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AVIATION AND THE ENVIRONMENT

NextGen and Research and Development Are Keys to Reducing Emissions and Their Impact on Health and Climate

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Highlights

Highlights of GAO-08-706T, a testimony before the Subcommittee on Aviation, Committee on Transportation and Infrastructure, House of Representatives

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Why GAO Did This Study

Collaboration between the federal government and the aviation industry has led to reductions in aviation emissions, but growing air traffic has partially offset these reductions. The Federal Aviation Administration (FAA), together with the National Aeronautics and Space Administration (NASA), the Environmental Protection Agency (EPA), and others, is working to increase the efficiency, safety, and capacity of the national airspace system and at the same time reduce aviation emissions, in part, by transforming the current air traffic control system to the Next Generation Air Transportation System (NextGen). This effort involves new technologies and air traffic procedures that can reduce aviation emissions and incorporates research and development (R&D) on emissions-reduction technologies. Reducing aviation emissions is important both to minimize their adverse health and environmental effects and to alleviate public concerns about them that could constrain the expansion of airport infrastructure and aviation operations needed to meet demand.

This testimony addresses (1) the scope and nature of aviation emissions, (2) the status of selected key federal efforts to reduce aviation emissions, and (3) next steps and challenges in reducing aviation emissions. The testimony updates prior GAO work with FAA data, literature reviews, and interviews with agency officials, industry and environmental stakeholders, and selected experts.

To view the full product, including the scope and methodology, click on GAO-08-706T. For more information, contact Gerald L. Dillingham at (202) 512-2834 or dillinghamg@gao.gov.

What GAO Found

Aviation contributes a modest but growing proportion of total U.S. emissions, and these emissions contribute to adverse health and environmental effects. Aircraft and airport operations, including those of service and passenger vehicles, emit ozone and other substances that contribute to local air pollution, as well as carbon dioxide and other greenhouse gases that contribute to climate change. EPA estimates that aviation emissions account for less than 1 percent of local air pollution nationwide and about 2.7 percent of U.S. greenhouse gas emissions, but these emissions are expected to grow as air traffic increases.

Two key federal efforts, if implemented effectively, can help to reduce aviation emissions—NextGen initiatives in the near term and research and development over the longer term. For example, NextGen technologies and procedures, such as satellite-based navigation systems, should allow for more direct routing, which could improve fuel efficiency and reduce carbon dioxide emissions. Federal research and development efforts—led by FAA and NASA in collaboration with industry and academia—have achieved significant reductions in aircraft emissions through improved aircraft and engine technologies, and federal officials and aviation experts agree that such efforts are the most effective means of achieving further reductions in the longer term. Federal R&D on aviation emissions also focuses on improving the scientific understanding of aviation emissions and developing lower-emitting aviation fuels.

Next steps in reducing aviation emissions include managing NextGen initiatives efficiently; deploying NextGen technologies and procedures as soon as practicable to realize their benefits, including lower emissions levels; and managing a decline in R&D funding, in part, by setting priorities for R&D on NextGen and emissions-reduction technologies. Challenges in reducing aviation emissions include designing aircraft that can simultaneously reduce noise and emissions of air pollutants and greenhouse gases; encouraging financially stressed airlines to purchase more fuel-efficient aircraft and emissions-reduction technologies; addressing the impact on airport expansion of more stringent EPA air quality standards and growing public concerns about the effects of aviation emissions; and responding to proposed domestic and international measures for reducing greenhouse gases that could affect the financial solvency and competitiveness of U.S. airlines.

Sources of Aviation Emissions

Source: FAA.

Mr. Chairman and Members of the Subcommittee:

I appreciate the opportunity to testify before you on aviation emissions, one of the key sources of concern about the environmental effects of aviation. Over the past 30 years, the federal government, the aviation industry, and other private parties have worked collaboratively to achieve steady reductions in aircraft emissions.[1] Nevertheless, increases in air traffic, which have enhanced the nation's productivity and mobility, have partially offset these reductions, as more flights have produced more emissions and congestion has led to flight delays. According to the Federal Aviation Administration (FAA), this growth in air traffic will continue, with the number of flights increasing 20 percent by 2015 and 60 percent by 2030.[2] In light of these developments, concerns about the environmental effects of aviation emissions have persisted. Moreover, better scientific understanding of the potential health effects of certain aviation emissions and their contribution to climate change has intensified the public's concerns.

To accommodate the expected growth in air traffic, FAA is leading a multipronged, multiagency effort to increase the efficiency, safety, and capacity of the national airspace system. This effort includes transforming the current air traffic control system into the Next Generation Air Transportation System (NextGen)[3] and will require airport and runway expansion. The NextGen initiative incorporates research and development (R&D) on emissions-reduction technologies, alternative fuels, and cleaner and quieter air traffic management procedures. This R&D is necessary both to meet anticipated domestic and international environmental standards and to reduce the environmental impact of aviation. Meeting environmental standards can limit the adverse effects of aviation emissions on air quality and climate, and addressing public concerns about

[1]These emissions include airborne pollutants, which affect air quality, and greenhouse gases, primarily carbon dioxide, which are produced by the combustion of fossil fuel, and contribute to climate change.

[2]These figures are based on a long-range FAA forecast using 2006 as the baseline.

[3]See the list of related products at the end of this statement, especially GAO, *Next Generation Air Transportation System: Progress and Challenges in Planning and Implementing the Transformation of the National Airspace System*, GAO-07-649T (Washington, D.C.: Mar. 22, 2007.)

aviation emissions is necessary to avoid constraints on the expansion of aviation operations and airport infrastructure planned under NextGen.[4]

Under the National Environmental Policy Act of 1969, agencies evaluate the likely environmental effects of projects they are proposing using an environmental assessment or, if the projects likely would significantly affect the environment, a more detailed environmental impact statement.[5] FAA typically carries out one of these evaluations for federally financed airport construction projects, including the construction of federally subsidized runways. In addition, under the Clean Air Act's conformity provision, no federal agency may approve or provide financial assistance for any activity that does not conform to an applicable state implementation plan.[6] Therefore, FAA must evaluate whether a proposed federal action associated with an airport project conforms with the applicable state implementation plan before approving or funding the project.[7] In addition, the Clean Air Act mandates standards for mobile sources of emission, such as aircraft and the equipment that service them at airports. EPA sets emissions standards for aircraft and has chosen to adopt international emissions standards for aircraft set by the International Civil Aviation Organization (ICAO).[8]

As requested, my testimony today focuses on aviation emissions. It will address the following questions: (1) What are the scope and nature of aviation emissions? (2) What is the status of selected key federal efforts to address aviation emissions? and (3) What are some next steps and major challenges for the federal government, the aviation industry, and Congress

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[4]As we noted in our recent testimony before this Subcommittee, aviation noise has been a greater constraint on airport expansion efforts than aviation emissions, but we are limiting our discussion in this testimony to aviation emissions.

[5]42 U.S.C. §4332(2)(C).

[6]States are required to submit implementation plans to EPA for reducing emissions in areas that fail to meet the National Ambient Air Quality Standards set by EPA under the Clean Air Act for common air pollutants with health and environmental effects (known as criteria pollutants). Geographic areas that have levels of a criteria pollutant above those allowed by the standard are called nonattainment areas.

[7]42 U.S.C. §7506(c)(1) (The Conformity Provision).

[8]ICAO is an organization affiliated with the United Nations that aims to promote the establishment of international civilian aviation standards and recommended practices and procedures. FAA, as the U.S. representative to ICAO, in consultation with EPA, works with representatives from other countries to formulate aircraft emissions standards.

related to aviation emissions? My statement is based on previous GAO reports[9] updated with a synthesis of recent empirical literature and interviews with officials from FAA, the National Aeronautics and Space Administration (NASA), and the U.S. Environmental Protection Agency (EPA); representatives of aviation industry and environmental associations, and selected aviation emissions experts.[10] We balanced the selection of these experts to capture the views of the many different groups involved in aviation emissions reduction efforts and NextGen. We conducted our work from March to May 2008 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the study to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our study objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our study objectives.

Summary

Currently, aviation contributes a modest proportion of total emissions in the United States, but its share could increase in the future, and aviation emissions can have a detrimental effect on health and the environment. Aircraft are the primary source of aviation emissions, but airport operations, including those of service and passenger vehicles, also produce emissions. Together, aircraft operations in the vicinity of the airport and other airport sources emit nitrogen oxides, which lead to the formation of ground-level ozone (also known as smog), and other substances that contribute to local air pollution, as well as carbon dioxide and other greenhouse gases that rise into the atmosphere and contribute to climate change. Aircraft operations in the upper atmosphere are, however, the primary aviation-related source of greenhouse gas emissions. Currently, according to EPA estimates, aviation emissions account for less than 1 percent of local air pollution nationwide and about 2.7 percent of U.S. greenhouse gas emissions. This proportion is, however, expected to grow with projected increases in air traffic, despite expected improvements in fuel efficiency. Notably, according to FAA, emissions of

[9]See the list of related GAO products at the end of this statement, especially GAO, *Aviation and the Environment: Strategic Framework Needed to Address Challenges Posed by Aircraft Emissions*, GAO-03-252 (Washington, D.C.; Feb. 28, 2003).

[10]We are currently undertaking a study on aviation environmental trends, efforts, and challenges for this Subcommittee and the Subcommittee on Space and Aeronautics, Committee on Science and Technology, House of Representatives.

nitrogen oxides from aviation sources will increase by over 90 percent by 2025 if not addressed. This increase is likely to increase ozone, which aggravates respiratory ailments. Increases in air traffic also mean increases in carbon dioxide emissions and increases in aviation's contribution to climate change, according to the International Panel on Climate Change (IPCC).

Two key federal efforts, if implemented effectively, can help to reduce aviation emissions—near-term NextGen initiatives and R&D over the longer term to fully enable NextGen and reduce aircraft emissions. Some NextGen technologies and procedures, such as satellite-based navigation systems, should allow for more direct routing, which could improve fuel efficiency and reduce carbon dioxide emissions. According to FAA, the full implementation of NextGen could reduce greenhouse gas emissions from aircraft by up to 12 percent by 2025. Federal R&D efforts—led primarily by FAA and NASA and often conducted in collaboration with industry and academia—have achieved significant reductions in aircraft emissions over the last 30 years, and FAA and NASA officials and aviation experts agree that such efforts are the most effective means of achieving further reductions in the longer term. As part of the a national plan for aeronautics R&D, issued by the White House Office of Science and Technology Policy, the federal government supports a comprehensive approach to R&D on aviation emissions involving FAA, NASA, and other federal agencies that is intended both to improve scientific understanding of the impact of aviation emissions and to develop new technologies, fuels, and air traffic management approaches. Better understanding of the nature and impact of aviation emissions can inform the development of lower-emitting alternative fuels, more efficient air traffic management technologies and procedures, and more fuel-efficient aircraft engines.

Reducing aviation emissions includes steps that FAA and others can take to move the implementation of NextGen forward and to support R&D on NextGen and emissions-reduction technologies, as well as technical, financial, and regulatory challenges facing the federal government, the aviation industry, and Congress. One step for FAA is to ensure the efficiency of NextGen's management by, for example, addressing congressional leaders' and stakeholders' concerns about the program's management structure and authority. Another step for FAA is to further deploy, as soon as practicable, NextGen technologies and procedures, such as the more efficient takeoff and landing procedures now in use at a few airports, to realize their benefits and lower emissions levels. A third step, for FAA and NASA, is managing a decline in federal funding for aeronautics research, the research category that includes work on aviation emissions, new aircraft and engine technologies, and alternative fuels. As a result of this decline, NASA is now sometimes developing technologies to a lower maturity level than in the past, and the technologies are less ready for manufacturers to adopt them. The administration's reauthorization bill for FAA seeks some additional funding for an initiative that could lead to the earlier maturation of certain emissions-reduction technologies, but according to some experts, increased funding of the initiative could increase the probability of success and decrease the time needed to achieve that success. Challenges in reducing aviation emissions for the federal government, the aviation industry, and Congress include designing aircraft that can simultaneously reduce noise and emissions of air pollutants and greenhouse gases; encouraging financially stressed airlines to purchase more fuel-efficient aircraft and emissions-reduction technologies; addressing the impact on airport expansion of more stringent EPA air quality standards and growing public concerns about effects of aviation emissions; and responding to proposed domestic and international measures for reducing greenhouse gases that could affect the financial solvency and competitiveness of U.S. airlines.

Aviation's Small but Growing Proportion of Total Emissions Contributes to Health and Environmental Effects

Aviation-related activities contribute to local air pollution and produce greenhouse gases that cause climate change. Aircraft account for about 70 to 80 percent of aviation emissions, producing emissions that mainly affect air quality below 3,000 feet and increase greenhouse gases at higher altitudes. At ground level, airport operations, including those of motor vehicles[11] traveling to and from the airport, ground service equipment,[12] and stationary sources such as incinerators and boilers, also produce emissions. Together, aircraft operations in the vicinity of the airport and other airport sources produce emissions such as carbon monoxide, sulfur oxides, particulate matter, nitrogen oxides, unburned hydrocarbons, hazardous air pollutants,[13] and ozone[14] that contribute to air pollution. In addition, these sources emit carbon dioxide and other greenhouse gases

[11]Motor vehicles include cars and buses for airport operations and passenger, employee, and rental agency vehicles.

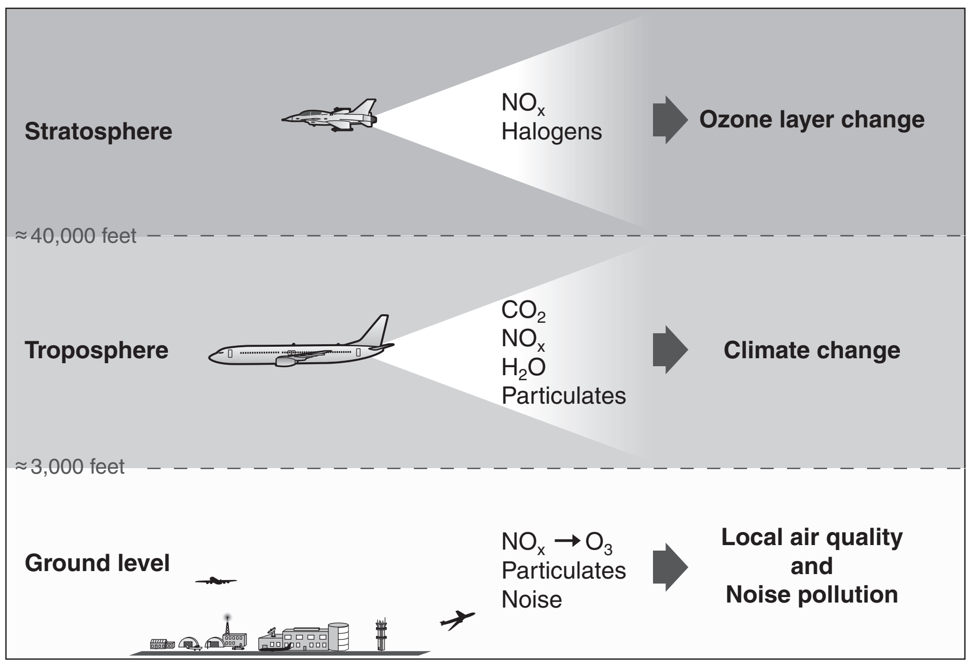
[12]Ground service equipment includes aircraft tugs, baggage and belt loaders, generators, lawn mowers, snow plows, loaders, tractors, air-conditioning units, and cargo moving equipment.

[13]Hazardous air pollutants from aviation activities include benzene and formaldehyde.

[14]Ground-level ozone is formed when nitrogen oxides and volatile organic compounds as well as other gases and substances are mixed and heated in the atmosphere.

that contribute to climate change, but aircraft operations in the upper atmosphere are the primary source of aviation-related greenhouse gases. Carbon dioxide is both the primary aircraft emission and the primary contributor to climate change. It survives in the atmosphere for over 100 years. Furthermore, other gases and particles emitted by aircraft—including water vapor, nitrogen oxides, soot, contrails,[15] and sulfate—can also have an impact on climate, but the magnitude of this impact is unknown, according to FAA. Figure 1 illustrates aviation's impact on air quality and climate.

Figure 1: Environmental Effects of Aviation Emissions and Noise



Source: GAO.

Currently, aviation accounts for a small portion of air pollutants and greenhouse gas emissions. Specifically, aviation emissions represent less than 1 percent of air pollution nationwide, but their impact on air quality could be higher in the vicinity of airports. In addition, aviation accounts for about 2.7 percent of the total U.S. contribution of greenhouse gas emissions, according to the Department of Transportation's Center for

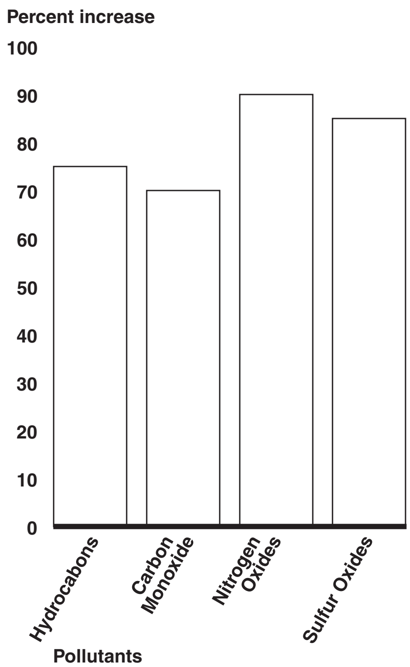
[15]Contrails are clouds and condensation trails that form when water vapor condenses and freezes around small particles (aerosols) in aircraft exhaust.

Climate Change and Environment. A 1999 study by the United Nations' Intergovernmental Panel on Climate Change (IPCC) estimated that global aircraft emissions generally accounted for approximately 3.5 percent of the warming generated by human activity.[16]

As air traffic increases, aviation's contribution to air pollution and climate change could also grow, despite ongoing improvements in fuel efficiency, particularly if other sectors achieve significant reductions. In addition, aviation's impact on air quality is changing as more fuel-efficient, quieter aircraft engines are placed in service. While new aircraft engine technologies have reduced fuel consumption, noise, and emissions of most pollutants, they have not achieved the same level of reductions in nitrogen oxide emissions, which contribute to ozone formation. According to FAA, nitrogen oxide emissions from aviation will increase by over 90 percent by 2025 without improvements in aircraft emissions technologies and air traffic management, and emissions of other air pollutants will also increase, as shown in figure 2. Additionally, aviation's greenhouse gas emissions and potential contribution to climate change is expected to increase. IPCC has estimated that aircraft emissions are likely to grow by 3 percent per year, outpacing the emissions reductions achieved through technological improvements. Furthermore, as emissions from other sources decline, aviation's contribution to climate change may become proportionally larger, according to FAA. Alternative fuels are not yet available in sufficient quantities for jet aircraft, as they are for some other uses, and therefore aviation cannot yet adopt this approach to reduce its greenhouse gas emissions (see discussion below on U.S. efforts to develop alternative fuels for aviation).

[16]Intergovernmental Panel on Climate Change, *Aviation and the Global Atmosphere* (1999).

Figure 2: FAA Analysis of Growth in Aviation Related Pollutants by 2025



Source: FAA.

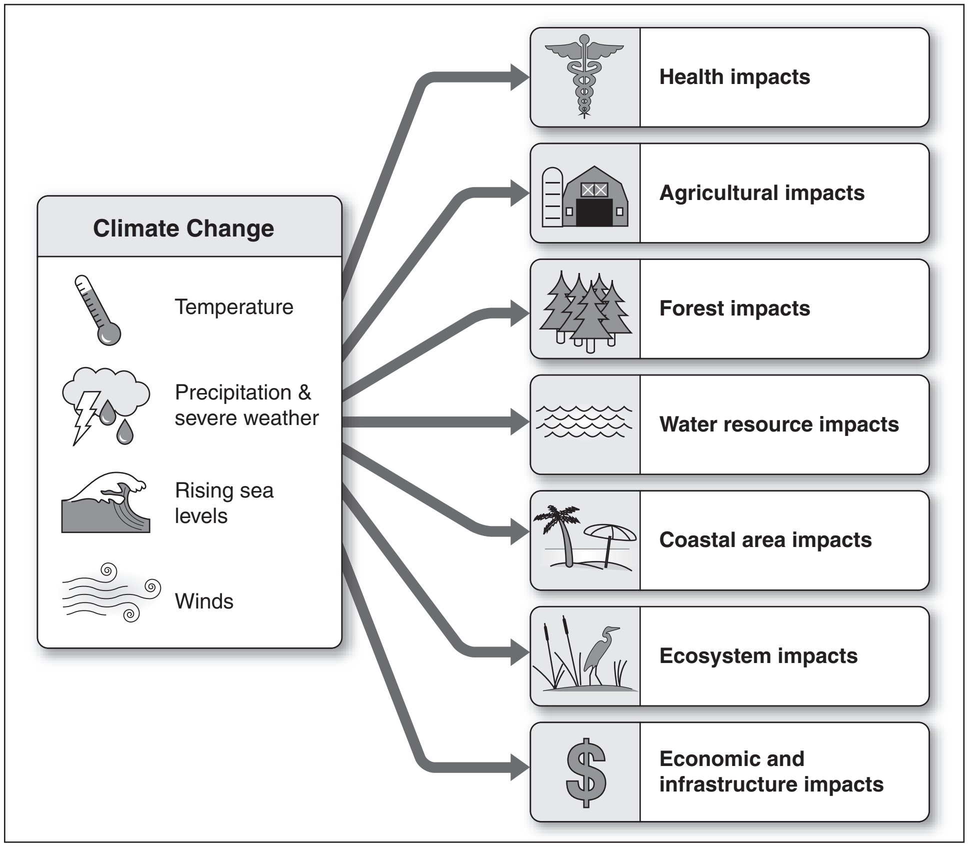
Note: According to FAA, the increases in aviation-related pollutants are baseline forecasts that do not account for potential improvements in aircraft technology and air traffic management.

Aviation emissions, like other combustible emissions, include pollutants that affect health. While it is difficult to determine the health effects of pollution from any one source, the nitrogen oxides produced by aircraft engines contribute to the formation of ozone, the air pollutant of most concern in the United States and other industrialized countries. Ozone has been shown to aggravate respiratory ailments. A National Research Council panel recently concluded that there is strong evidence that even short-term exposure to ozone is likely to contribute to premature deaths of people with asthma, heart disease, and other preexisting conditions. With improvements in aircraft fuel efficiency and the expected resulting increases in nitrogen oxide emissions, aviation's contribution to ozone formation may increase. In addition, aviation is associated with other air pollutants, such as hazardous air pollutants, including benzene and formaldehyde, and particulate matter, all of which can adversely affect health. Data on emissions of hazardous air pollutants in the vicinity of airports are limited, but EPA estimates that aviation's production of these pollutants is small relative to other sources, such as on-road vehicles. Nevertheless, according to EPA, there is growing public concern about the health effects of the hazardous air pollutants and particulate matter associated with aviation emissions. See appendix I for more detailed information on the health and environmental effects of aviation emissions.

Carbon dioxide and other greenhouse gas emissions from aircraft operations in the atmosphere, together with ground-level aviation emissions that gradually rise into the atmosphere, contribute to global warming and climate change. IPCC's most recent report[17] documents mounting evidence of global warming and projects the potential catastrophic effects of climate change. As figure 6 shows, climate change affects precipitation, sea levels, and winds as well as temperature, and these changes in turn will increasingly affect economies and infrastructure around the world.

[17]Intergovernmental Panel on Climate Change, Fourth Assessment Report, *Summary for Policy Makers*, Cambridge University Press, Cambridge, UK, November 2007.

Figure 3: Concerns about the Effects of Climate Change



Source: EPA and FAA.

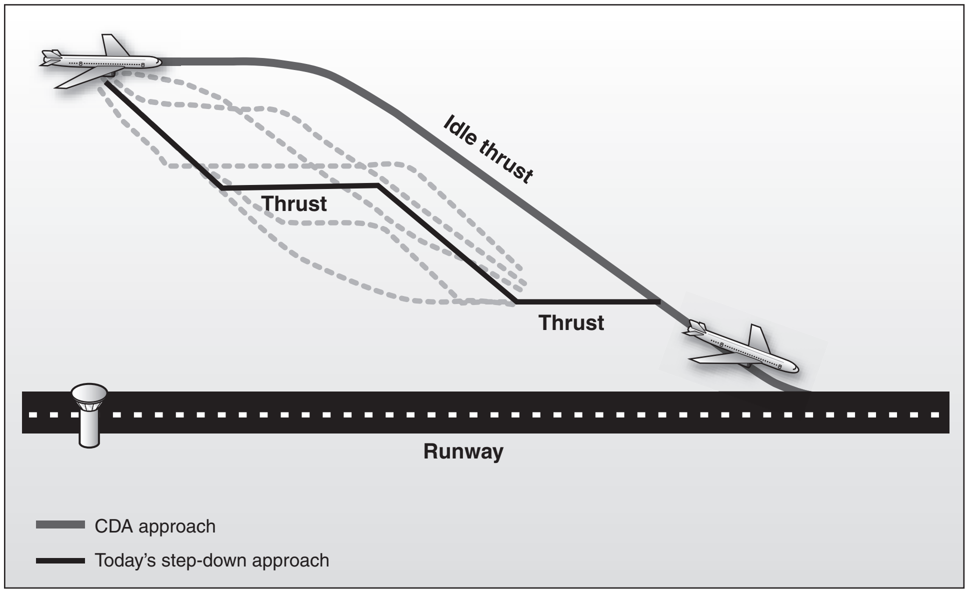
Key Federal Efforts to Address Aviation Emissions Include Near-Term Operational Changes and Longer-Term R&D Initiatives

Two key federal efforts, if implemented effectively, can help to reduce aviation emissions—near-term NextGen initiatives and an array of R&D programs over the longer term to fully enable NextGen and to reduce aircraft emissions. The NextGen initiatives are primarily intended to improve the efficiency of the aviation system so that it can handle expected increases in air traffic, but these initiatives can also help reduce aviation emissions. In addition, the federal government, led by FAA and NASA, has longer-term R&D programs in place to improve the scientific understanding of the impact of aviation emissions in order to inform decisions about emissions-reduction strategies, explore potential emissions-reducing alternative fuels, and develop NextGen and aircraft emissions-reduction technologies.

NextGen Initiatives Have the Potential to Help Reduce Emissions

Technologies and procedures that are being developed as part of NextGen to improve the efficiency of flight operations can also reduce aircraft emissions. According to FAA, the implementation of NextGen could reduce greenhouse gas emissions from aircraft by up to 12 percent. One NextGen technology, considered a centerpiece of NextGen, is the Automatic Dependent Surveillance-Broadcast (ADS-B) satellite aircraft navigation system. ADS-B is designed, along with other navigation technologies, to enable more precise control of aircraft during en route flight, approach, and descent. ADS-B will allow for closer and safer separations between aircraft and more direct routing, which will improve fuel efficiency and reduce carbon dioxide emissions. This improved control will also facilitate the use of air traffic control procedures that will reduce communities' exposure to aviation emissions and noise. One such procedure, Continuous Descent Arrivals (CDA), allows aircraft to remain at cruise altitudes longer as they approach destination airports, use lower power levels, and thereby lower emissions and noise during landings. Figure 3 shows how CDA compares with the current step-down approach to landing, in which aircraft make alternate short descents and forward thrusts, which produce more emissions and noise than continuous descents. A limited number of airports have already incorporated CDA into their operations. For example, according to officials from Los Angeles International Airport, nearly 25 percent of landings at their airport use CDA procedures in one of the airport's standard terminal approaches. In addition, United Parcel Service plans to begin using a nighttime CDA procedure, designed and tested at the Louisville International Airport, for its hub operations.

Figure 4: Comparison of CDA and Current Step-Down Approach



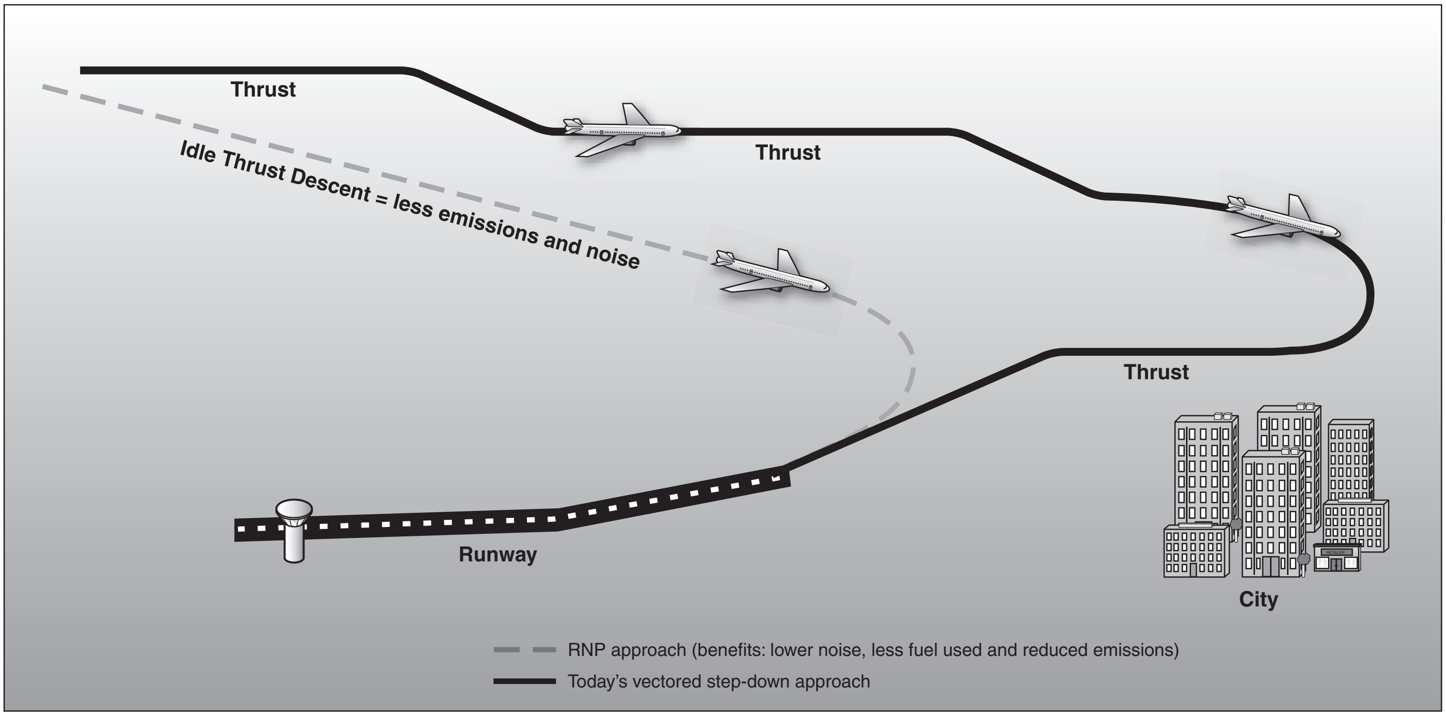
Sources: Naverus and AVTECH.

Note: Continuous Descent Arrivals keep aircraft higher for longer and have them descend at near-idle power to touchdown. Optimal profiles are not always possible, especially at busy airports.

Two closely associated NextGen initiatives, Area Navigation (RNAV) and Required Navigation Performance (RNP), have the potential to modify the environmental impact of aviation by providing enhanced navigational capability to the pilot. RNAV equipment can compute an airplane's position, actual track, and ground speed, and then provide meaningful information on the route of flight selected by the pilot. RNP will permit the airplane to descend on a precise route that will allow it to avoid populated areas, reduce its consumption of fuel, and lower its emissions of carbon dioxide and nitrogen oxides.[18] See figure 4. Currently, over 350 RNAV/RNP procedures are available at 54 airports, including Dallas/Fort Worth, Miami International, Washington Dulles, and Atlanta Hartsfield.

[18]A critical component of RNP is the ability of the navigation system to monitor its achieved navigation performance and to identify for the pilot if an operational requirement is or is not being met during an operation.

Figure 5: Comparison of RNP and Current Step-Down Approach



Sources: Naverus and AVTECH.

Note: An RNP approach and path allows for idle-thrust, continuous descent instead of today's step-down approaches with vectors. RNP precision and curved-approach flexibility can shift flight paths to avoid populated areas.

Still another NextGen initiative, High-Density Terminal and Airport Operations, is intended to improve the efficiency of aircraft operations at busy airports, and, in the process, reduce emissions. At high-density airports, the demand for access to runways is high, and arrivals and departures take place on multiple runways. The combination of arrivals, departures, and taxiing operations may result in congestion, which in turn produces delays, emissions, and noise as aircraft wait to take off and land. Under the High-Density Terminal and Airport Operations initiative, which FAA has just begun to implement, aircraft arriving and departing from different directions would be assigned to multiple runways and safely merged into continuous flows despite bad weather and low visibility. To guarantee safe separation, these airports would need enhanced navigation capabilities and controllers with access to increased automation. Under this initiative, aircraft would also move more efficiently on the ground, using procedures that are under development to reduce spacing and separation requirements and improve the flow of air traffic into and out of busy metropolitan airspace. More efficient aircraft movement would increase fuel efficiency and reduce emissions and noise. Although the implementation of this initiative is in the early stages, FAA has identified the R&D needed to move it forward.

Technologies and procedures planned for NextGen should also help improve the efficiency of flights between the United States and other nations, further reducing emissions, particularly of greenhouse gases. A test program scheduled to begin in the fall of 2008, known as the Atlantic Interoperability Initiative to Reduce Emissions (AIRE), sponsored by FAA and the European Commission, Boeing, and Airbus, will involve gate-to-gate testing of improved procedures on the airport surface, during departures and arrivals, and while cruising over the ocean. Some of the procedures to be tested will use technologies such as ADS-B. A similar effort—the Asia and South Pacific Initiative to Reduce Emissions (ASPIRE)—was launched earlier this year, involving the United States, Australia, and New Zealand.

Federal R&D Focuses on Long-Term Approaches to Addressing Aviation Emissions

We have previously reported[19] that the federal government and industry have achieved significant reductions in some aircraft emissions, such as carbon dioxide, through past R&D efforts, and federal officials and aviation experts agree that such efforts are the most effective means of achieving further reductions in the longer term[20]. As part of the a national plan for aeronautics R&D, issued by the White House Office of Science and Technology Policy, the federal government supports a comprehensive approach to R&D on aviation emissions that involves FAA, NASA, and other federal agencies. According to FAA, this approach includes efforts to improve the scientific understanding of the nature and impact of aviation emissions and thereby inform the development of more fuel-efficient aircraft, of alternative fuels that can reduce aircraft emissions, and of air traffic management technologies that further improve the efficiency of aviation operations. NASA, industry, and academia are important partners in these efforts. Notably, however, the development of breakthrough technologies, such as highly fuel-efficient aircraft engines that emit fewer greenhouse gases and air pollutants, is expensive and can take a long time,

[19]GAO-03-252.

[20]Alternatively, some scientists studying options for addressing climate change believe that a price on emissions would represent the most effective means of achieving reductions overall.

both to conduct the research and to implement the new technologies in new aircraft designs and introduce these new aircraft into the fleet. Successfully developing these technologies also requires the support and cooperation of stakeholders throughout the aviation industry.

FAA Supports Research on Improving the Scientific Understanding of Aviation Emissions and on Alternative Fuels

Improving the scientific understanding of aviation emissions can help guide the development of approaches to reducing emissions by improving aircraft manufacturers' and operators' and policy makers' ability to assess the environmental benefits and costs of alternative policy measures. Such an assessment can then lead to the selection of the alternative that will achieve the greatest net environmental benefits. For example, one technology might greatly increase fuel efficiency, but produce higher nitrogen oxide emissions than another, somewhat less fuel-efficient technology. Overall, a cost benefit analysis might indicate that the less fuel-efficient technology would produce greater net benefits for the environment.

FAA currently supports several recent federal efforts to better quantify aviation emissions and their impact through improvements in emissions measurement techniques and modeling capability. One of these efforts is FAA's Partnership for Air Transportation and Emissions Reduction (PARTNER) Center of Excellence.[21] Created in 2003, PARTNER carries on what representatives of airlines, aircraft and engine manufacturers, and experts in aviation environmental research have described as a robust research portfolio. This portfolio includes efforts to measure aircraft emissions and to assess the human health and welfare risks of aviation emissions and noise. For example, researchers are developing an integrated suite of three analytical tools—the Environmental Design Space, the Aviation Environmental Design Tool, and the Aviation Environmental Portfolio Management Tool – that can be used to identify interrelationships between noise and emissions. Data from these three tools, together with the Aviation Environmental Design tool being developed by the Volpe National Transportation Systems Center and

[21]FAA Centers of Excellence are FAA partnerships with universities and affiliated industry associations and businesses throughout the country that conduct aviation research in a number of areas, including advanced materials, aircraft noise, and aircraft emissions. PARTNER is a cooperative research organization that includes 10 collaborating universities and approximately 50 advisory board members who represent aerospace manufacturers, airlines, airports, state and local governments, and professional and community groups. NASA, FAA, and Transport Canada are sponsors of PARTNER. The collaborating universities and organizations represented on the advisory board provide equal matches for federal funds for research and other activities.

others, will allow for assessing the benefits and costs of aviation environmental policy options. Another R&D initiative, the Airport Cooperative Research Program (ACRP),[22] conducts applied research on aviation emissions and other environmental issues facing airports. The program is managed by the National Academies of Science through its Transportation Research Board under a contract with FAA, which provided $10 million for the program in both 2007 and 2008 and is seeking to increase these investments through its reauthorization to specifically focus on aviation environmental issues. Several of the emissions-related projects undertaken through ACRP have concentrated on developing methods to measure particulate matter and hazardous air pollutants at airports in order to identify the sources of these pollutants and determine whether their levels could have adverse health effects. FAA has also developed an Aviation Emissions Characterization roadmap to provide a systematic process to enhance understanding of aviation's air quality emissions, most notably particulate matter and hazardous air pollutants. In addition, FAA, in conjunction with NASA and the National Oceanic and Atmospheric Administration, launched the Aviation Climate Change Research Initiative to develop the scientific understanding necessary for informing efforts to limit or reduce aviation greenhouse gas emissions.

Another effort, the Commercial Aviation Alternative Fuels Initiative (CAAFI),[23] led by FAA, together with airlines, airports, and manufacturers, is intended to identify and eventually develop alternative fuels for aviation that could lower emissions of greenhouse gases, and other pollutants; increase fuel efficiency; and reduce U.S. dependence on foreign oil. CAAFI supports research on low-carbon fuel from sources such as plant oils, algae, and biomass that are as safe as petroleum-based fuel and compare favorably in terms of environmental impact. Part of the research will involve assessing the environmental impact of alternative fuels to determine whether their use could reduce emissions of pollutants that affect climate and air quality. The research will also assess the impact of producing these fuels on the overall carbon footprint. The CAAFI sponsors have set goals for certifying a 50 percent synthetic fuel for aviation use in

[22]ACRP was authorized in 2003 as part of Vision 100—Century of Aviation Reauthorization Act, Pub. L. 108-176, Section 712 (Dec 12, 2003).

[23]CAAFI, established in October 2006, is sponsored by the Air Transport Association, the Aerospace Industries Association, and the Airports Council International-North America under the direction of FAA, and involves stakeholders from industry, universities, and other federal agencies, including NASA.

2008, a 100 percent synthetic fuel for use by 2010, and a biofuel made from renewable resources such as palm, soy, or algae oils. As part of CAAFI, Virgin Atlantic Airlines, together with Boeing, has tested a blend of kerosene (normal jet fuel) and biofuels in a flight from London to Amsterdam, and Continental, in association with Boeing and jet engine manufacturer General Electric, is planning a similar test in 2009.

NASA Conducts Fundamental Aeronautics R&D in Support of NextGen, Including Efforts That Can Help Lower Emissions

NASA has devoted a substantial portion of its aeronautical R&D program to the development of technologies critical to the implementation of NextGen, as well as new aircraft and engine technologies, both of which can help reduce aviation emissions.

NASA has three main aeronautics research programs – Fundamental Aeronautics, Aviation Safety, and Airspace Systems – each of which contributes directly and substantially to NextGen. For example, the Airspace Systems program supports research on air traffic management technologies for NextGen, and the Fundamental Aeronautics program focuses on removing environmental and performance barriers, such as noise and emissions, that could constrain the capacity enhancements needed to accommodate projected air traffic increases. Appendix II describes in more detail how NASA's aeronautics R&D programs support the implementation of NextGen.

NASA also works with aircraft and aircraft engine manufacturers to increase fuel efficiency and reduce emissions. Their efforts have contributed to a number of advancements in aircraft engine and airframe technology, and NASA's R&D on emissions-reduction technologies continues. NASA has set technology-level goals for reducing greenhouse gases, nitrogen oxides, and noise, which have become part of the U.S. National Aeronautics Plan. For example, the plan includes a goal for developing technologies that could reduce nitrogen oxide emissions during landings and takeoffs by 70 percent[24] below the ICAO current standard. The plan also sets a goal of increasing fuel efficiency (and thereby decreasing greenhouse gases emissions) by 33 percent. These technologies would be incorporated in the next generation of aircraft, which NASA refers to as N+1,[25] by 2015. However, as NASA officials note,

[24]This goal is at a pressure ratio of 30, over the ICAO standard adopted at the Committee on Aviation Environmental Protection's sixth meeting (CAEP 6), with commensurate reductions over the full pressure ratio range.

[25]"N" refers to the current generation of tube-and-wing aircraft entering service in 2008, such as the Boeing 787.

these goals must be viewed within the context that each of the goals can be fully met only if it is the only goal. For example, the goal for reducing nitrogen oxides can be fully achieved only at the expense of the goals for lowering greenhouse gas emissions and noise, because it is technologically challenging to design aircraft that can simultaneously reduce all of these environmental impacts.

For the longer term (2020), NASA is focusing on developing tools and technologies for use in the design of advanced hybrid-wing body aircraft, the following generation of aircraft, or N+2. Emissions from these aircraft would be in the range of 80 percent below the ICAO standard for nitrogen oxide emissions during landings and takeoffs, and fuel consumption would be 40 percent less than for current aircraft. The U.S. aircraft and engine manufacturing industry has also set goals for reducing aircraft emissions in the engines the industry plans to produce. According to the Aerospace Industries Association, which represents this industry, its members have set a goal of reducing carbon dioxide emissions by 15 percent in the next generation of aircraft while continuing to significantly reduce nitrogen oxide emissions and noise.

The development of aircraft technologies such as those that NASA is currently working on to reduce emissions can take a long time, and it may be years before the technologies are ready to be incorporated into new aircraft designs. According to FAA, the development process generally takes 12 to 20 years. For example, the latest Pratt and Whitney engine, the geared turbofan, which is expected to achieve significant emissions and noise reductions, took 20 years to develop.

Several Steps Can Be Taken to Help Reduce Aviation Emissions, but Challenges Remain to Be Addressed

Reducing aviation emissions includes steps that FAA and others can take to move the implementation of NextGen forward and support R&D on NextGen and emissions-reduction technologies, as well as technical, financial, regulatory challenges facing the federal government, the aviation industry, and Congress.

Expediting the Implementation of NextGen Can Help Reduce Aviation Emissions

Implementing NextGen expeditiously is essential to handle the projected growth in air traffic efficiently and safely, and in so doing, help to reduce aircraft emissions. Steps to advance NextGen's implementation include management improvements and the deployment of available NextGen components.

Management Improvements Can Move NextGen Forward More Efficiently

Several management actions are important to advance the implementation of NextGen. One such action is to establish a governance structure within FAA that will move NextGen initiatives forward efficiently and effectively. FAA has begun to establish a governance structure for NextGen, but it may not be designed to give NextGen initiatives sufficient priority to ensure the system's full implementation by 2025. Specifically, FAA's implementation plan for NextGen is called the Operational Evolution Partnership (OEP). The manager responsible for OEP is one of nine Vice Presidents who report to the Chief Operating Officer (COO) of FAA's Air Traffic Organization (ATO), who reports directly to the FAA Administrator. While the manager responsible for OEP is primarily responsible for implementing NextGen, other Vice Presidents are responsible for NextGen-related activities in their designated areas. In addition, the FAA managers responsible for airports and aviation safety issues are Associate Administrators who report through the Deputy FAA Administrator to the FAA Administrator. Some of the activities for which these Associate Administrators are responsible are critical to NextGen's implementation, yet there is no direct line of authority between the OEP manager and these activities.

Some congressional leaders and other stakeholders, including aviation industry representatives and aviation experts, view FAA's management structure for NextGen as too diffuse. Some of the stakeholders have called for the establishment of a position or NextGen program office that reports directly to the FAA Administrator to ensure accountability for NextGen results. These stakeholders have expressed frustration that a program as large and important as NextGen does not follow the industry practice of having one person with the authority to make key decisions. They point out that although the COO is nominally in charge of NextGen, the COO must also manage FAA's day-to-day air traffic operations and may therefore not be able to devote enough time and attention to managing NextGen. In addition, these stakeholders note that many of NextGen's capabilities span FAA operational units whose heads are on the same organizational level as the head of OEP or are outside ATO, and they believe that an office above OEP and these operational units is needed. In prior work, we have found that programs can be implemented most efficiently when managers are empowered to make critical decisions and are held accountable for results.[26]

Another management action is needed to help ensure that FAA acquires the skills required for implementation, such as contract management and systems integration skills. Because of the scope and complexity of the NextGen implementation effort, FAA may not have the in-house expertise to manage it without assistance. In November 2006, we recommended that FAA examine its strengths and weaknesses and determine whether it has the technical expertise and contract management expertise that will be needed to define, implement, and integrate the numerous complex programs inherent in the transition to NextGen.[27] In response to our recommendation, FAA has contracted with the National Academy of Public Administration (NAPA) to determine the mix of skills and number of skilled persons, such as technical personnel and program managers, needed to implement the new OEP and to compare those requirements with FAA's current staff resources. In December 2007, NAPA provided FAA with its report on the types of skills FAA will require to implement NextGen, and it has undertaken a second part of the study that focuses on identifying any skill gaps between FAA's current staff and the staff that would be required to implement NextGen.[28] NAPA officials told us that they expect to publish the findings of the second part of the study in the summer of 2008. We believe this is a reasonable approach that should help FAA begin to address this challenge as soon as possible. It may take considerable time to select, hire, train, and integrate into the NextGen initiative what could be a large number of staff.

We have also identified potential approaches for supplementing FAA's capabilities, such as having FAA contract with a lead systems integrator

[26]See GAO, *Best Practices: Better Support of Weapon System Program Managers Needed to Improve Outcomes*, GAO-06-110 (Washington, D.C.: Nov. 30, 2005). In this study of private-sector best practices that could be applied to federal programs,[26] we found that program managers at highly successful companies were empowered to decide whether programs were ready to move forward and to resolve problems and implement solutions. In addition, program managers were held accountable for their choices.

[27]GAO, *Next Generation Air Transportation System: Progress and Challenges Associated with the Transformation of the National Airspace System*, GAO-07-25 (Washington, D.C.: Nov. 13, 2006).

[28]NAPA, *Workforce Needs Analysis for the Next Generation Air Transportation System (NEXTGEN): Preliminary Findings and Observations* (Washington, D.C.: December 2007).

(LSI)–that is, a prime contractor who would help to ensure that the discrete systems used in NextGen will operate together and whose responsibilities may include designing system solutions, developing requirements, and selecting major system and subsystem contractors.[29] However, this approach would require careful oversight to ensure that the government's interests are protected and could pose significant project management and oversight challenges for the Joint Planning and Development Office (JPDO), the organization within FAA responsible for planning NextGen, and for FAA.

Deploying Available NextGen Components Can Demonstrate Their Ability to Operate Together and Achieve Anticipated Efficiencies

Moving from planning to implementing some components of NextGen can begin to demonstrate the potential of the system as well as reduce congestion in some areas of the country, thereby also reducing emissions. Many of the technologies and procedures planned for NextGen are already available, and a few have been implemented individually, such as the CDA procedures in use in Los Angeles and Louisville and ADS-B in Alaska. However, the available technologies and procedures have not yet been deployed simultaneously to demonstrate that they can be operated safely as an integrated suite of technologies and procedures in the national airspace system. Several stakeholders have suggested that FAA consider a gradual rollout of NextGen technologies and procedures in a particular area. For example ADS-B technologies, CDA and RNAV/RNP procedures, and high-density airport operations could be deployed in a defined area of the current system, possibly in sequence over time, to test their combined use and demonstrate the safety of an integrated suite of NextGen advancements. Such a graduated rollout is sometimes referred to as "NextGen Lite." FAA is currently considering a demonstration project in Florida and Georgia, in which it, together with aviation equipment manufacturers and municipalities, would use the NextGen capabilities of ADS-B, RNAV, and RNP for on-demand air taxi fleet[30] operations. As other NextGen capabilities, such as System-Wide Information Management (SWIM),[31] are deployed and as air taxi fleet operations move to other airports and regions, the demonstration will be expanded to include those

[29]GAO-07-25.

[30]Air taxis are small aircraft that can be hired to carry passengers or cargo and are regulated under Part 135 of the Federal Aviation Regulations.

[31]SWIM is information-management architecture for the national airspace system, acting as its "World-Wide Web." SWIM will manage surveillance, weather, and flight data, as well as aeronautical and system status information and will provide the information securely to users.

new capabilities and other airports and regions. According to the airlines and other stakeholders we interviewed, a demonstration of the successful integration of NextGen capabilities and of efficiencies resulting from their use would give the airlines an incentive to equip their aircraft with NextGen technologies. They could then lower their costs by reducing their fuel consumption and decrease the impact of their operations on the environment. The findings from our research indicate that such regional or targeted demonstrations could accelerate the delivery of NextGen benefits while helping to ensure safe operations within the current system. In addition, demonstrations can increase stakeholders' confidence in the overall NextGen initiative.

Resolving Aeronautics R&D Funding Issues Is a Further Step in Addressing Aviation Emissions

Federal funding for aeronautics research, the category that includes work on aviation emissions, has declined over the past decade, particularly for NASA, which historically provided most of the funding for this type of research. NASA's current aeronautics research budget is about half of what it was in the mid-1990s. Moreover, the budget request for aeronautics R&D for fiscal year 2009 is $447 million, or about 25 percent less than the $594 million provided in fiscal year 2007. (See table 1.) According to NASA, about $280 million of the proposed $447 million would contribute to NextGen. In addition, according to NASA officials, a significant portion of the funding for subsonic fixed-wing aircraft is directed toward emissions-related research, and many other research efforts contribute directly or indirectly to potential emissions-reduction technologies.

Table 1: The President's Budget for NASA's Aeronautics Programs for Fiscal Years 2007 and 2008 and Budget Projections for Fiscal Years 2009 through 2013

(Dollars in millions)

	Fiscal year						
	Enacted		Requested	Proposed			
Program	**2007**	**2008**	**2009**	**2010**	**2011**	**20112**	**2013**
Aviation Safety							
Integrated Vehicle Health Management	30.7	22.2	19.7	19.9	18.8	18.6	19.2
Aging Aircraft	14.9	10.0	10.6	11.3	11.2	12.0	12.4
Integrated Resilient Aircraft Control	22.2	15.3	17.1	18.5	19.0	18.2	18.8
Integrated Intelligent Flight Deck Technologies	19.5	19.3	15.2	16.3	16.0	15.7	16.1
Subtotal	**87.3**	**66.5**	**62.6**	**65.9**	**65.0**	**64.5**	**66.5**
Airspace Systems							
NextGen – Airspace	85.1	83.3	61.3	56.0	57.3	58.5	60.8
NextGen – Airportal	17.4	16.8	13.3	16.7	16.9	16.9	17.5
Subtotal	**102.5**	**100.1**	**74.6**	**72.7**	**74.2**	**75.4**	**78.4**
Fundamental Aeronautics							
Subsonic – Rotary Wing	36.1	30.8	25.8	26.6	26.7	26.9	28.0
Subsonic – Fixed Wing	133.9	119.9	108.4	105.3	107.6	109.1	111.5
Supersonics	67.7	53.0	44.0	44.9	44.3	45.2	46.6
Hypersonics	92.8	66.2	57.3	56.4	56.5	57.4	58.4
Subtotal	**330.4**	**269.9**	**235.4**	**233.2**	**235.2**	**238.6**	**244.6**
Aeronautics Test Program							
Aero Ground Test Facilities	48.5	50.0	48.2	49.4	50.8	51.0	51.0
Flight Operations and Test Infrastructure	25.0	25.1	25.6	26.4	27.2	27.2	27.2
Subtotal	73.5	75.1	73.9	75.8	78.0	78.2	78.2
Total	**593.8**	**511.7**	**446.5**	**447.5**	**452.4**	**456.7**	**467.7**

Source: NASA.

Note: Most of the research on aircraft emissions reductions that NASA performs is funded through the Fundamental Aeronautics – Fixed Wing program.

As its funding for aeronautics R&D has declined, NASA has emphasized fundamental research, which serves as the basis for developing technologies and tools that can later be integrated into aviation systems, and has focused less on developmental and demonstration work. As a result, NASA is now sometimes developing technologies to a lower maturity level than in the past, and the technologies are less ready for manufacturers to adopt them, resulting in a gap in the research needed to bring technologies to a level where they can be transferred to industry for further development. Failure to address this gap could postpone the development of emissions-reduction technologies.

As a partial response to the gap, the administration has proposed some additional funding for FAA that could be used to further develop NASA's and others' emissions- and noise reduction technologies. Specifically, FAA's reauthorization proposal seeks $111 million through fiscal year 2011 for the CLEEN Engine and Airframe Technology Partnership,[32] which FAA officials said is intended to provide for earlier maturation of emissions and noise technologies while NASA focuses on longer-term fundamental research on noise and emissions. The CLEEN partnership, which is also contained in the House's FAA reauthorization bill,[33] would create a program for the development and maturation of certifiable engine and airframe technologies for aircraft over the next 10 years which would reduce aviation noise and emissions. The legislation would require the FAA Administrator, in coordination with the NASA Administrator, to establish objectives for developing aircraft technology outlined in the legislation. The technology requested to be developed would increase aircraft fuel efficiency enough to reduce greenhouse gas emissions by 25 percent relative to 1997 subsonic jet aircraft technology, and, without increasing other gaseous or particle emissions, reduce takeoff-cycle nitrogen oxide emissions by 50 percent relative to ICAO's standard. Although FAA's reauthorization bill has not yet been enacted, the administration's proposed fiscal year 2009 budget includes $10 million for the CLEEN program.

The CLEEN program would be a first step toward further maturing emissions and noise reduction technologies, but experts agree that the proposed funding is insufficient to achieve needed emissions reductions. While acknowledging that CLEEN would help bridge the gap between NASA's R&D and manufacturers' eventual incorporation of technologies into aircraft designs, aeronautics industry representatives and experts we consulted said that the program's funding levels may not be sufficient to attain the goals specified in the proposal. According to these experts, the proposed funding levels would allow for the further development of one or possibly two projects. Moreover, in one expert's view, the funding for these projects may be sufficient only to develop the technology to the level that achieves an emissions-reduction goal in testing, not to the level required for the technology to be incorporated into a new engine design. Nevertheless, according to FAA and some experts we consulted, the CLEEN program amounts to a pilot project, and if it results in the development of emissions-reduction technologies that can be introduced

[32]CLEEN stands for continuous lower energy emissions and noise.

[33]H.R. 2881.

into aircraft in the near future, it could lead to additional funding from the government or industry for such efforts.

FAA and NASA have identified the R&D that is needed for NextGen, but have not determined what needs to be done first, at what cost, to demonstrate and integrate NextGen technologies into the national airspace system. Completing this prioritization is critical to avoid spending limited funds on lower-priority efforts or conducting work out of sequence. Once the identified R&D has been prioritized and scheduled, cost estimates can be developed and funds budgeted. Prioritizing research needs is an essential step in identifying the resources required to undertake the research.

The European Union is investing substantially in R&D that can lead to fuel-efficient, environmentally friendly aircraft. In February 2008, the European Union announced the launch of the Clean Sky Joint Technology Initiative, with total funding of $2.4 billion over 7 years—the European Union's largest-ever research program. The initiative establishes a Europe-wide partnership between industry, universities, and research centers and aims to reduce aircraft emissions of carbon dioxide and nitrogen oxides by up to 40 percent and aircraft noise levels by 20 decibels. According to FAA, it is difficult to compare funding levels for U.S. and European R&D efforts because of differences in program structures and funding mechanisms, Nevertheless, foreign government investments of such magnitude in R &D on environmentally beneficial technologies could reduce the competitiveness of the U.S. aircraft manufacturing industry, since greater investments are likely to lead to greater improvements in fuel efficiency and keep U.S. aircraft manufacturers competitive in the global economy as well as reducing aviation's impact on the environment.

Reducing the Impact of Aviation Emissions Poses Technical, Financial, and Regulatory Challenges

Reducing aviation emissions will require technological advances, the integration of lower-emitting aircraft and NextGen technologies into airline fleets, and strengthened or possibly new regulations to improve air quality and limit greenhouse gas emissions. Fulfilling these requirements will pose challenges to aviation because of the technical difficulties involved in developing technologies that can simultaneously address air pollutants, greenhouse gases, and noise; constraints on the airline industry's resources to invest in new aircraft and technologies needed to reduce emissions and remain competitive; and the impact that emissions regulations can have on the aviation system's expansion and the financial health of the aviation industry.

Simultaneously Addressing Air Pollutants, Greenhouse Gases, and Noise from Aircraft Presents Technical Challenges

Although the aviation industry has made strides in lowering emissions, more reductions are needed to keep pace with the projected growth in aviation, and achieving these reductions will be technically challenging. NASA's efforts to improve jet engine designs illustrate this challenge: While new designs have increased fuel efficiency, reduced most emissions, and lowered noise, they have not achieved comparable reductions in nitrogen oxide emissions. Nitrogen oxide emissions have increased because new aircraft engines operate at higher temperatures, producing more power with less fuel and lower carbon dioxide and carbon monoxide emissions, but also producing higher nitrogen oxide emissions, particularly during landings and takeoffs, when engine power settings are at their highest. It is during the landing/takeoff cycle that nitrogen oxide emissions also have the greatest impact on air quality. As discussed, nitrogen oxides contribute to ground-level ozone formation. Similarly, as we noted in a report on NASA's and FAA's aviation noise research earlier this year,[34] it is technologically challenging to design aircraft engines that simultaneously produce less noise and fewer greenhouse gas and other emissions. Although it is possible to design such engines, the reductions in greenhouse gases could be limited in engines that produce substantially less noise. NASA and industry are working on technologies to address these environmental trade-offs. For example, the Pratt & Whitney geared turbo fan engine that we mentioned earlier is expected to cut nitrogen oxide emissions in half while also improving fuel efficiency and thereby lowering carbon dioxide emissions. Nevertheless, it remains technologically challenging to design aircraft that can reduce one environmental concern without increasing another.

In a 2004 report to Congress on aviation and the environment,[35] FAA noted that the interdependencies between various policy, technological, and operational options for addressing the environmental impacts of aviation and the full economic consequences of these options had not been appropriately assessed. However, in recent years, FAA has made progress in this area, including its sponsorship of the previously mentioned PARTNER study on the interrelationships between noise and emissions. This study can be used to assess the costs and benefits of aviation environmental policy options.

[34]GAO, *Aviation and the Environment: Impact of Aviation Noise on Communities Presents Challenges for Airport Operations and Future Growth of the National Airspace System*, GAO-08-216T (Washington, D.C.: Oct. 24, 2007).

[35]FAA, *Aviation and the Environment: A National Vision Statement, Framework for Goals and Recommended Actions* (Washington, D.C.: December 2004).

The Financial Condition of the Airline Industry Creates a Challenge to Implementing Emissions-Reduction Technologies

Most U.S. airlines have stated that they plan to invest in aircraft and technologies that can increase fuel efficiency and lower emissions, but in the near term, integrating new aircraft into the fleet, or retrofitting aircraft with technologies that can improve their operational efficiency, poses financial challenges to the airline industry. Aircraft have an average lifespan of about 30 years, and the airlines can take almost that entire period to pay for an aircraft. The current fleet is, on average, about half as many years old—11 years for wide-body aircraft, and 14 years for narrow-body aircraft—and therefore is expected to be in operation for many years to come. In addition, the financial pressures facing many airlines make it difficult for them to upgrade their fleets with new, state-of-the-art aircraft, such as the Boeing 787 and Airbus A380, which are quieter and more fuel efficient, emitting lower levels of greenhouse gases.[36] Currently, U.S. carriers have placed a small proportion (40, or less than 6 percent) of the over 700 orders that Boeing officials say the company has received for its 787 model. Furthermore, no U.S. carriers have placed orders for the new Airbus 380. These financial pressures also limit the airlines' ability to equip new and existing aircraft with NextGen technologies such as ADS-B that can enable more efficient approaches and descents, resulting in lower emissions levels. FAA estimates that it will cost the industry about $14 billion to equip aircraft to take full advantage of NextGen.

Delays by airlines in introducing more fuel-efficient, lower-emitting aircraft into the U.S. fleet and in equipping or retrofitting the fleet with the technologies necessary to operate NextGen could limit FAA's ability to efficiently manage the forecasted growth in air traffic. Without significant reductions in emissions and noise around the nation's airports, efforts to expand their capacity could be stalled and the implementation of NextGen delayed because of concerns about the impact of aviation emissions. As we previously reported,[37] offering operational advantages, such as preferred takeoff and landing slots, to fuel-efficient, lower-emitting aircraft or aircraft equipped with ADS-B could create incentives for the airlines to invest in the necessary technologies. Similarly, as noted, deploying an integrated suite of

[36]We are currently undertaking a study for this Subcommittee and the House Committee on Transportation and Infrastructure that, among other things, will assess the financial condition of the airlines.

[37]GAO, *Aviation and the Environment: FAA'S and NASA's Research and Development Plan's for Noise Reduction Are Aligned, but the Prospects of Achieving Noise Reduction Goals Are Uncertain*, GAO-08-384 (Washington, D.C.: Feb. 15, 2008).

NextGen technologies and procedures in a particular region could create incentives for carriers to equip their aircraft with NextGen technologies.

More Stringent Regulatory Standards Pose Challenges for Airport Expansion Projects

Concerns about the health effects of air pollutants have led to more stringent air quality standards that could increase the costs or delay the implementation of airport expansion projects. In recent years, EPA has been implementing a more stringent standard for ozone emissions to better protect the health of people exposed to it, and this standard could require more airports to tighten controls on nitrogen oxides and some types of volatile organic compounds that also contribute to ozone formation. Under the current standard,[38] 122 airports are located in areas that are designated as nonattainment areas. This number includes 43 of the 50 busiest U.S. commercial service airports. In March 2008, EPA further revised the ozone standard, because new evidence demonstrated that exposure to ozone at levels below the level of the current standard are associated with a broad array of adverse health effects.[39] This recent revision to the ozone standard will increase the number of U.S. counties, and hence airports, that will be in nonattainment. EPA estimated that the number of affected counties could potentially grow from 104 to 345 nationwide. While the exact number of airports that will be affected has not been officially determined at this time, FAA estimates that a modest number of commercial service airports in California, Arizona, Utah, Texas, Oklahoma, Arkansas, and along the gulf coast to Florida will be in nonattainment areas for the revised 8-hour ozone standard. According to EPA, any development project beginning in 2011 at these airports would have to conform to the state implementation plan.

As communities gain more awareness of the health and environmental effects of aviation emissions, opposition to airport expansion projects, which has thus far focused primarily on aviation noise, could broaden to include emissions. According to a California air quality official, many of the same communities that have interacted with airports over aviation noise have more recently recognized that they could also be affected by emissions from airport sources. In Europe, concerns about the impact of aviation on air quality and

[38] In 2003, EPA began implementing a new standard that called for concentrations of ozone not to exceed 0.08 parts per million over an 8-hour period. The former standard required concentrations not to exceed 0.12 parts per million over a 1-hour period. The more stringent standard resulted in the designation of more nonattainment areas for ozone. These areas contained 12 airports.

[39] 73 Fed. Reg. 16436 (Mar. 27, 2008). The new standard would lower the allowed concentrations of ozone from 0.08 parts per million in an 8-hour period to 0.075 parts per million during that period.

climate change have led to public demands for tighter control over aircraft emissions, and these demands have hindered efforts to expand airports in Birmingham, and London (Heathrow). Moreover, a plan to expand London's Stansted Airport was rejected because of concerns about climate change that could result from additional emissions.

To minimize constraints on the future expansion of airport capacity stemming from concerns about the health and environmental effects of aviation emissions, it will be important for airports; the federal and state governments; and the airline industry to work together to accurately characterize and address these concerns and to take early action to mitigate emissions. As noted, constraints on efforts to expand airports or aviation operations could affect the future of aviation because the national airspace system cannot expand as planned without a significant increase in airport capacity. The doubling or tripling of air traffic that FAA expects in the coming decades cannot occur without additional airports and runways.

Market-Based Initiatives to Reduce Aviation Emissions of Greenhouse Gases Could Pose Challenges for U.S. Airlines by Increasing Their Costs

Concerns about the environmental effects of greenhouse gas emissions have grown steadily over the years, leading to national and international efforts to limit them. In the

In the United States, EPA has not regulated greenhouse gas emissions;[40] however, Congress is taking steps to deal with climate change, some of which could include market-based measures that would affect the aviation industry. For example, several bills were introduced in the 110th Congress to initiate

[40]Recently, however, the Supreme Court ruled that greenhouse gases meet the Clean Air Act's definition of an air pollutant and that EPA has the statutory authority to regulate greenhouse gas emissions from new motor vehicles under the Clean Air Act. *Massachusetts v. Environmental Protection Agency*, 127 S.Ct. 1438, 1459-62 (2008). As a result of this opinion, EPA must take one of three actions: (1) issue a finding that greenhouse gas emissions cause or contribute to air pollution that may endanger public heath or welfare; (2) issue a finding that greenhouse gases do not endanger public health or welfare; or (3) provide a reasonable explanation as to why it cannot or will not exercise its discretion to issue a finding. If EPA makes an endangerment finding, the Clean Air Act requires EPA to regulate greenhouse gas emissions from new motor vehicles. In response to this case, EPA has announced that it will issue an Advance Notice of Proposed Rulemaking on "specific effects of climate change and potential regulation of greenhouse gas emissions from stationary and mobile sources under the Clean Air Act.

cap and trade[41] programs for greenhouse gas emissions[42] None of these bills would include aviation directly in a cap and trade program. However, some could have indirect consequences for the aviation industry by, for example, requiring fuel producers to purchase allowances through the system to cover the greenhouse gas content of the fuel they sell to the aviation sector. The cost of purchasing these allowances could be passed on to fuel consumers, including airlines, raising the cost of jet fuel. Fuel is already the airline industry's largest cost. According to the Air Transport Association, cap and trade programs that significantly increase airline fuel costs could have significant consequences for the industry and such programs could make it more difficult for carriers to pay for aircraft or technologies that would reduce greenhouse gas emissions. As we have previously noted,[43] cap and trade programs can cost-effectively reduce emissions of greenhouse gases such as carbon dioxide, especially when compared with other regulatory programs. However, it is important that the impact of such measures on various sectors of the economy, such as the aviation industry, be thoroughly considered.

Internationally, ICAO has not set standards for aircraft carbon dioxide emissions,[44] but it has been working, with the support of FAA, other government aviation authorities, and the aviation industry, to develop a strategy for addressing the impact of aviation on climate change, among several efforts to address climate change. For example, ICAO published a

[41]Cap and trade programs combine a regulatory limit or cap on the amount of a substance—in this case a greenhouse gas such as carbon dioxide—that can be emitted into the atmosphere with market elements like credit trading to give industries flexibility in meeting this cap. A current example is the cap and trade program for sulfur dioxide under the Clean Air Act. This program includes electric utilities, which are the primary emitters of sulfur dioxide, and established a cap on the utilities' emissions. Sulfur dioxide allowances were primarily given (rather than auctioned) to companies.

[42]S. 28, S, 309, S. 317, S. 485, S. 1168, S. 1177, S. 1201, S. 1554, S. 1766, S. 2191,H.R. 620, H.R. 1590, H.R. 3989, H.R. 4226.

[43]GAO, *Vehicle fuel Economy: Reforming Fuel Economy Standards Could Help Reduce Oil Consumption by Cars and Light Trucks, and Other Options Could Complement These Standards*, GAO-07-921 (Washington, D.C.: Aug. 2, 2007).

[44]According to FAA, the last extensive discussion within ICAO on carbon dioxide emissions from aircraft occurred several years ago. At that time, ICAO's experts agreed that the cost of fuel provided sufficient incentive to minimize fuel consumption – hence carbon dioxide emissions. There was some technical work around 2001 on the development of an aircraft efficiency parameter, which might have been used to target carbon dioxide reductions. However, it failed to identify a parameter that would be able to assess aircraft fleets in their multiple operational environments in an equitable manner.

manual for countries, Operational Opportunities to Minimize Fuel Use and Reduce Emissions. In 2004, ICAO endorsed the development of an open emissions trading system as one option countries might use and endorsed draft guidance for member states on establishing the structural and legal basis for aviation's participation in a voluntary open trading system. The guidance includes information on key elements of a trading system, such as reporting, monitoring, and compliance, while encouraging flexibility to the maximum extent possible. In adopting the guidance last fall at the ICAO Assembly, all 190 Contracting States—with the exception of those in the European Union—agreed that the inclusion of one country's airlines in another country's emissions trading system should be based on mutual consent between governments.

Consistent with the requirement to pursue reductions of greenhouse gas emissions from international aviation through ICAO, some countries that have included the aviation sector in their emissions trading systems or other emissions-reduction efforts have, excluded international flights. Consequently, these countries' efforts will not affect U.S. airlines that fly into their airports. The European Union (EU), however, is developing legislation, which has not been finalized, that would include both domestic and international aviation in an emissions trading scheme.[45] As proposed, the EU's scheme would apply to air carriers flying within the EU and to carriers, including U.S. carriers, flying into and out of EU airports in 2012. For example, under the EU proposal, a U.S. airline's emissions in domestic airspace as well as over the high seas would require permits if a flight landed or departed from an EU airport. Airlines whose aircraft emit carbon dioxide at levels exceeding prescribed allowances would be required to reduce their emissions or to purchase additional allowances. Although the legislation seeks to include U.S. airlines within the emissions trading scheme, FAA and industry stakeholders have argued that U.S. carriers would not legally be subject to the legislation.

While the EU's proposal to include international aviation in its emissions trading system is intended to help forestall the potential catastrophic effects of climate change, according to FAA and airlines, it will also affect the aviation industry's financial health. In particular, according to FAA and airline and aircraft and engine manufacturing industry representatives, the

[45]The emissions trading scheme involves a cap and trade system that sets allowances for greenhouse gas emission for industries and other sources. Parties that pollute below their allowance receive emissions credits, which they can trade in a market to other parties that have exceeded their allowance.

EU's proposal could disadvantage U.S. airlines, which have older, less fuel-efficient fleets than their European competitors. Paying for emissions credits could, according to U.S. airlines, also leave them with less money for other purposes, including investing in newer, more fuel-efficient aircraft and technologies to improve flight efficiency and reduce fuel usage. Furthermore, according to U.S. carriers, the proposed trading scheme unfairly penalizes the aviation sector because it lacks a readily available non-carbon-based alternative fuel, whereas other sectors can use alternative fuels to reduce their emissions.

The governments of many nations, including the United States, oppose the European Union's proposal to unilaterally include international aviation in its emissions trading system because the proposed approach is not consistent with ICAO guidance. Furthermore, such an approach could be inconsistent with international aviation agreements and may not be enforceable. According to FAA, the EU's inclusion of aviation in its emissions trading scheme violates the Chicago Convention on International Civil Aviation[46] and other international agreements. FAA further notes that the EU proposal ignores differences in the U.S. and EU aviation systems[47] and ignores a performance-based approach in which countries decide which measures are most appropriate for goals on emissions. We are currently undertaking for this Subcommittee a study of the EU emissions trading system and its potential impact on U.S. airlines, and other issues relating to aviation and climate change.[48]

Mr. Chairman, this concludes my prepared statement. I would be pleased to respond to any questions that you or other Members of the Subcommittee may have.

[46]The Chicago Convention on International Civil Aviation of 1944 organized global aviation. According to the Convention, no state may condition the right of transit over or entry into or exit from its territory of any aircraft of another state on their operator's payment of fees, dues, or other charges.

[47]For example, FAA notes that there are considerable differences in the air traffic system efficiencies across the Atlantic, that the United States has a domestic fuel tax while nearly all EU states have none, and that the cost of fuel is about 50 percent more expensive for U.S. airlines because of the dollar's weakness in recent years.

[48]This ongoing work was jointly requested by the Committee on Transportation and Infrastructure, House of Representatives, and the Committee on Science and Technology, House of Representatives.

Contacts and Acknowledgments

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Appendix I: Federal Agency Views on Health and Environmental Effects of Air Pollution

Pollutant	Heath effects	Environmental effects
Ozone	Lung function impairment, effects on exercise performance, increased airway responsiveness, increased susceptibility to respiratory infection, increased hospital admissions and emergency room visits, pulmonary inflammation, and lung structure damage (long term).	Results from animal studies indicate that repeated exposure to high levels of ozone for several months or more can produce permanent structural damage in the lungs. Ozone is also responsible for several billion dollars of agricultural crop yield loss in the United States each year.
Carbon monoxide	Most serious for those who suffer from cardiovascular disease. Healthy individuals are also affected, but only at higher levels of exposure. Exposure to elevated carbon monoxide levels is associated with visual impairment, reduced work capacity, reduced manual dexterity, poor learning ability, and difficulty in performing complex tasks.	Adverse health effects on animals similar to effects on humans.
Nitrogen oxides	Lung irritation and lower resistance to respiratory infections.	Acid rain, visibility degradation, particle formation. Contributes toward ozone formation, and acts as a greenhouse gas in the atmosphere and, therefore, may contribute to climate change.
Particulate matter	Effects on breathing and respiratory systems, damage to lung tissue, cancer, and premature death. The elderly, children, and people with chronic lung disease, influenza, or asthma, tend to be especially sensitive to the effects of particulate matter.	Visibility degradation, damage to monuments and buildings, safety concerns for aircraft from reduced visibility. .
Volatile organic compounds	Eye and respiratory tract irritation, headaches, dizziness, visual disorders, and memory impairment.	Contribute to ozone formation, odors, and have some damaging effect on buildings and plants.
Carbon dioxide, water vapor, and contrails	None.	Act as greenhouse gases in the atmosphere and, therefore, may contribute to climate change. Contrails and contrail-induced clouds produce warming effect regionally where aircraft fly.
Sulfur dioxide	Breathing, respiratory illness, alterations in pulmonary defenses, and aggravation of existing cardiovascular disease.	Together, sulfur dioxide and nitrogen oxides are the major precursors to acid rain, which is associated with the acidification of lakes and streams, accelerated corrosion of buildings and monuments, and reduced visibility.

Sources: EPA and FAA.

Appendix II: Examples of the National Aeronautics and Space Administration's Research and Development Programs Supporting NextGen

NextGen research and development (R&D) needs	NextGen capabilities from the National Aeronautics and Space Administration's (NASA) R&D programs
Safety management procedures that can predict, rather than respond to, safety risks, in a high density, complex operating environment; research to support safety analysis, development of advanced materials for continued airworthiness of aircraft, aircraft system and equipage management; and adaptive aircraft control systems to allow the crew and aircraft to recover from unsafe conditions.	Under its Aviation Safety program, NASA research supports development of Safety Management Systems to provide a systematic approach to manage safety risks; integrates prediction and mitigation of risks prior to aircraft accidents or incidents; and shares safety-related information through programs such as the Aviation Safety Analysis and Information Sharing program.
Improved air traffic management technologies to manage airspace configuration, support increases in volume and complexity of traffic demands, mitigate weather impacts, and maintain safe and efficient operations at airports, decrease runway incursions, and address wake vortex issues.	Under its Airspace Systems program, NASA research supports development of variable separation standards based on aircraft performance levels in the en route environment; trajectory-based operations, traffic spacing, merging, metering, flexible terminal airspace, and expanded airport access; technologies and procedures for safe runway procedures in low-visibility conditions; coordinated arrival/departure management; and mitigation of weather and wake vortex issues.
Management of aviation growth to meet the complexity of operations within the NextGen environment, regulation and certification of new manned and unmanned aircraft, and management of operations in an environmentally sound manner.	Under its Fundamental Aeronautics program, NASA research supports development of improved performance for the next generation of conventional subsonic aircraft, rotorcraft and supersonic aircraft and develops methods for environmental management system to measure and assess reductions in air quality impact, noise, and emissions.

Source: GAO analysis of Joint Planning and Development Office and NASA information.

Related GAO Products

Aviation and the Environment: FAA's and NASA's Research and Development Plans for Noise Reduction Are Aligned, but the Prospects of Achieving Noise Reduction Goals Are Uncertain. GAO-08-384. Washington, D.C.: February 15, 2008.

Aviation and the Environment: Impact of Aviation Noise on Communities Presents Challenges for Airport Operations and Future Growth of the National Airspace System. GAO-08-216T. Washington, D.C.: October 24, 2007.

Climate Change: Agencies Should Develop Guidance for Addressing the Effects on Federal Land and Water Resources. GAO-07-863. Washington, D.C.: August 7, 2007.

Responses to Questions for the Record; Hearing on the Future of Air Traffic Control Modernization. GAO-07-928R. Washington, D.C.: May 30, 2007.

Responses to Questions for the Record; Hearing on JPDO and the Next Generation Air Transportation System: Status and Issues. GAO-07-918R. Washington, D.C.: May 29, 2007.

Next Generation Air Transportation System: Status of the Transition to the Future Air Traffic Control System. GAO-07-748T. Washington, D.C.: May 9, 2007.

Joint Planning and Development Office: Progress and Key Issues in Planning the Transition to the Next Generation Air Transportation System. GAO-07-693T. Washington, D.C.: March 29, 2007.

Next Generation Air Transportation System: Progress and Challenges in Planning and Implementing the Transformation of the National Airspace System. GAO-07-649T. Washington, D.C.: March 22, 2007.

Next Generation Air Transportation System: Progress and Challenges Associated with the Transformation of the National Airspace System. GAO-07-25. Washington, D.C.: November 13, 2006.

Aviation and the Environment: Strategic Framework Needed to Address Challenges Posed by Aircraft Emissions. GAO-03-252. Washington, D.C.: February 28, 2003.

Aviation and the Environment: Transition to Quieter Aircraft Occurred as Planned, but Concerns about Noise Persist. GAO-01-1053. Washington, D.C.: September 28, 2001.

*Aviation and the Environment: Aviation's Effects on the Global Atmosphere Are Potentially Significant and Expected to Gro*w. GAO/RCED-00-57. Washington, D.C.: February 18, 2000.

Aviation and the Environment: Results from a Survey of the Nation's 50 Busiest Airports. GAO/RCED-00-222. Washington, D.C.: August 30, 2000.

Aviation and the Environment: Airport Operations and Future Growth Present Environmental Challenges. GAO/RCED-00-153. Washington, D.C.: August 30, 2000.

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