviation; and 3) to determine whether there are unique health effects associated with particulate matter and hazardous air pollutants from aviation. These programs have been defined by a broad cross-section of stakeholders who developed a National Aircraft Particulate Matter Roadmap under the leadership of FAA and NASA. Pursuing this Roadmap will provide greater reliability in environmental analyses, more informed decision-making, and greater benefit of actions to protect the public from harmful aircraft emissions. These efforts are critical because many airports and military installations are being required to assess the impacts of aviation particulate matter and hazardous air pollutants even though data and methods to perform the assessment do not exist.

6.2.4 Assessing Impacts and Developing More Effective Metrics

FAA, NASA and DoD are investing approximately $3M per year to better identify, understand, and measure health and welfare impacts of aircraft noise and aviation emissions, including: 1) the development and assessment of supplemental metrics for noise that better represent community response; 2) the assessment of low frequency noise impacts of aviation; 3) a study of community response to sonic booms; 4) modeling and measurements to better understand unique source noise and propagation effects for military aviation; 5) the development of aviation particulate matter and climate change metrics for aviation; 6) the development of risk-based damage cost metrics to enable interrelationships and tradeoffs between noise and emissions to be assessed; and 7) a study of land-use patterns including the development of appropriate metrics to measure encroachment and its relationship to socio-economic effects around airports. Future work should consider: 1) establishing appropriate noise, and air quality metrics at the national level and harmonizing these metrics globally; 2) if warranted by scientific information, pursuing a metric for global climate change effects; 3) developing metrics for assessing the industry economic impacts of technological, operational and policy options for mitigation; and 4) developing tools and metrics for assessing the regional economic effects of aviation mobility and environmental impacts.

6.2.5 Public Education and Communication

The FAA plans to invest $0.4M per year to provide an Internet capability to educate and inform the public about aviation and the environment. NASA is investing approximately $5M per year to develop improved aircraft and airport system tools for noise assessment that could contribute to the effort. Greater coordination between the FAA and NASA work in this area is recommended through the interagency coordinating group discussed in Section 6.1. Future work should consider: 1) developing new audio/visual simulation tools to extend the NASA tools and enable improved communication of airport noise issues with the public and decision makers; and 2) expanding these capabilities to include emissions and to include additional noise metrics of interest to the public. NASA and FAA should consult some of the successful community-based groups (e.g., the O'Hare Noise Compatibility Commission and San Francisco International Airport/Community Roundtable) throughout the design and development of these tools.

6.3 Recommendation 3: Technology, Operations and Policy

The nation should vigorously pursue a balanced approach towards the development of operational, technological and policy options to reduce the unfavorable impacts of aviation. Because they offer near-term improvements, priority should be given to developing and implementing improved operational procedures for both noise and emissions reduction that satisfy safety requirements. Innovative market and land-use options should be evaluated and implemented for mid-term improvements. For the long-term, but commencing immediately, integrated programs should be strengthened to bring economically reasonable advanced technologies to levels of development that allow more rapid insertion into aircraft and engines. Strategic decisions about what options to pursue should be considered within the interagency coordinating group and informed by improved metrics and tools.

The plan for implementing this recommendation should include the following program elements.

6.3.1 Operational Options

There are many operational options for reducing fuel burn, emissions and noise from aviation. For example, standard airport approach paths involve a series of stepped descents. However, new continuous descent approach procedures, collaboratively developed by an FAA/NASA/industry/academia team, have been shown to reduce noise impacts by keeping aircraft higher, longer. They have also been shown to reduce fuel burn and emissions of local air quality pollutants. As a second example, by combining two existing technologies, the Precision Runway Monitor and the Simultaneous Offset Instrument Approach, the San Francisco International Airport has been able to increase the landing operations per hour during weather conditions with low clouds. This is expected to reduce delays by 25% and will help to reduce environmental effects by decreasing the need for aircraft circling while waiting for landing clearance. In addition, airlines have worked collaboratively with the FAA to implement many measures to reduce fuel burn and emissions. These measures include reduced auxiliary power unit usage, single engine taxiing, coordination with air traffic control centers to select more fuel-efficient routes and speeds, reduced levels of excess fuel carried, and more regular maintenance and cleaning of engines and airframes to correct minor deterioration, among other measures. There are also significant opportunities for reduced fuel burn, noise and emissions, both local and enroute, from major infrastructure changes such as the National Airspace Redesign and modernization of the air traffic management system.

Operational procedures will provide the greatest near term benefits for both noise and emissions. A significant new program should be established to accelerate the assessment, development, and implementation of operational strategies for reducing noise and emissions. The program should be built upon existing NASA and FAA efforts in this area. The program should address community noise impacts, local air quality impacts and climate impacts of aviation and thus should focus on both airport-area operations and enroute operations.

6.3.2 Land-use and other policy options

New policies and programs will be required to provide incentives and funding opportunities to enable the adoption of best practices for reducing the environmental impacts of aviation.

One recent example of such a program is the Voluntary Airport Low Emissions (VALE) program, a national program designed to reduce airport ground emissions at commercial service airports located in air quality nonattainment and maintenance areas. This program was mandated by the United States Congress in the *Vision 100 — Century of Aviation Reauthorization Act* (P.L. 108-176). This statute directed the FAA to establish a national program to provide airport sponsors with financial and regulatory incentives to take early action to reduce airport emissions using proven low emission technologies. The VALE program allows airport sponsors to use the Airport Improvement Program (AIP) and Passenger Facility Charges to finance the airport air quality improvements. Funding for the program is being made available under the new Noise Abatement/ Air Quality "Set-Aside" within the AIP. Eligible vehicles include ground service equipment, airport service and security vehicles, and parking lot shuttles and buses. Under the new legislative guidelines, the FAA, in consultation with the EPA, is required to issue guidance that will ensure airport sponsors receive appropriate airport emission reduction credits for VALE projects.

Bill Varie/CORBIS

Although there are likely to be many opportunities for innovative policies, one of the most pressing needs is in the area of land-use planning around airports. Community noise is the most significant environmental impediment to expanding airports to satisfy mobility needs. There is also ample evidence that local land-use decisions around airports contribute to the problem. Therefore, we recommend that a new program be developed to address the disconnect between federal aviation policy and local land-use decision-making. This program should be built upon the Land-Use Planning Initiative (LUPI) that the FAA initiated in 1999 to develop processes by which the agency can better influence land-use planning and zoning around airports. One of the products of this initiative was the formation of an Airport Compatibility Planning Committee. This committee provides an opportunity for interaction among federal government agencies, planning organizations, airports, state and local governments, and public interest groups involved with airport compatibility planning issues. The committee pursues the goal of improving airport land-use compatibility by: (1) identifying issues, as perceived by individual stakeholders; (2) analyzing the causes and constraints including legal, institutional, and fiscal; and (3) discussing strategies for addressing the issues. The FAA currently invests $0.25M per year to staff the LUPI initiative.

6.3.3 Technology Options

The greatest historical gains in environmental performance have come from technological innovation. These gains include a 60% improvement in aircraft fuel efficiency and a 95% reduction in the number of people significantly impacted by aircraft noise in the last 35 years. As reflected in NASA program plans, many more gains are possible. These plans include developing technologies needed to reduce contributors to CO_2 emissions by 25%, reduce contributors to smog (NOx) by 70% relative to 1996 ICAO Standards, and reduce contributors to aircraft noise by 50% (-10 dB) in comparison to 1997 state-of-the-art technology. The National Research Council [NRC 2002] and the stakeholders who participated in this study believe that NASA's goals are technically feasible and that NASA is pursuing the appropriate technology options. However, the level of funding (approximately $925M per year, not all directed towards environmental goals) is such that there is a significant risk the goals will not be achieved on schedule. A key concern is the limited number of technology options that will be brought to a technology-readiness-level such that they can be effectively transitioned to industry. The development and full-scale validation of additional engine and airframe noise and emissions reduction technologies is vital. By considering more technology options and by developing them to higher technology-readiness-levels, the risk of not achieving the goals on schedule will be reduced. The programs will also be more robust and responsive to potential changes in the industry, enabling additional technologies to be developed specifically for regional jet, microjet, cargo, rotorcraft and supersonic applications.

Appendix A
Public Law 108-176: *Vision 100–Century of Aviation Reauthorization Act*

Section 321: Report on Long-Term Environmental Improvements

(a) IN GENERAL – The Secretary of Transportation, in consultation with the Administrator of the National Aeronautics and Space Administration, shall conduct a study of ways to reduce aircraft noise and emissions and to increase aircraft fuel efficiency. The study shall –

(1) explore new operational procedures for aircraft to achieve those goals;

(2) identify both near-term and long-term options to achieve those goals;

(3) identify infrastructure changes that would contribute to attainment of those goals;

(4) identify emerging technologies that might contribute to attainment of those goals;

(5) develop a research plan for application of such emerging technologies, including new combustor and engine design concepts and methodologies for designing high bypass ratio turbofan engines so as to minimize the effects on climate change per unit of production of thrust and flight speed; and

(6) develop an implementation plan for exploiting such emerging technologies to attain those goals.

(b) REPORT – The Secretary shall transmit a report on the study to the Senate Committee on Commerce, Science, and Transportation and the House of Representatives Committee on Transportation and Infrastructure within 1 year after the date of enactment of this Act.

(c) AUTHORIZATION OF APPROPRIATIONS – There is authorized to be appropriated to the Secretary $500,000 for fiscal year 2004 to carry out this section.

Appendix B
List of Acronyms

ACARE	Advisory Council for Aeronautical Research in Europe
AERONET	Thematic Network of the European Commission on Aircraft Emissions and Reduction Technologies
AEAP	Atmospheric Effects of Aviation Program
AEE	FAA Office of Environment and Energy
ANCA	Aircraft Noise and Capacity Act
ASP	Airspace Systems Program (NASA)
CAEP	ICAO Committee on Aviation Environmental Protection
CEQ	Council on Environmental Quality
CO	Carbon monoxide
CO_2	Carbon Dioxide
COE	Center of Excellence, Partnership for Air Transportation Noise and Emissions Reduction (PARTNER)
DNL	Day-Night Noise Level
DOC	Department of Commerce
DoD	Department of Defense
DOI	Department of the Interior
DOT	Department of Transportation
EPA	Environmental Protection Agency
EU	European Union
FAA	Federal Aviation Administration
FICON	Federal Interagency Committee on Noise
GAO	General Accounting Office
GSE	Ground service equipment
HAPS	Hazardous air pollutants
ICAO	International Civil Aviation Organization
IPT	Integrated product team

JPDO	Joint Planning and Development Office
NASA	National Aeronautics and Space Administration
NGATS	Next Generation Air Transportation System
NOAA	National Oceanic and Atmospheric Administration
NOx	Oxides of Nitrogen
NPS	National Park Service
NRC	National Research Council
OST	Office of the Secretary of Transportation
OSTP	Office of Science and Technology Policy
PARTNER	Partnership for AiR Transportation Noise and Emissions Reductions
PM	Particulate matter
QAT	Quiet Aircraft Technology
REDAC	Research, Engineering and Development Advisory Committee
TRL	Technology readiness level
UEET	Ultra-Efficient Engine Technology Program
UHC	Unburned Hydrocarbons
VSP	Vehicle Systems Program (NASA)

Appendix C
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Appendix D
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Department of Commerce	Mr. Jon Montgomery
Department of Transportation	Ms. Camille Mittelholtz Mr. Arnie Konheim
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Airports Council International (ACI)	Mr. Richard Marchi
Air Transport Association (ATA)	Ms. Nancy Young Mr. Ray Brown (Delta Airlines) Ms. Leah Raney (Continental Airlines) Mr. John Begin (Northwest Airlines) Mr. Barry Brown (Southwest Airlines)

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