CONTROL OF AIR POLLUTANT EMISSIONS FROM AIRCRAFT ENGINES: LOCAL IMPACTS OF NATIONAL CONCERN

by

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Although exhaust emissions from aircraft engines constitute only a small portion of national emission inventories, they are nevertheless important because of their impact on certain metropolitan areas. Aircraft engine emissions contribute significantly to the nonattainment of National Ambient Air Quality Standards in several Air Quality Control Regions. Despite the detrimental impact aircraft engine emissions have on these areas, they have historically been minimally regulated. Given the anticipated growth expected in the air transportation market, aircraft emissions problems are likely to worsen in the years to come.

This Article evaluates the United States' current command and control scheme for regulating aircraft engine emissions, as implemented by the United States Environmental Protection Agency and the Federal Aviation Administration. The Article also examines the relationship between the U.S. scheme and the scheme utilized by the International Civil Aviation Organization to regulate aircraft engine emissions on a global scale. The Article lays out the aircraft engine design and certification process to help the reader understand the complexity of altering the emissions characteristics of an aircraft engine. The Article then evaluates possible changes to aircraft engine design and airline practices, and the relative potential of these measures to contribute toward successfully meeting the heightened reduction of aircraft emissions advocated by the Article.

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I. INTRODUCTION

Aircraft engine exhaust emissions are a vexing problem for metropolitan areas in the Air Quality Control Regions (AQCR) with the nation's worst air pollution.[1] Exhaust emissions from aircraft engines include carbon dioxide (CO_2), carbon monoxide (CO), hydrocarbons (HC), volatile organic compounds (VOCs), nitrogen oxides (NO_x), particulate matter (PM), sulfur dioxide (SO_2), and water vapor.[2] Carbon monoxide, NO_2, PM, and SO_2 emissions are regulated as "criteria pollutants"[3] under the Clean Air Act (CAA).[4] As precursors of the criteria pollutant ozone (O_3), VOCs and NO_x are regulated as part of overall O_3 regulation.[5] Although the U.S. General Accounting Office reported in 1992 that jet aircraft emissions have a "minimal impact on pollution problems at ground level,"[6] aircraft emissions nevertheless contribute significantly to the

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[1] *See* Natural Resources Defense Council (NRDC), *Flying Off Course*, <http://www.nrdc.org/nrdcpro/foc/aairexsu.html> (visited Feb. 1, 1999) [hereinafter NRDC, *Flying Off Course*]. An Air Quality Control Region (AQCR) is the basic geographic unit regulators start from to devise their plans for improving or maintaining air quality. *See* ARNOLD W. REITZE, JR., AIR POLLUTION LAW § 2-5, at 72 (1995 & Supp. 1997). Regulators then divide AQCRs into "areas" for the purpose of determining compliance with the National Ambient Air Quality Standards (NAAQS). Clean Air Act (CAA) § 107(d)(1), 42 U.S.C. § 7407(d)(1) (1994). The CAA categorizes areas according to their attainment or nonattainment of the NAAQS. *Id.*

[2] *See* ICAO/CAEP WORKING GROUP 3 (EMISSIONS) THIRD MEETING, COMBINED REPORT OF THE CERTIFICATION AND TECHNOLOGY SUBGROUPS 15-17 (1995) [hereinafter ICAO/CAEP, EMISSIONS REPORT].

[3] "Criteria pollutants" are those pollutants the United States Environmental Protection Agency (EPA) Administrator has designated as "endanger[ing] public health or welfare." CAA § 108(a)(1)(A), 42 U.S.C. § 7408(a)(1)(A). The Administrator is responsible for establishing "air quality criteria" for pollutants pursuant to section 108 of the CAA. *Id.* § 108(a)(2), 42 U.S.C. § 7408(a)(2). EPA has designated the following as criteria pollutants: carbon monoxide (CO), lead, nitrogen dioxide (NO_2), ozone (O_3), particulate matter (PM), and sulfur dioxide (SO_2). 40 C.F.R. § 52.31(b)(4) (1998).

[4] *See* CAA § 109, 42 U.S.C. § 7409; 40 C.F.R. § 52.31(b)(4); *see also* REITZE, *supra* note 1, § 2-1, at 47.

[5] *See* CAA § 182(b)-(e), 42 U.S.C. § 7511a(b)-(e) (prescribing control measures for O_3 nonattainment areas). Nitrogen dioxide is also a separately regulated criteria pollutant. 40 C.F.R. § 52.31(b)(4) (1998).

[6] U.S. GEN. ACCOUNTING OFFICE (GAO), AIR POLLUTION: GLOBAL POLLUTION FROM JET AIRCRAFT COULD INCREASE IN THE FUTURE (GAO/RCED-92-72) 1 (1992) [hereinafter GAO, GLOBAL POLLUTION FROM JET AIRCRAFT].

nonattainment of National Ambient Air Quality Standards (NAAQS)[7] for several AQCRs.[8]

This Article discusses the current environmental impact and regulation of aircraft engine emissions, focusing on aircraft engine certification standards adopted by the International Civil Aviation Organization, the United States Environmental Protection Agency (EPA), and the Federal Aviation Administration (FAA). Part II identifies the local and national environmental impacts of aircraft engine exhaust emissions. Part III provides an overview of the aircraft and engine design parameters considered in controlling pollution. Part IV summarizes the international and domestic legislative and regulatory command and control schemes for regulating aircraft engine exhaust emissions. Part V discusses anticipated control strategies for aircraft engine exhaust emissions that provide for future air transportation needs. Part VI concludes the Article with insights concerning the factors that must be considered to ensure the contribution of aircraft emissions to the nonattainment status of metropolitan areas is minimized.

II. LOCAL IMPACTS OF AIRCRAFT EMISSIONS: REASON FOR NATIONAL CONCERN

Aircraft engine emissions currently contribute only about two percent of the total U.S. inventory of NO_x and CO ground level emissions from mobile sources.[9] Thus, at first glance it may appear that aircraft emissions represent a *de minimis* percentage of local emissions.[10] A more in depth analysis, however, reveals that this is not the case. First, emissions from aircraft have a significant impact on metropolitan areas.[11] The bigger the metropolitan area, the greater the area's demand for air traffic. These are usually the areas that have O_3 nonattainment problems.[12] Second, emissions from aircraft have historically been only minimally regulated.[13]

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[7] The EPA Administrator must promulgate NAAQS for each criteria pollutant. CAA § 109(a)(1)(A), 42 U.S.C. § 7409(a)(1)(A).

[8] *See generally* NRDC, *Flying Off Course*, *supra* note 1. The list of the nation's 264 AQCRs can be found at 40 C.F.R. pt. 81 (1998).

[9] Control of Air Pollution from Aircraft and Aircraft Engines; Emission Standards and Test Procedures, 62 Fed. Reg. 23,356, 23,358 (May 8, 1997) (codified at 40 C.F.R. pt. 87).

[10] *See* GAO, GLOBAL POLLUTION FROM JET AIRCRAFT, *supra* note 6, at 4.

[11] NRDC, *Flying Off Course*, *supra* note 1.

[12] *See* GAO, GLOBAL POLLUTION FROM JET AIRCRAFT, *supra* note 6, at 1.

[13] *See* NRDC, *Flying Off Course*, *supra* note 1.

Simply put, the contribution of aircraft engine emissions, while a small proportion of the national NO_x and CO emission inventories, is a particular problem in the metropolitan nonattainment areas struggling to receive credit in their state implementation plans (SIP)[14] for reduction of CO, NO_x and VOCs.[15]

One of the major frustrations for state and local regulators is that while the impact of these emissions is felt in localized areas, under the CAA, states are preempted from regulating either emissions from aircraft or aircraft engine design.[16] Aircraft emissions are regulated pursuant to a federal program controlled by the FAA and EPA.[17] The inability to regulate a significant source of criteria pollutants forces states to more stringently regulate other sources of emissions, even where those sources have already been subjected to heavy regulation.[18]

A. Aircraft Emissions at the Local Level

While ostensibly not a national concern, emissions from aircraft are a problem for metropolitan areas across the United States that are nonattainment for various NAAQS.[19] In 1996, the Natural Resources Defense Council (NRDC) published the results of its 1995 study of emissions generated from data gathered from the nation's busiest airports ("the 1995 NRDC Report").[20] The 1995 NRDC Report concluded that airports are not regulated to the same degree as other major sources of air pollution, and contended that airports and airlines are therefore not held accountable for the totality of their environmental impacts.[21] Such criticism has not been limited to studies by advocacy

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[14] A state implementation plan (SIP) details a state's plan for implementing, maintaining, and enforcing NAAQS. CAA § 110, 42 U.S.C. § 7410.

[15] *See* 62 Fed. Reg. at 23,358; NRDC, *Flying Off Course*, *supra* note 1.

[16] CAA § 233, 42 U.S.C. § 7573; NRDC, *Flying Off Course*, *supra* note 1. Although section 233 of the CAA permits states to regulate aircraft emissions if their standards are identical to those of the federal government, there is no impetus to do so. *See* NRDC, *Flying Off Course*, *supra* note 1. In a situation where federal standards are insufficient, state regulations matching those standards would really add nothing. *See id.*

[17] *See infra* text accompanying notes 180-85.

[18] *See* NRDC, *Flying Off Course*, *supra* note 1.

[19] *Id.*

[20] *Id.*

[21] *Id.*

groups. Major newspapers have also taken up this issue and have heightened public scrutiny of the problem.[22]

1. Los Angeles

Los Angeles International Airport's (LAX) contribution to the region's smog is only twenty-five percent less than the volume generated by the area's fourteen oil refineries, which are the area's greatest industrial source of air pollution.[23] An EPA study prepared in 1991 showed that emissions from airports within the South Coast Air Quality Management District ("South Coast AQMD")[24] totaled approximately 8000 tons per year of NO_x and 20,000 tons per year of CO.[25] Los Angeles news reports criticize EPA and the FAA for this ineffective control of emissions from aircraft.[26]

Los Angeles' air quality has consistently been so poor that on May 5, 1994, EPA proposed to implement a federal implementation plan (FIP)[27] in

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[22] *See, e.g.*, Donald Bertrand, *Sky Wars Picking Up Tempo*, QUEENS DAILY NEWS, Jan. 11, 1998, at 1; Tom Charlier, *As Memphis Flights Increase, Airport Pollution Fouls Area*, COMM. APPEAL, Dec. 28, 1997, at A1; Marla Cone, *Jet Lag in Pollution Control*, L.A. TIMES, Mar. 18, 1997, at B2; Mary Jo Pitzl, *Sky Harbor Under Cloud*, ARIZ. REPUBLIC, June 7, 1998, at A1.

[23] Cone, *supra* note 22, at B2.

[24] The South Coast Air Quality Management District ("South Coast AQMD") includes the Sacramento, Ventura, and South Coast areas of California. The South Coast area encompasses all of Orange County as well as the more populated areas of Los Angeles, San Bernardino, and Riverside counties. Approval and Promulgation of State and Federal Implementation Plans; California—Sacramento and Ventura Ozone; South Coast Ozone and Carbon Monoxide; Sacramento Ozone Area Reclassification, 59 Fed. Reg. 23,264, 23,278-79 (1994) (to be codified at 40 C.F.R. pt. 52 and 81) (proposed May 5, 1994).

[25] ENERGY AND ENVTL. ANALYSIS, INC. (EEA), INVENTORY OF CIVIL AIRCRAFT EMISSIONS FOR TWENTY-FIVE NONATTAINMENT AREAS 22-2 (1991) [hereinafter EEA, CIVIL AIRCRAFT EMISSIONS INVENTORY]. The study looked at emissions from the 20 general aviation and commercial airports in the South Coast AQMD. *Id.* at 22-1. Los Angeles International Airport (LAX) accounted for roughly 80% of the total commercial landing and takeoff cycles and arguably a similar amount of emissions. *Id.*

[26] *See* Cone, *supra* note 22, at B2. "On some days, the runways and roads at [LAX] are clogged with traffic worse than on any freeway. Jets idle, spewing fumes into the air as they await clearance for takeoff. . . . [I]f city officials fulfill their promise to expand the airport . . . as many as 60% more [passengers] than today . . . will be descending on LAX by 2015." *Id.*

[27] A federal implementation plan (FIP) allows EPA "to promulgate a federal air quality plan in place of the SIP, if a state fails to develop and implement an approvable state plan." Karl James Simon, *The Application and Adequacy of the Clean Air Act in Addressing Interstate Ozone Transport*, 5 ENVTL. LAW. 129, 149 (1998); *see* CAA § 110(c)(1), 42 U.S.C. § 7410(c)(1) (1994).

the South Coast AQMD to attain the NAAQS for O_3 and CO promulgated under the CAA Amendments of 1977.[28] In particular, the FIP proposed by EPA set forth innovative control programs to decrease aircraft and airport emissions.[29] The proposed FIP came over thirteen years after California first submitted SIP revisions for the South Coast AQMD to EPA in 1980,[30] and was the result of a number of citizen suits,[31] as well as several appeals and remands between federal district courts and the U.S. Court of Appeals for the Ninth Circuit.[32] The proposed FIP drew upon four technical support studies dealing specifically with aviation; over seven hundred comments from persons outside EPA, including elected officials, the regulated community, trade groups, academics, and the general public; and a Technical Support Document dedicated strictly to aircraft and airports.[33]

Despite years of protracted litigation and countless hours and dollars spent preparing and commenting on the FIP, ultimately it was not implemented.[34] On April 10, 1995, Congress enacted the Emergency Supplemental Appropriations and Rescissions for the Department of Defense to Preserve and Enhance Military Readiness Act of 1995.[35] The act rescinded the FIP and stripped it of further legal effect.[36] In the act, Congress declared that the CAA Amendments of 1990 "superseded prior [1977] requirements of the Clean Air Act regarding the demonstration of National Ambient Air Quality Standards for the [South Coast AQMD] and thus eliminated the obligation of the Administrator of [EPA] to promulgate

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[28] 59 Fed. Reg. at 23,268-69; *see also* Leigh Ann Karr Epperson, Comment, *The South Coast Basin: The Long-Awaited FIP and the Aviation Industry*, 60 J. AIR L. & COM. 917, 919-20 (1995).

[29] 59 Fed. Reg. at 23,268.

[30] *See* Nonattainment Area Plan; Approval and Promulgation of Implementation Plans; South Central Coast Air Basin, 45 Fed. Reg. 58,912 (proposed Sept. 5, 1980).

[31] Abramowitz v. EPA, 832 F.2d 1071, 1072 (9th Cir. 1987); Coalition for Clean Air v. EPA, 762 F. Supp. 1399, 1400-01 (C.D. Cal. Jan. 9, 1991); *see also* Epperson, *supra* note 28, at 923-27.

[32] *See* Coalition for Clean Air v. Southern Cal. Edison Co., 971 F.2d 219 (9th Cir. 1992), *cert. denied sub nom.* EPA v. Coalition for Clean Air, 507 U.S. 950 (1993).

[33] *See* Federal Implementation Plans for California: EPA Studies or Contractor Reports (EPA No. A-94-09).

[34] *See* Lisa H. Harrington, *EPA, OSHA and RSPA: The Regulatory Year in Review*, TRANSP. & DISTRIBUTION, Nov. 1, 1995, at 29, 34.

[35] Emergency Supplemental Appropriations and Rescissions for the Department of Defense to Preserve and Enhance Military Readiness Act of 1995, Pub. L. No. 104-6, ch. 7, 109 Stat. 73, 88.

[36] *Id.*

a Federal Implementation Plan under section 110(e) of the Clean Air Act."[37]

2. *New York*

The 1995 NRDC report found that the LaGuardia and John F. Kennedy (JFK) International Airports are among the five biggest sources of VOCs and NO_x in New York City.[38] An EPA study showed that annual emissions from New York Consolidated Metropolitan Statistical Area (CMSA) airports totaled over 23,000 tons per year of NO_x and approximately 31,000 tons per year of CO.[39] In New York, the United States Department of Transportation (DOT) is under scrutiny for granting exemptions from slot limitations at LaGuardia.[40] The exemptions resulted in twenty-one additional flights per month, spurring other airlines to apply for a total of thirty-three additional slots at LaGuardia and JFK.[41] DOT grants exemptions for "exceptional circumstances", which the agency interprets as arising simply when an exemption is necessary, unless the exemption would result in substantial operational delays.[42] Ironically, this congestion evaluation appears to take place without consideration of the noise or pollution concerns that will result from additional slots.[43]

3. *Memphis*

Commercial aircraft at Memphis International Airport reportedly accounted for an estimated 4300 tons of combined CO, HC, and NO_x

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[37] *Id.*

[38] Bertrand, *supra* note 22, at 1.

[39] EEA, CIVIL AIRCRAFT EMISSIONS INVENTORY, *supra* note 25, at 15-2. The study looked at emissions from the thirty-three airports in the New York Consolidated Metropolitan Statistical Area ("New York CMSA"). *Id.* at 15-1. The LaGuardia and John F. Kennedy (JFK) International Airports, which are located approximately 8 to 10 miles from each other, accounted for roughly 23% of the total landing and takeoff cycles and arguably a proportional amount of emissions. *Id.* at 15-1. Aircraft traffic at the Newark International Airport represented roughly 12% of the total landing and takeoff cycles. *Id.* The aggregate for these three major airports in the CMSA is 35%. *Id.*

[40] *See* Bertrand, *supra* note 22, at 1. "A 'slot' is a takeoff or landing at an airport." *Id.* Airports have a fixed number of slots that are allowed to be increased as circumstances warrant. *Id.*

[41] *Id.*

[42] Federal Aviation Administration Authorization Act of 1994, Pub. L. No. 103-305, 108 Stat. 1570, 1584 (codified at 49 U.S.C. § 41714 (1994)); *see also* Betrand, *supra* note 22, at 1.

[43] *See* Betrand, *supra* note 22, at 1.

emissions in the Memphis area during 1990.[44] In 1989, the last year for which emissions data is available for the Memphis area, ground-support equipment (GSE), fueling operations, and ground access vehicles (GAV)—vehicles that are necessary to bring people to and from the airport—accounted for the release of a combination of CO, HC, and NO_x in the amount of 1300 tons.[45] That year, the facility emitted twice the amount of HC and NO_x as a large petroleum refinery located nearby and twenty percent more than a large chemical plant similarly situated.[46] County officials discounted the significance of aircraft emissions, as they amounted to only one to two percent of the county's mobile source air pollution.[47] By 1996, however, there were thirteen percent more takeoffs and landings than in 1991, and the FAA estimates an increase as great as one-third by 2005.[48] Additionally, while Memphis International Airport is only the thirty-eighth busiest airport in the United States for passenger traffic, the airport handles more cargo volume than any other airport in the world.[49] This is largely explained by the fact that the Federal Express Corporation has its headquarters there.[50] Therefore, growth in air cargo operations could significantly increase the contribution of aircraft emissions to Memphis' already impaired air quality.

4. Phoenix

More than 1400 airplanes per day take off or land at the Phoenix Sky Harbor International Airport ("Sky Harbor").[51] The emissions from these airplanes are a significant contributor to the Phoenix area's O_3 nonattainment problem.[52] Airplane traffic throughout the metropolitan area constitutes the largest source of industrial NO_x emissions in Phoenix and the third biggest source of industrial HC pollution.[53] Not only does Sky Harbor contribute twenty-five percent of the total NO_x and HC emissions for the

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[44] Charlier, *supra* note 22, at A12.
[45] *Id.*
[46] *Id.* at A1.
[47] *Id.* at A12.
[48] *Id.*
[49] *Id.*
[50] *Id.*
[51] Pitzl, *supra* note 22, at A1.
[52] *Id.*
[53] *Id.* at A12.

area, but its relative contribution is growing.[54] Air travel at Sky Harbor is expected to increase by thirty to fifty percent during the next seventeen years.[55] In addition, over the past seven years, the contribution from airplanes to the Sky Harbor emissions inventory doubled, rising from twelve percent to twenty-three percent of the emissions total.[56]

Some clean-air advocates support the construction of a new airport outside Phoenix as a way to reduce emissions in the metropolitan area.[57] Apart from the prohibitive cost, this alternative may not solve Phoenix's O_3 nonattainment problems.[58] Critics argue that a new airport would actually add to Phoenix's O_3 nonattainment problems by increasing the distance traveled by passengers to access the airport.[59] Another alternative is to shift air traffic to existing facilities in the area.[60] Local planners are also considering the use of the Williams Gateway Airport in the Phoenix suburb of Mesa for cargo and passenger operations.[61] Unfortunately, shifting traffic to Williams will not reduce either passenger or freight air traffic volume, although it may reduce ground delays.[62] More likely, it will result in the addition of more passenger and freight flights to fill the anticipated capacity.[63]

B. Projected Impacts of Aircraft Emissions

The contribution of aircraft emissions to the national inventory is small but growing.[64] Between 1970 and 1995, the contribution of aircraft

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[54] *Id.*

[55] *Id.*

[56] *Id.* tbl. Although airport ground access vehicles and ground-support equipment (GSE) still contribute a significant amount to the Phoenix Sky Harbor International Airport's emissions inventory, concerted efforts are being made to reduce emissions from these sources. *See id.* Shuttle vans and most taxicabs run on alternative fuels. *Id.* In August 1998, a fleet of 16 natural gas shuttle buses was sent to replace diesel powered buses. *Id.* Southwest Airlines is currently operating 22 electrically powered baggage vehicles. *Id.* This represents about half of Southwest's fleet of baggage vehicles. *Id.*

[57] *Id.*

[58] *See id.*

[59] *Id.*

[60] *See id.*

[61] *Id.* at A1.

[62] *See generally id.* at A12.

[63] *See generally id.*

[64] *See* OFFICE OF AIR QUALITY, U.S. ENVTL. PROTECTION AGENCY (EPA), NATIONAL AIR POLLUTANT EMISSION TRENDS, 1900-1996, at 3-10 to 3-11 tbls.3-1, 3-2 (1997) [hereinafter EPA, EMISSION TRENDS].

emissions to the total national emissions of CO grew from 0.39% to 1.01%.[65] During that same period, the contribution of aircraft emissions to the total national emissions of NO_x grew from 0.33% to 0.71%.[66] These emissions figures only include the emissions from aircraft; they do not take into account the other emissions associated with airports such as GAV emissions.[67] Commercial aircraft emissions account for about seventy percent of NO_x aircraft emissions inventories and about thirty percent of CO aircraft emissions inventories.[68] Commercial aircraft are growing more rapidly than other mobile sources in the transportation industry's emissions inventory.[69] In addition, between 1960 and 1995, the total number of available aircraft seat-miles grew from 66.9 billion to 830.8 billion (combined domestic and international operations).[70] The number of aircraft seat-miles declined in only one year, 1991.[71] This decline is explained by heightened fears of terrorism following the Gulf War.[72] Air passenger traffic is expected to grow in the range of five to six percent per year over the next twelve years.[73]

Further complicating regulators' ability to adequately control aircraft emissions is the lag in regulatory effect. The CAA Amendments of 1990, for example, are only now beginning to have an impact on emission levels.[74] While some standards came into effect in 1996, significant emission reductions will not be realized until after the year

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65 *Id.* at 3-10 tbl.3-1.

66 *Id.* at 3-11 tbl.3-2.

67 *See id.* at 3-10 tbl.3-1, 3-11 tbl.3-2.

68 Control of Air Pollution from Aircraft and Aircraft Engines; Emission Standards and Test Procedures, 62 Fed. Reg. 23,356, 23,358 (May 8, 1997) (codified at 40 C.F.R. pt. 87).

69 *See* EPA, EMISSION TRENDS, *supra* note 64, at 3-10 tbl.3-1, 3-11 tbl.3-2.

70 *See* BUREAU OF TRANSP. STATISTICS, U.S. DEP'T OF TRANSP. (DOT), NATIONAL TREANSPORTATION STATISTICS 1997, at 178 tbl.4-17 (1997) [hereinafter DOT, TRANSPORTATION STATISTICS].

71 LAURIE MICHAELIS, ORG. FOR ECON. CO-OPERATION AND DEV., SPECIAL ISSUES IN CARBON/ENERGY TAXATION: CARBON CHARGES ON AVIATION FUELS 15 (1997), <http://www.oecd.org/env/docs/cc/wpaper12.pdf> (visited Feb. 1, 1999).

72 *Id.*

73 *Id.* at 40. "The major manufacturers of aircraft and their engines . . . all forecast passenger traffic growth during 1990 to 2010 in the range [of] 5 to 6% per year." *Id.* The International Civil Aviation Organization (ICAO) "forecasts 5% per year growth [overall] . . . and 6.5% per year in international passenger traffic." *Id.*

74 EPA, EMISSION TRENDS, *supra* note 64, at ES-2.

2000.[75] Meanwhile, aircraft emissions remain minimally regulated and air traffic is projected to increase significantly.[76]

III. AIRCRAFT ENGINES AND AIRCRAFT ENGINE EMISSIONS

The environmental impact resulting from the exhaust emissions of an aircraft engine is only one of many considerations taken into account when designing an aircraft engine.[77] Other aircraft engine attributes, which designers have an independent economic incentive to exploit, have the added benefit of reducing the output of some aircraft engine emissions that are harmful to the environment.[78]

A. Aircraft and Engine Design

The most important factors evaluated in the design of a commercial transport aircraft include the number of passengers, weight of cargo, range, airport runway length, cruising speed, and altitude.[79] Specifications concerning the number of passengers, cargo weight, and range are driven by airline customer demand, while other factors generally remain constant.[80] Because of the interrelationship of different parts of the airplane to the airplane as a unit, the design process involves a series of iterative estimates and calculations to reach the optimum design.[81] Ultimately, the engineer obtains the optimum airplane design by varying the design factors to produce the airplane with the lowest direct operating costs.[82]

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[75] *Id.*

[76] *See id.*

[77] *See generally* General Electric (GE), *GE Aircraft News Release: Advanced Technology Makes Jet Engines Cleaner and Quieter*, <http://www.ge.com/aircraftengines/cleaner.html> (visited Feb. 1, 1999) [hereinafter GE, *Jet Engine Technology News Release*].

[78] *See generally id.*

[79] GERALD CORNING, SUPERSONIC AND SUBSONIC, CTOL AND VTOL, AIRPLANE DESIGN 1:7 (1960).

[80] *Id.* at 2:1.

[81] *Id.* at 2:1-2:2.

[82] *Id.* at 2:2.

While factors such as flight crew labor costs, service costs, maintenance costs, and depreciation all contribute to direct operating costs,[83] an airline's second biggest expense is fuel cost (labor is the first).[84] Fuel expenditures account for 15% of an airlines total expenses.[85] Fuel cost is generally a function of market supply and demand, and is beyond the power of the airline executives to control.[86] Fuel consumption, on the other hand, is a design criteria which is controllable.[87] The rate at which fuel is burned is referred to as specific fuel consumption (SFC) and is expressed in terms of pounds of fuel per hour per pound of thrust produced.[88] Reduced SFC results in lower direct operating costs.[89] Because fuel costs make up 15% of total expenses, a 10% reduction in fuel consumption reduces total operating costs by 1.5%.[90]

Lower SFC arguably reduces the quantity of emissions.[91] Thus, the design process incorporates economic incentives that can have a beneficial environmental impact.[92] Aircraft engineers contribute to fuel efficiency and reduced emissions by designing airplanes that use composite structures,[93] supercritical airfoils,[94] and active

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[83] *See* AIR TRANSPORT ASSOCIATION OF AMERICA (ATA), THE AIRLINE HANDBOOK 26 (1995) [hereinafter ATA, THE AIRLINE HANDBOOK].

[84] *Id.*

[85] *Id.*

[86] *See* Paul Stephen Dempsey, *Airlines in Turbulence: Strategies for Survival*, 23 TRANSP. L.J. 15, 53 (1995).

[87] *See* ATA, THE AIRLINE HANDBOOK, *supra* note 83, at 61.

[88] CORNING, *supra* note 79, at 2:38.

[89] *See* ATA, THE AIRLINE HANDBOOK, *supra* note 83, at 26, 61.

[90] *See id.* at 26. Although this margin of savings may seem trivial, airline profits over the past forty years have been described as razor thin and anemic. *See* ATA, THE AIRLINE HANDBOOK, *supra* note 83, at 25; Dempsey, *supra* note 86, at 21. The average overall profit margin for the U.S. airline industry was only 2.8% between 1955 and 1977, it then dropped to 0.7% from 1978 to 1988, during the first decade of airline deregulation. Dempsey, *supra* note 86, at 21. Between 1989 and 1993, the average profit dropped to negative 0.4%. *Id.* Therefore, any variable cost which can be reduced improves the already low, or nonexistent, profits realized by airlines.

[91] *See* ATA, THE AIRLINE HANDBOOK, *supra* note 83, at 61-62; *see also* CORNING, *supra* note 79, at 2:96.

[92] *See* ATA, THE AIRLINE HANDBOOK, *supra* note 83, at 61-62; *see also* CORNING, *supra* note 79, at 2:2, 2:96.

[93] CORNING, *supra* note 79, at 2:97-2:98. Composite structures are lightweight materials that result in greater fuel efficiency. *Id.*

[94] *Id.* at 2:96-2:97. Supercritical airfoils are used to reduce the compressibility drag coefficient and wing weight, which results in greater fuel efficiency. *Id.*

fly-by-wire controls,[95] as well as focusing on optimizing SFC without increasing emissions.[96]

B. The Composition of Aircraft Engine Emissions and Factors Affecting Fuel Consumption

Emissions from aircraft engine combustion include CO, CO_2, VOCs, NO_x, PM, SO_2, and water vapor.[97] Historically, it has been necessary to balance HC/VOCs and CO emissions with NO_x reductions, and smoke emissions with NO_x reductions.[98] VOCs and CO are products of incomplete and inefficient combustion from low power engine operations;[99] NO_x results from high power operation of engines.[100] Smoke is also generally associated with higher power engine operations.[101] In early attempts to control emissions, engine designers and manufacturers focused engineering efforts on reducing or eliminating visible smoke emissions from jet exhaust.[102] The focus on smoke reduction was the result of regulatory efforts by EPA to control emissions of smoke from aircraft.[103] Between 1982 and 1997, the only aircraft engine emissions that were regulated were emissions of smoke and vented fuel.[104] A likely result of these regulations was the development by aircraft engine manufacturers of cleaner burning combustion chambers that have significantly reduced smoke emissions.[105]

The combined efforts of aircraft and engine designers and manufacturers to reduce smoke emissions have reaped large dividends in terms of reduced energy consumption per passenger mile by the air carrier sector of the transportation industry.[106] As it turns out, the cleaner burning

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[95] *Id.* at 2:98. Active fly-by-wire controls alter the structure and design of the aircraft itself, to reduce total aircraft weight and thereby improve fuel efficiency. *Id.*

[96] *See* GE, *Jet Engine Technology News Release*, *supra* note 77.

[97] ICAO/CAEP, EMISSIONS REPORT, *supra* note 2, at 15-17.

[98] *Id.* at 16.

[99] *Id.*

[100] ATA, THE AIRLINE HANDBOOK, *supra* note 83, at 62.

[101] ICAO/CAEP, EMISSIONS REPORT, *supra* note 2, at 16.

[102] *See* ATA, THE AIRLINE HANDBOOK, *supra* note 83, at 61.

[103] *See* 40 C.F.R. § 52.31(b)(4) (1998).

[104] *See* Control of Air Pollution from Aircraft and Aircraft Engines; Emission Standards and Test Procedures, 47 Fed. Reg. 58,462, 58,462 (Dec. 30, 1982) (codified at 40 C.F.R. §§ 87.21, 87.31); *see also* Control of Air Pollution from Aircraft and Aircraft Engines, 38 Fed. Reg. 19,088, 19,090-19,103 (July 17, 1973) (codified as amended at 40 C.F.R. pt. 87).

[105] *See* ATA, THE AIRLINE HANDBOOK, *supra* note 83, at 61.

[106] DOT, TRANSPORTATION STATISTICS, *supra* note 70, at 178, tbl.4-17.

aircraft engine characteristics attributable to reducing smoke emissions also make the engine more efficient in terms of fuel consumption.[107] Between 1960 and 1995, the number of seat-miles per gallon of fuel consumed increased from twenty-seven for domestic operations and twenty-five for international operations to forty-eight for both domestic and international operations.[108]

Efforts to increase fuel efficiency have also reduced HC and CO emissions.[109] The tradeoff, however, is that NO_x emissions have increased.[110] NO_x emissions are, and will continue to be, a constant reduction target for those AQCRs designated nonattainment for O_3.[111] Current emissions reduction technology therefore focuses on improving combustors and electronically controlled fuel systems because these technologies improve fuel efficiency without increasing NO_x emissions.[112]

Fuel efficiency and emission levels are not the only criteria that designers take into account when designing aircraft engines. Airworthiness safety considerations are given priority when designing combustors, for example.[113] The role of safety considerations is prominently reflected in both the statutory and regulatory provisions for controlling emissions from aircraft. For example, the applicable section of the CAA governing aircraft emission standards requires EPA to consult with the FAA on aircraft emission standards and prohibits EPA from changing the standards if such change will adversely affect safety.[114] Additionally, EPA and FAA regulations specify that regulatory provisions concerning aircraft emission

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[107] *See* ATA, THE AIRLINE HANDBOOK, *supra* note 83, at 62.

[108] DOT, TRANSPORTATION STATISTICS, *supra* note 70, at 178, tbl.4-17.

[109] *See* GAO, GLOBAL POLLUTION FROM JET AIRCRAFT, *supra* note 6, at 4.

[110] *Id.*

[111] *See* NRDC, *Flying Off Course*, *supra* note 1 (recommending more stringent NO_x standards).

[112] ICAO/CAEP, EMISSIONS REPORT, *supra* note 2, at 15. "[C]urrent technology combustors for regulated engines incorporate a short (straight through) annular design, fuel atomisers using air in some way to assist the process, efficient cooling configuration, low residence times, minimum pressure drop, fixed geometry air entry and a fuel injector spacing approximately the same as the combustor height." *Id.*

[113] *Id.* at 17-18. "Any new engine development designed to reduce emissions must perform at least as well as current in service designs, with respect to all airworthiness considerations.... [E]xamples of the most important airworthiness considerations include acceleration times, altitude relight, hail, rain and bird ingestion [requirements]." *Id.* at 18. Airworthiness considerations are part of the type certification process, and changes in combustor design to reduce emissions may thus have to be adjusted to meet airworthiness and reliability requirements. *Id.*; *see also* discussion *infra* Part IV.B.3.

[114] *See* CAA § 231(a)(2)(B), 42 U.S.C. § 7571(a)(2)(B) (1994).

limits will be revised if they either cannot be achieved within a set amount of time, or if they create a safety hazard.[115]

IV. INTERNATIONAL STANDARDS AND DOMESTIC LEGISLATIVE AND REGULATORY PROVISIONS

Efforts to regulate aircraft engine emissions take place in both international and domestic arenas. Both the international and domestic approaches have met with varying degrees of success. Future success in minimizing the contribution of aircraft emissions to nonattainment will depend on a combination of factors. Renewed emphasis on command and control emission limitations,[116] cooperative efforts to develop state of the art technology,[117] and efficient operational practices will all play a role in reducing the contribution of aircraft emissions to the national emissions inventory.[118]

A. The International Civil Aviation Organization's Role in Environmental Protection

Near the end of World War II, representatives from nations around the world gathered in Chicago to discuss the future of the burgeoning international aviation industry.[119] The conference resulted in the Convention on International Civil Aviation ("Chicago Convention" or "the Treaty"),[120] its supporting agreements, [121] and the formation of the International Civil Aviation Organization (ICAO).[122] The Treaty provides

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[115] 40 C.F.R. § 87.6 (1998); 14 C.F.R. § 34.6(a) (1998).

[116] *See* FAA, *FREE FLIGHT Introduction: What is Free Flight?*, <http://www.faa.gov/freeflight/ff_ov.htm> (visited Feb. 1, 1999) [hereinafter FAA, *What is Free Flight?*].

[117] *See* NATIONAL AERONAUTICS & SPACE ADMINISTRATION (NASA), AERONAUTICS & SPACE TRANSPORTATION TECHNOLOGY: THREE PILLARS FOR SUCCESS 2 (1997) [hereinafter NASA, THREE PILLARS FOR SUCCESS].

[118] *See* NATIONAL SCIENCE & TECHNOLOGY COUNCIL (NSTC), GOALS FOR A NATIONAL PARTNERSHIP IN AERONAUTICS RESEARCH AND TECHNOLOGY 13 (1995) [hereinafter NSTC, GOALS FOR A NATIONAL PARTNERSHIP].

[119] Convention on International Civil Aviation, Dec. 7, 1944, 15 U.N.T.S. 295 [hereinafter Chicago Convention].

[120] *Id.*

[121] *See* International Air Transport Agreement, *opened for signature* Dec. 7, 1944, 171 U.N.T.S. 387.

[122] *See* Chicago Convention, *supra* note 119, art. 37, 15 U.N.T.S. at 320.

for collaboration among contracting States[123] to develop "international standards" and "recommended practices" to facilitate and improve air navigation.[124] The Chicago Convention requires these standards and recommended practices to be codified in Annexes to the Treaty.[125] The Treaty lists several subjects for which the ICAO Council, the governing body of the ICAO, is to adopt international standards and practices,[126] including: communications systems; airport characteristics; air traffic control practices; personnel licensing; aircraft airworthiness; aircraft registration; and other matters dealing with the "safety, regularity and efficiency of air navigation."[127]

Between 1948 and 1953, the ICAO Council adopted fifteen Annexes and has gradually amended them to meet the ever increasing needs of modern international civil aviation.[128] The ICAO member States are urged to comply with the international standards and recommended practices by incorporating such standards into their national regulations.[129] The ICAO further urges member States to use ICAO language to the greatest extent possible,[130] to avoid losing the benefits of the international standardization of practices.[131] Along this vein, article 38 of the Chicago Convention requires contracting States to notify the ICAO of any differences between their national regulations and the international standards contained in properly adopted or amended Annexes.[132]

At the 1972 United Nations Conference on the Human Environment, the ICAO acknowledged "the adverse environmental impact that may be related to aircraft activity and its responsibility and that of its member States to achieve maximum compatibility between the safe and orderly development of civil aviation and the quality of the human environment."[133]

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[123] For the purposes of this Article, "States" refers to the official parties to the Chicago Convention.

[124] *Id.* art. 37, 15 U.N.T.S. at 320-22.

[125] *Id.* art. 54, 15 U.N.T.S. at 334.

[126] *See id.*

[127] *Id.* art. 37, 15 U.N.T.S. at 320-22.

[128] THOMAS BUERGENTHAL, LAW-MAKING IN THE INTERNATIONAL CIVIL AVIATION ORGANIZATION 60 (1969).

[129] *See id.* at 103.

[130] *Id.*

[131] *Id.*

[132] Chicago Convention, *supra* note 119, art. 38, 15 U.N.T.S. at 322.

[133] 2 ICAO, *Foreword* to ENVIRONMENTAL PROTECTION: ANNEX 16 TO THE CONVENTION ON INTERNATIONAL CIVIL AVIATION v (2d ed. 1993) [hereinafter ICAO, ANNEX 16].

The ICAO established an Action Programme Regarding the Environment and a Study Group to assist the Secretariat in its study of aircraft engine emissions.[134] In 1977, the Study Group published a circular on the control of engine emissions containing guidance material regarding certification procedures for the control of vented fuel, smoke, and gaseous emissions from aircraft that are intended for subsonic propulsion.[135]

The ICAO Council agreed with the Study Group that the subject of aircraft emissions was sufficiently complex to merit the participation of numerous experts in differing fields in addition to the representatives from contracting States.[136] In furtherance of this proposal, the ICAO established the Committee on Aircraft Engine Emissions (CAEE) in 1977 to pursue the subject of aircraft engine exhaust emissions.[137] At the second meeting of CAEE, held in May 1980, members proposed material to be incorporated in an ICAO Annex.[138] The ICAO Council adopted the proposed material in the form of an Annex on Aircraft Engine Emissions.[139] The ICAO Council decided to include all provisions that pertained to environmental aspects of aviation in a single Annex.[140] It therefore renamed Annex 16 "Environmental Protection," made the existing text of Annex 16 into "Volume I—Aircraft Noise," and made the new material into "Volume II—Aircraft Engine Emission" ("Volume II").[141] Additionally, the responsibilities of the Aircraft Noise and the Aircraft Engine Emissions Committees were combined to create the Committee on Aviation Environmental Protection (CAEP or "the Committee").[142]

After its second meeting, CAEP adopted a recommendation that Volume II be amended.[143] Proposed amendments included new regulatory levels for NO_x; modified smoke emission evaluation procedures; and modified general test procedures including leakage and cleanliness checks and specifications for HC, CO, CO_2, and NO_x analyzers.[144] The proposals were adopted by the ICAO Council in March of 1993 and became

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[134] *Id.*
[135] *Id.*
[136] *Id.*
[137] *Id.*
[138] *Id.*
[139] *Id.*
[140] *Id.*
[141] *Id.*
[142] *Id.* at vii tbl.A.
[143] *Id.*
[144] Control of Air Pollution from Aircraft and Aircraft Engines; Emission Standards and Test Procedures, 62 Fed. Reg. 25,356, 25,357-58 (May 8, 1997).

applicable in November of 1993.[145] These newly adopted regulatory levels became the basis for EPA's 1997 rulemaking on aircraft engine emissions.[146]

At the Third Meeting of the CAEP in 1995, the Committee recommended further amendments to Volume II.[147] The Committee's recommendation regarding calibration and test gases was adopted as an Amendment to Volume II, in March of 1997.[148] The Committee also recommended that Volume II be amended to increase the stringency of NO_x emission limits for certain aircraft engines.[149] The Committee wants to achieve a sixteen percent emission reduction in aircraft engines with a first production model manufacture date after December 31, 1999, or with an individual engine manufacture date after December 31, 2007.[150]

This last recommendation has been resisted by the United States, Canada, and Russia, leading to unilateral action by the European Commission to adopt the more stringent NO_x standards in the European Union (EU).[151] The proposed EU legislation, which would transpose the NO_x recommendations from the Third Meeting of the CAEP into EU law, was adopted without alteration by the European Parliament in April 1998.[152] The measure applies to the registration of additional aircraft within the EU by EU member states.[153] The draft is going to the EU Council of Ministers, who will determine their common position on the proposals, and, barring significant changes by members, will return it to the European Parliament where passage is expected to be a mere formality.[154]

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[145] ICAO, ANNEX 16, *supra* note 133, at vii tbl.A.

[146] 62 Fed. Reg. at 25,358. *See infra* text accompanying notes 180-85.

[147] *Report of the Committee on Aviation Environmental Protection, Held at Montreal from 5 to 15 December 1995*, ICAO, 3d Meeting, Doc. No. 9675, Agenda Item 2, at 2-7, 2-13, and 2-A-1 app.A (1995) [hereinafter *CAEP/3 Report*].

[148] ICAO, ANNEX 16, *supra* note 133, at vii tbl.A.

[149] *CAEP/3 Report*, *supra* note 147, Agenda Item 2, at 2-12 to 2-13, 2-C-1 app.C.

[150] *Id.*

[151] *See Tighter Standards for Aircraft Emissions Approved by Assembly Without Amendments*, Daily Env't Rep. (BNA) No. 65, at A-6 (Apr. 6, 1998).

[152] *Id.*

[153] *Id.*

[154] *Id.* at A-6 to A-7.

B. Domestic Legislative and Regulatory Provisions

1. Legislative Authority

EPA has authority to promulgate aircraft emission standards, subject to presidential veto upon the advice of the FAA on flight safety issues.[155] The Secretary of Transportation ("the Secretary") is charged with ensuring compliance with these standards.[156] Because statutory authority for enforcement of aircraft emission standards is delegated to the FAA,[157] EPA does not conduct widespread in-use testing of aircraft engines and does not have an aircraft engine emissions enforcement program. The EPA regulations for in-use testing of aircraft engines are limited to Smoke Number (SN)[158] testing for limited classes of engines.[159]

CAA section 232 directs the Secretary to prescribe regulations ensuring compliance with CAA section 231.[160] The FAA's statutory mandate includes "promot[ing] safe flight of civil aircraft . . . by prescribing . . . minimum standards . . . for the design, material, construction, quality of work, and performance of aircraft [engines]."[161] Additionally, the FAA prescribes regulations and minimum standards for (1) inspecting, servicing, and overhauling aircraft engines; (2) equipment and facilities for and the timing and manner of the inspecting, servicing, and overhauling; and (3) the reserve supply of aircraft engines.[162] In order to ensure compliance with EPA's emission standards, the FAA makes the emissions standards applicable in the

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[155] CAA § 231(c), 42 U.S.C. 7571(c) (1994).

[156] *Id.* § 232(a), 42 U.S.C. § 7572(a).

[157] *See* 14 C.F.R. § 21.33 (1998).

[158] Smoke number (SN) is a "[d]imensionless term quantifying smoke emission level based upon the staining of a filter by the reference mass of exhaust gas sample, and is rated on a scale of 0 to 100." ICAO, ANNEX 16, *supra* note 133, at 14 app.2. The stained filter specimens are analyzed using a reflectometer which conforms to American National Standards Institute (ANSI) Standard No. PH2.17/1977 for diffuser reflection. *Id.* at 16. "The backing material [for stained filter specimens] . . . used shall be black with an absolute reflectance of less than 3 per cent." *Id.* at 17 app.6. "The SN at every power setting must be such that there is a high degree of confidence that the standard will not be exceeded by any engine of the model being tested." 40 C.F.R. § 87.89 (1997).

[159] *See id.* § 87.31.

[160] CAA § 232(a), 42 U.S.C. § 7572(a).

[161] 49 U.S.C. § 44701(a)(1) (1994).

[162] *Id.* § 44701(a)(2)(A)-(B), (a)(3).

issuance, amendment, modification, suspension, or revocation of certificates of airworthiness.[163] Consequently, the forum for ensuring compliance with emissions standards is the aircraft certification process, and, more precisely as discussed below, the type certification process.[164]

2. *EPA's Regulation of Aircraft Engine Emissions*

EPA has conducted several rulemakings under its section 231 authority to establish emission standards and related requirements for several classes of commercial and general aviation aircraft and aircraft engines.[165]

In 1973, EPA promulgated emission regulations for vented fuel, smoke, and exhaust (HC, NO_x, and CO) emissions.[166] Three tiers of standards were promulgated: (1) retrofit standards for in-use engines; (2) standards for newly manufactured engines (those engines built after the effective date of the regulations); and (3) standards for newly certified engines (those engines designed and certified after the effective date of the regulations).[167] On August 16, 1976, EPA promulgated emission standards for supersonic aircraft engines.[168] On January 7, 1980, EPA rescinded all gaseous emission requirements for piston engines (P1) and auxiliary power units.[169]

As previously discussed, the ICAO issued its initial standards and recommended practices concerning emissions from aircraft engines in 1981.[170] Under Chicago Convention treaty obligations, the United States is required to notify ICAO of differences between its domestic standards

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[163] CAA § 232(a), 42 U.S.C. § 7572(a).

[164] *Id.*; *see* discussion *infra* Part IV.B.3.

[165] CAA § 231(c), 42 U.S.C. 7571(c).

[166] Control of Air Pollution from Aircraft and Aircraft Engines, 38 Fed. Reg. 19,088, 19,090-103 (July 17, 1973) (codified as amended at 40 C.F.R. pt. 87).

[167] *Id.* (codified as amended at 40 C.F.R. §§ 87.10-.11, 87.20-.21, 87.40-.41).

[168] Control of Air Pollution from Aircraft and Aircraft Engines, 41 Fed. Reg. 34,722, 34,724-25 (Aug. 16, 1976) (codified as amended at 40 C.F.R. § 87.21).

[169] Control of Air Pollution from Aircraft and Aircraft Engines; Amendments to the Emission Standards for Aircraft Engines, 45 Fed. Reg. 1419, 1421 (Jan. 7, 1980) (codified as amended at 40 C.F.R. §§ 87.2, 87.60, 87.63). Piston engines are primarily used in general aviation aircraft. *See id.* at 1420.

[170] Control of Air Pollution from Aircraft and Aircraft Engines; Emission Standards and Test Procedures, 62 Fed. Reg. 25,356, 25,357 (May 8, 1997).

and the standards of the ICAO.[171] When the 1981 ICAO standards were issued, EPA was involved in a rulemaking that reconsidered a number of the agency's then-current regulatory provisions pertaining to aircraft emissions.[172] On December 30, 1982, EPA made comprehensive changes to U.S. aircraft emission standards.[173] EPA withdrew HC, CO, and NO_x emission standards for several types of aircraft engines.[174] EPA also transferred responsibility and authority for the evaluation of requests for exemption from emission standards to the Secretary of Transportation.[175]

The 1982 rulemaking cut back the initial emissions program that EPA established in 1973.[176] Although EPA decided not to fully adopt the 1981 ICAO standards, the agency stated that its standards were compatible with the ICAO requirements.[177] On October 18, 1984, EPA amended the test fuel specifications by broadening the ranges of allowable test fuel naphthalene content, hydrogen content, viscosity, and final boiling point values.[178]

At that time, EPA regulations were limited to smoke and fuel venting emissions standards for all commercial jet aircraft classes—turboprop (TP), turbofan or turbojet (TF), turbine engines of the JT3D model family (T3), turbine engines of the JT8D model family (T8), and gas turbine engines for aircraft designed to operate at supersonic flight speeds (TSS)—as well as HC emission standards for newly

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[171] Chicago Convention, *supra* note 119, art. 38, 15 U.N.T.S. at 322.

[172] 62 Fed. Reg. at 25,357; *see* Control of Air Pollution from Aircraft and Aircraft Engines; Emission Standards and Test Procedures, 47 Fed. Reg. 58,462, 58,470-74 (Dec. 30, 1982) (codified as amended at 40 C.F.R. §§ 87.1-.7, 87.10-.11, 87.20-.21, 87.30-.31, 87.60-.71, 87.80-.89).

[173] *See* 42 Fed. Reg. at 58,470-74 (codified as amended at 40 C.F.R. pt. 87).

[174] *See id.* at 58,464-65 (codified as amended at 40 C.F.R. §§ 87.21, 87.31). EPA withdrew the standards for aircraft engines used only for general aviation applications, aircraft engines with rated thrust less than 26.7 kilonewtons (kN), and newly certified aircraft gas turbine engines in all rated thrust categories. *Id.*

[175] *Id.* at 58,471. EPA also revised smoke emission standards for turboprop engines to agree with existing U.S. Air Force smoke standards; revised the compliance date for all gaseous emission standards from January 1, 1983 to January 1, 1984; exempted engine models produced in quantities of 20 units per year or less or not more than 200 units total future production; redefined the idle power set point for engine compliance testing; and revised the test fuel specification for engine compliance testing. *Id.*

[176] *Id.* at 58,464.

[177] *Id.*

[178] Control of Air Pollution from Aircraft and Aircraft Engines; Exemptions for Low Production Engines, 49 Fed. Reg. 41,000, 41,002 (Oct. 18, 1984) (codified at 40 C.F.R. § 87.61).

manufactured aircraft engines of the TF, T3, and T8 classes with thrust greater than 26.7 kilonewtons (kN).[179]

In 1997, EPA determined that NAAQS violations for NO_x and CO endangered public health and welfare in several AQCRs.[180] EPA also concluded that airports and aircraft either were, or were soon to be, significant sources of NO_x and CO emissions in some of the AQCRs with nonattainment problems.[181] Consequently, EPA issued a final rule adopting the 1981 ICAO standards for the regulation of CO and NO_x emissions, the ICAO's 1993 amendments to the NO_x standards, and several technical amendments necessary to conform EPA standards more closely to ICAO requirements.[182] The agency felt that the adoption of the ICAO NO_x and CO emission standards and related test procedures would help achieve and maintain nationwide NAAQS compliance for O_3, NO_x, CO, and PM.[183] In describing this rulemaking action, EPA stated that NAAQS cannot be maintained unless aircraft engines are controlled in accordance with their significance as pollution sources.[184] While the enactment of the rule is commendable, most of the affected engines were already meeting the international CO and NO_x emission standards when the rule was adopted.[185] Therefore, only a few engine models will have to accomplish minor reductions to satisfy the regulation.

Aircraft and aircraft engines are sold in the international marketplace. Consequently, they are often designed and manufactured to meet international standards. Thus, the United States' initial failure to adopt the ICAO CO and NO_x standards in 1982 did not prevent progress from being made in the reduction of these emissions.[186] These new standards, however, will not be immediately effective in reducing emissions because aircraft and aircraft engines have a very long useful life and complete fleet turnover is not expected for at least another twenty years.[187]

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[179] *Id.*

[180] 62 Fed. Reg. at 25,358.

[181] *Id.*

[182] *See id.*

[183] *Id.*

[184] *Id.* at 25,359.

[185] Control of Air Pollution From Aircraft and Aircraft Engines; Emission Standards and Test Procedures, 62 Fed. Reg. 25,368, 25,368 (May 8, 1997) (to be codified at 40 C.F.R. pt. 87).

[186] *Id.*

[187] *See* Government Aviation Administration and Coordination, 56 Fed. Reg. 5356, 5361-62 (Feb. 11, 1991) (codified as amended at 41 C.F.R. § 101-37.506(b)(4)(I)).

Having said this, it is important to note that command and control regulations for criteria pollutants are not the only factors influencing emissions from aircraft. Relatively low emissions rates are driven partially by EPA's smoke regulations.[188] Airline manufacturer efforts to reduce their direct operating costs by lowering fuel consumption also play a major role.[189] Statistical analysis shows that energy use by aircraft per unit of passenger travel dramatically improved in the 1970s and 1980s.[190]

3. *FAA's Role in the Regulation of Aircraft Engine Emissions*

An airworthiness certificate is required to place an aircraft in service.[191] To obtain an airworthiness certificate for an aircraft, the registered owner of the aircraft must apply to the Administrator of the FAA.[192] The FAA issues an airworthiness certificate if it determines that the aircraft "conforms to its type certificate and, after inspection, is in condition for safe operation."[193] The FAA has the authority to include terms in the airworthiness certificate that it determines to be "in the interest of safety."[194]

a. Aircraft Engine Certification: Administrative Matters

Administrative rules regarding aircraft engine certification are found at 14 C.F.R. § 21. The first step a manufacturer undertakes in obtaining an airworthiness certificate, which allows for introduction of an aircraft engine

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[188] Control of Air Pollution from Aircraft and Aircraft Engines; Emission Standards and Test Procedures, 47 Fed. Reg. 58,462, 58,462 (Dec. 30, 1982) (codified at 40 C.F.R. §§ 87.21, 87.31); *see also* Control of Air Pollution from Aircraft and Aircraft Engines, 38 Fed. Reg. 19,088, 19,090-103 (July 17, 1973).

[189] *See* CORNING, *supra* note 79, at 2:96.

[190] *See* MICHAELIS, *supra* note 71, at 16. Energy intensity, as measured for international civil aviation by the ICAO, takes account of changes in aircraft load factor. *See id.* Similarly, energy intensiveness measurements for U.S. domestic civil aviation includes load factor as a measurement characteristic. DOT, TRANSPORTATION STATISTICS, *supra* note 70, at 178 tbl.4-17. Energy intensiveness is listed in British Thermal Units (BTU) per passenger-mile flown. *Id.* If an aircraft flies with fewer passengers, it will burn more fuel per passenger. Telephone Interview with Donald Bright, Bureau of Transportation Statistics, Office of Airline Information, DOT (Jul. 30, 1998).

[191] *See* 49 U.S.C. § 44701(a), 44704(a) (1994).

[192] *Id.* § 44704(c).

[193] *Id.* § 44704(c)(1).

[194] *Id.*

into commercial service, is obtaining a type certification.[195] Applications for type certification are submitted to the regional Aircraft Certification Office.[196] The FAA issues a type certificate for an aircraft engine if the engine "is properly designed and manufactured, performs properly, and meets the regulations and minimum standards prescribed."[197] The FAA has established four Aircraft Certification Directorates with subordinate Aircraft Certification Offices that perform technical policy and airworthiness certification management programs, which include issuing type certificates, production certificates, and airworthiness certificates.[198]

Each directorate is assigned a discrete airworthiness standards program over which it has primary authority.[199] Within its area of authority, each directorate has responsibility "for determining compliance with applicable noise and engine emissions standards."[200] The FAA's Office of Environment and Energy handles noise and emissions standards, and also

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[195] *Id.*

[196] 14 C.F.R. § 21.17 (1998).

[197] 49 U.S.C. § 44704(a). "[A] description of the engine design features, the engine operating characteristics, and the proposed engine operating limitations" must accompany an application for an aircraft engine type certificate. 14 C.F.R. § 21.15(c). "[F]ailure, malfunction, or defect in any product, part, process, or article manufactured by" the certificate holder must be reported to the Federal Aviation Administration (FAA). *Id.* § 21.3. The type certification applicant may also be required "to make tests the [FAA] considers necessary in the interest of safety." 49 U.S.C. § 44704(a).

[198] FEDERAL AVIATION ADMINISTRATION (FAA), DOT, ORDER NO. 8000.51: AIRCRAFT CERTIFICATION DIRECTORATES 1-3 (Feb. 1, 1982).

[199] *Id.* at 2-3. For the airworthiness standards for which they have responsibility, Aircraft Certification Directorates are delegated the authority to:

> (1) Issue, amend, suspend or cancel type and supplemental type certificates.
> (2) Grant or deny exemptions.
> (3) Issue, amend, extend, or withdraw notices of proposed rulemaking.
> (4) Issue, amend, or cancel advisory circulars.

Id. at 2-3. The Small Airplane Certification Directorate is assigned Federal Aviation Regulation, part 23 (Airworthiness for Normal, Small, Utility, Acrobatic and Commuter Aircraft). *Id.* at 4. The Transport Airplane Certification Directorate is assigned Federal Aviation Regulation, part 25 (Airworthiness for Transport Aircraft). *Id.* at 5. The Rotortcraft Certification Directorate is assigned Federal Aviation Regulation, parts 27 and 29 (Airworthiness for Normal and Transport Rotorcraft). *Id.* The Engine and Propeller Certification Directorate is assigned Federal Aviation Regulation, parts 33 and 35 (Airworthiness for Aircraft Engines and Aircraft Engine Propellers). *Id.*

[200] *Id.* at 6.

provides technical guidance on measurement, evaluation, and test procedures.[201]

After the Aircraft Certification Office receives an application for a type certification, it assigns a project manager.[202] The project manager heads up a project team that meets with the applicant to give the FAA a general understanding of the design, design objectives, certification schedule, possible problem areas, and other relevant issues.[203] After this initial meeting, the type certification process then involves additional data submittal, design evaluation, conformity inspections, engineering compliance determinations, flight tests, manufacturing inspections, functional and reliability testing, and reviews by an Interim Type Certification Board and a Final Type Certification Board.[204] Requests for approval of deviations from approved test procedures, as well as requests to use an equivalent means of compliance, are made via the accountable directorate to the FAA Offices of Airworthiness and Environment and Energy.[205]

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[201] *Id.* To ensure efficient operation of the Aircraft Certification Directorate system, an Aircraft Certification Policy Board, composed of the FAA Administrator, the Associate Administrator for Aviation Standards, the Director of Airworthiness and the Directors of each of the four Aircraft Certification Directorates, gather periodically "to review and resolve significant national policy issues affecting the aircraft certification programs." *Id.* at 3-5.

[202] FAA, DOT, AIRCRAFT CERTIFICATION DIRECTORATE PROCEDURES 14 (1982) [hereinafter FAA, DIRECTORATE PROCEDURES]. The project manager notifies the accountable directorate of his preliminary determination regarding whether or not the certification application involves a significant action. *Id.* The accountable directorate, upon receipt of the project manager's notice and preliminary determination of significance, will make its own significance determination. *Id.* Responsibility for nonsignificant projects remains with the Aircraft Certification Office, whereas significant projects involve both the Aircraft Certification Office and the accountable directorate. *Id.* When the accountable directorate deems a project significant, despite the opinion of the Aircraft Certification Office, the accountable directorate will assign a project officer. *Id.*

[203] *Id.* at 15-16. "The bulk of the type certification activity should be accomplished through ongoing technical assessments [by the project team members] in conjunction with accountable directorate specialist[s]" when necessary. *Id.* at 17. "Depending on the extent and complexity of the project, the amount of . . . design information available, the use of novel or unique design features, materials or processes, and the possible need for regulatory actions and public notices, the first meeting may be combined with a preliminary [Type Certification] Board meeting." *Id.* at 16.

[204] *Id.* at 16-18; FAA, DOT, ORDER NO. 8110.4A: TYPE CERTIFICATION PROCESS 6-8 (Mar. 2, 1995).

[205] FAA, DIRECTORATE PROCEDURES, *supra* note 202, at 19.

When the FAA finds that the reproduction of an aircraft engine for which a type certificate has been issued will conform to the certificate, it issues a production certificate.[206] On receiving a production certificate application, the FAA inspects, and may require the testing of, a duplicate engine to ensure that it conforms to the requirements of the certificate.[207] The agency may also include additional terms required in the interest of safety.[208]

A supplemental type certificate may be issued for a change to an aircraft engine.[209] The basic relationships between accountable directorates and the Aircraft Certification Offices regarding the issuance of type certificates also apply for supplemental type certificates, however, the extent of participation by personnel from the accountable directorates may be significantly less.[210]

b. Aircraft Engine Certification: The Approved Test Procedures

The approved test procedure consists of operating the engine at particular power settings that are measured by an engine dynamometer or thrust measuring test stand.[211] The regulation covers the following classes of engines: (1) T3; (2) T8; (3) TF; (4) TP; and (5) TSS.[212] Exhaust gases generated during engine operation are sampled continuously to determine their chemical makeup.[213] The test is designed to simulate an aircraft landing-takeoff cycle (LTO).[214] The LTO cycle consists of at least four modes of engine operation: taxi/idle, takeoff, climbout, and approach.[215] The test does not include the thrust reverse, or beta mode, used by pilots to decelerate from approach speed to a safe taxi speed after landing. The LTO power setting for each mode is dependent on the class of engine tested.[216]

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206 49 U.S.C. § 44704(b) (1994).
207 *Id.*
208 *Id.*
209 *Id.*; 14 C.F.R. § 21.
210 FAA, DIRECTORATE PROCEDURES, *supra* note 202, at 19.
211 40 C.F.R. § 87.60(b) (1997).
212 *See id.* § 87.1(a).
213 *Id.* § 87.60(b).
214 *Id.* § 87.60(c).
215 *Id.*
216 *See id.* § 87.62(a)(1).

The sampling and measurement system for gaseous emissions is taken directly from ICAO procedures,[217] which have been incorporated by reference into the federal regulations.[218] The ICAO procedures provide measurement techniques and technical specifications for instrumentation; HC, CO, and CO_2 emission levels; NO_x analyzers; and specific techniques for the measurement of gaseous emissions.[219] There are a set of procedures for engines not employing afterburners (subsonic aircraft) and a set of procedures for engines employing afterburners (supersonic aircraft).[220] The federal regulation prescribes that compliance will be determined by comparing the pollutant emission level observed during the test with the applicable emissions standards.[221]

The approved federal testing procedures incorporate an alternative to testing every engine[222]—a procedure which is described in Appendix 6 of ICAO Annex 16.[223] The ICAO Appendix 6 procedure allows the manufacturer to select any number of engines for certification testing, including even a single engine.[224] For the purposes of the application, the results from all certification tests performed are evaluated.[225] The engines submitted for testing must have emissions features representative of the engine type for which certification is sought.[226] There must be at least one reference standard engine that is "configured to the production standard of the engine type and [has] fully representative operating and performance characteristics."[227] Moreover, the ICAO Appendix 6 procedure prescribes that at least three engine tests be conducted.[228] If the manufacturer elects to submit only one engine for testing, it must be tested at least three times.[229]

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[217] ICAO, ANNEX 16, *supra* note 133, at 18-34 app.3, 36-53 app.5.

[218] *See* 40 C.F.R. § 87.64.

[219] ICAO ANNEX 16, *supra* note 133, at 18-34 app.3, 36-53 app.5.

[220] *Id.*

[221] 40 C.F.R. § 87.71. The standards for SN and gaseous exhaust emissions are listed in 40 C.F.R. § 87.21. If an engine type fails a certification test, the certificating authority can permit additional tests and modifications, "until compliance has been demonstrated or the engine type application is withdrawn." ICAO, ANNEX 16, *supra* note 133, at 54-55 app.6.

[222] 40 C.F.R. § 87.89.

[223] ICAO, ANNEX 16, *supra* note 133, at 54 app.6.

[224] *Id.*

[225] *Id.*

[226] *Id.*

[227] *Id.*

[228] *Id.*

[229] *Id.*

If a given engine is tested more than once, the arithmetic mean of the test results is used as the mean value for that engine.[230] A certificate of compliance is awarded "if the mean of the values measured and corrected . . . [and] converted . . . does not exceed the [prescribed] regulatory level."[231]

c. Aircraft Engine Certification: Designated Engineering Representatives

The FAA delegates most of the responsibility for designing and conducting emission tests to jet engine manufacturers.[232] The agency appoints a designated engineering representative (DER), who is an employee of the jet engine manufacturer seeking certification, to represent the FAA throughout the emissions testing process.[233] The FAA delegates responsibilities to manufacturers and DERs in many of its operations, not just in the regulation of engine emissions.[234] The FAA emphasizes that this delegation is necessary because the FAA does not have the resources to perform the emission tests and because the engine and aircraft manufacturers have the legal responsibility for ensuring compliance.[235] The DER process has been upheld by the United States Supreme Court, so it is unlikely that significant changes will be made to the program.[236]

DERs are responsible for assessing whether the manufacturers' procedures and processes meet FAA and ICAO requirements for examining

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[230] *Id.*

[231] *Id.* The characteristic level is "the mean value of all the engines tested, measured, and corrected to the reference standard engine and reference ambient conditions divided by the coefficient corresponding to the number of engines tested." *Id.* The coefficient for determining the characteristic level for SN increases with the number of engines tested. *Id.* The coefficient ranges from 0.776 for one engine, to 0.950 for ten engines. *Id.* The formula provides an incentive for engine manufacturers to test multiple engines. The greater the number of engines tested, the higher the denominator and therefore the lower the characteristic level. *See id.* The test procedures for smoke emission are completed by comparing the plot of the SN with the applicable emission standard for the type of engine. 40 C.F.R. § 87.89.

[232] 14 C.F.R. §§ 21.33, 21.35 (1998); *see also* GAO, AIR POLLUTION: FAA'S RELIANCE ON MANUFACTURERS FOR JET ENGINE EMISSION TESTING (GAO/RCED-94-99) 1 (1994) [hereinafter GAO, JET AIRCRAFT EMISSION TESTING].

[233] 14 C.F.R. § 183.29.

[234] GAO, JET AIRCRAFT EMISSION TESTING, *supra* note 232, at 2.

[235] *See id.* at 4.

[236] *See* United States v. S.A. Empresa De Viacao Aerea Rio Grandense, 467 U.S. 797, 807 (1984).

and approving engineering technical data and for submitting final certification documents.[237] To meet these responsibilities, DERs function as day-to-day liaisons between the FAA and the manufacturers.[238] Although the FAA reviews and approves test plans and results, it rarely inspects the manufacturers when they conduct such tests.[239]

It is important to note, however, that the emissions test is only one of more than eighty tests an engine must complete before a type certificate is awarded.[240] Since 1984, sixty-one jet engine designs have been certified under the emission standards, but only twelve of those engines were physically tested.[241] The remaining forty-nine engine designs share the same emissions characteristics as the twelve engine prototypes, and were certified using data from physical tests performed on the prototypes.[242] Once a manufacturer tests and certifies a prototype engine, there is no limit to the number of engines of the same type that it can manufacture, put in service, and then operate.[243] No additional emissions testing is necessary.[244]

There is at best a perceived conflict of interest in the DER process, and at worst an actual conflict.[245] At the same time the DERs are employed by the engine manufacturers, they have primary responsibility for a government regulatory compliance program.[246] In a survey of forty-two DERs conducted by the Engine and Propeller Directorate, nine said "they felt limited or moderate pressure from their employers to compromise their responsibility to FAA."[247] The balance of the respondents reported that they felt "no pressure to compromise their responsibilities to FAA."[248] To overcome apparent and actual conflicts, the FAA has a policy of appointing only those employees who have sufficient authority within their companies to resist pressure to bypass FAA's requirements.[249] In addition, manufacturers align their organizational structures so that DERs report to

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[237] *See* 14 C.F.R. § 183.29; GAO, JET AIRCRAFT EMISSION TESTING, *supra* note 232, at 2-3.

[238] GAO, JET AIRCRAFT EMISSION TESTING, *supra* note 232, at 3-4.

[239] *Id.* at 1-2.

[240] *See also id.* at 3.

[241] *Id.* at 5.

[242] *Id.*

[243] *Id.*

[244] *Id.*

[245] *See id.* at 8.

[246] *Id.*

[247] *Id.*

[248] *Id.* at 8-9.

[249] *Id.* at 8.

managers who are not directly responsible for the design and development of engines.[250]

d. Aircraft Engine Certification of Foreign Manufactured Products

The procedures for issuance of type certificates for imported products are different from those for domestic products. Once a type certificate is issued for an imported product, however, it has the same status and validity as one issued to a domestically manufactured product.[251] Aircraft manufactured outside the United States are type certified in the United States under the provisions of 14 C.F.R. § 21.29 and the applicable Bilateral Airworthiness Agreement (BAA).[252] Presently, there are twenty-seven BAAs in existence between the United States and foreign countries.[253] Compliance findings for imported products are based on technical evaluations, inspections, and certifications conducted both by the FAA and the competent airworthiness authority of the manufacturing country.[254]

When the United States has a BAA agreement with a particular country for the acceptance of a product manufactured in that country, a type certificate may be issued.[255] BAAs minimize the burden that would be placed on the FAA if it were required to approve the products on site. Before a type certificate will be issued for a product manufactured abroad, several requirements must be met.[256] The foreign country entrusted to examine the product must be approved by the FAA.[257] The foreign manufacturer must submit certain technical data regarding aircraft noise and airworthiness.[258] All manuals, listings, and instrument markings must be printed in English.[259] After ascertaining that the foreign manufacturer has met these requirements, the FAA must verify that the airworthiness and

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[250] *Id.*

[251] *See* FAA, DIRECTORATE PROCEDURES, *supra* note 202, at 23-24.

[252] *Id.*

[253] DOT, FAA, *Overview of Bilateral Airworthiness Agreements*, <http://www.fedworld.gov/pub/faa-cai/0_about> (visited Feb. 1, 1999).

[254] FAA, DIRECTORATE PROCEDURES, *supra* note 202, at 23.

[255] *Id.*

[256] *Id.* at 23-24.

[257] *Id.*

[258] *Id.*

[259] *Id.*

environmental standards applied by the Foreign Civil Airworthiness Authority (FCAA) are in compliance with U.S. requirements.[260]

The existence of a BAA does not always guarantee acceptance of a type certification issued by an FCAA.[261] Minor differences may exist between the FAA and FCAA regarding engine component standards.[262] For example, an FCAA may have a bird ingestion, icing, or parts life cycle standard that is not acceptable to the FAA.[263] In such cases, the FAA dispatches a harmonization team to the FCAA to attempt to resolve the differences.[264]

V. FUTURE ISSUES

Air travel will continue to play a vital role in future domestic and international growth. The commercial airline industry currently carries 1.25 billion passengers and 22 million tons of cargo, accounting for a $1 trillion per year contribution to the global economy.[265] Because of the vital role transportation industries play in economic growth, they are extremely important to a country's economic well-being.[266] Furthermore, developments in the transportation industries often lead to broader domestic and international economic prosperity.[267] The North American air transportation market is projected to grow four percent per year over the next two decades, while the global market is projected to increase by five to six percent per year during this same period.[268] Estimates for the Asian-Pacific market range from seven to approximately ten percent per year.[269]

Manufacturers' efforts to develop environmentally compatible aircraft to meet future transportation needs will be shaped both by improved technologies and an assortment of nontechnical measures.[270] Technological

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[260] *Id.*

[261] Telephone Interview with Locke Easton, Engine and Propeller Directorate, FAA (June 8, 1998).

[262] *Id.*

[263] *Id.*

[264] *Id.*

[265] Dempsey, *supra* note 86, at 16-17 (citing an ICAO statistic).

[266] *Id.* at 16. (citing PAUL DEMPSEY, THE SOCIAL & ECONOMIC CONSEQUENCES OF DEREGULATION: THE TRANSPORTATION INDUSTRY IN TRANSITION 5 (1989)).

[267] *Id.*

[268] *Id.* at 81.

[269] *Id.*

[270] *See* NSTC, GOALS FOR A NATIONAL PARTNERSHIP, *supra* note 118, at 13. The

approaches are anticipated to include cleaner, more efficient low emission combustors, advanced wing designs, integrated flight, propulsion controls, and use of lightweight materials.[271] Nontechnical measures will likely include: (1) operational practices such as reduced use of auxiliary power units (APUs);[272] (2) scheduling of low emission aircraft in problem areas; (3) single engine taxi, derated power takeoff; (4) reduced use of thrust reverse on landing roll out; (5) air traffic management measures; and (6) fiscal disincentives such as user fees and environmental charges.[273]

A wildcard that is only now emerging as a factor in the control of emissions from aircraft is the control of greenhouse gas emissions.[274] The impacts of the greenhouse gas constituents in aircraft emissions released at high altitudes is uncertain.[275] In particular, the effects of NO_x, in conjunction with the combined effects of water vapor, unburned HCs, CO, PM, and SO_2, are unclear.[276] Preliminary atmospheric modeling results indicate that O_3 generated by NO_x emissions at an altitude of 32,000 to 39,000 feet may have a greenhouse effect similar to that of CO_2 emissions.[277] Current analysis of atmospheric models has not yet resolved these uncertainties.[278] The draft of a new study by the U.N. Intergovernmental Panel on Climate Change reports that aircraft emissions could be responsible for five to six percent of the warming caused by greenhouse gases.[279] Some of the study's authors even suggest the true

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National Science and Technology Council (NSTC) was established by Executive Order 12,881 on November 23, 1993. Exec. Order No. 12,881, 58 Fed. Reg. 62,491 (Nov. 26, 1993). The NSTC "is the principal means for the President to coordinate science, space, and technology policies across the Federal Government." NSTC, GOALS FOR A NATIONAL PARTNERSHIP, *supra* note 118, at I. The NSTC "acts as a 'virtual' agency . . . to coordinate the diverse parts of the Federal research and development enterprise." *Id.* at ii.

[271] *Id.* at 9.

[272] Auxiliary power units (APUs) generate electricity and provide compressed air to operate the aircraft's electrical and ventilation (heating and cooling) systems and to start the main engines. EEA, TECHNICAL DATA TO SUPPORT FAA'S ADVISORY CIRCULAR ON REDUCING EMISSIONS FROM COMMERCIAL AVIATION 29 (1995) [hereinafter EEA, TECHNICAL DATA TO SUPPORT FAA'S ADVISORY CIRCULAR].

[273] *See* Dempsey, *supra* note 86, at 50-58.

[274] MICHAELIS, *supra* note 71, at 12.

[275] *Id.*

[276] *Id.*

[277] *Id.*

[278] *Id.*

[279] *Climate Change: Aircraft Have Global Warming Potential*, <http://www.ns.ec.gc.ca:4000/articles/April/april13.html> (visited Feb. 1, 1999).

figure could be as high as ten percent.[280] Therefore, the contribution of aircraft emissions to global warming cannot be ignored. The Kyoto Protocol to the United Nations Framework Convention on Climate Change thus calls for industrialized countries to work through the ICAO to pursue limits on emissions from aviation fuels.[281]

A. Technological Approaches: Government Initiative

The future of the aeronautics industry, in terms of the technological ability to produce aircraft and engines that are both environmentally compatible and economically competitive, is dependent upon the combined efforts of government agencies, industries, and universities.[282] Because the FAA's role is limited due to its extremely small research and development programs,[283] the leadership role will likely be fulfilled by the National Aeronautics and Space Administration (NASA).[284]

In 1994, the U.S. aerospace industry produced manufactured goods with an estimated value of $102 billion, exporting $40 billion worth of those goods to 181 countries worldwide.[285] In 1994, the aeronautics industry as a whole had a foreign trade surplus of approximately $25 billion, the largest of any U.S. manufacturing industry.[286] Despite this stellar past, U.S. aeronautics shipments have been declining for several years.[287] Prior to 1974, the United States held more than ninety percent of the world market share in large commercial transport aircraft manufacturing.[288] By 1994, however, aeronautics shipments were down twelve percent as compared with 1993.[289] Europe's Airbus Industries, on

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280 *Id.*

281 *See* Kyoto Protocol to the United Nations Framework Convention on Climate Change, Dec. 10, 1997, 37 I.L.M. 22, *opened for signature* Mar. 16, 1998.

282 *See* NSTC, GOALS FOR A NATIONAL PARTNERSHIP, *supra* note 118, at 2, 13.

283 *See* 49 U.S.C. § 48102 (1994). In fiscal years 1995 through 1996, the FAA's research and development appropriations for environment and energy projects were $8.124 million and $8.532 million, respectively, which represented 3.04% and 3.05%, respectively, of the agency's budget. *Id.*

284 *See generally* NASA, THREE PILLARS FOR SUCCESS, *supra* note 117, at 2.

285 NSTC, GOALS FOR A NATIONAL PARTNERSHIP, *supra* note 118, at 3.

286 *Id.*

287 *Id.*

288 NASA, THREE PILLARS FOR SUCCESS, *supra* note 117, at 2.

289 NSTC, GOALS FOR A NATIONAL PARTNERSHIP, *supra* note 118, at 3.

the other hand, exceeded thirty percent of the market share and is aiming to control more than fifty percent of the world market.[290]

Europeans have made considerable investments in state-of-the-art wind tunnel facilities for aircraft development.[291] Brazil, Indonesia, Korea, and Taiwan have also made their aeronautics industries a priority, and the Russian and Ukrainian aerospace industries are now entering the commercial market.[292] These developments have reduced profit margins across the industry, increasing the financial risk of developing state-of-the-art technologies.[293] They are also leading manufacturers to form alliances and partnerships, often transboundary in nature, to spread risk and gain greater leverage from their resources.[294] As a result of these new partnerships, the core design and development capabilities in the United States are eroding and the U.S. aeronautics industries are losing their competitive edge.[295]

The National Science and Technology Council (NSTC) points to post-Cold War reductions in defense spending, the financial weakness of the global airline industries worldwide, and strong support and subsidization by foreign governments of their national aeronautics industries as the challenges facing U.S. domestic manufacturers.[296] To maintain global leadership, the NSTC is calling for a renewal of the partnership that once existed between government, industry and universities.[297] The NSTC aims to develop "an integrated view of aviation system performance and affordability."[298]

The NSTC's key goals for helping the U.S. aeronautics industry maintain its global competitiveness include: (1) maintaining the dominance of U.S. aircraft and engines; (2) improving air transportation safety and efficiency worldwide; and (3) ensuring the compatibility of avionics with environmental concerns.[299] In conjunction, these three goals—particularly

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[290] *Id.*
[291] *Id.*
[292] *Id.* at 4.
[293] *Id.*
[294] *Id.*
[295] *See id.* at 3.
[296] *Id.*
[297] *Id.*
[298] *Id.* at 2.
[299] *Id.* at 3.

the last two goals as they bear on the first—are anticipated to lead to reductions in aircraft emissions.[300]

1. Market Demand for Subsonic and Supersonic Aircraft

Economic recovery and growth in air traffic demand are expected to reestablish demand for commercial airliners.[301] Projections indicate that air travel demand will increase threefold over the next twenty years,[302] with approximately 14,000 new commercial airplanes valued at $1 trillion required to satisfy the projected growth in travel as well as to replace older aircraft.[303] There is also a strong global interest in improving the environmental soundness of the air transportation industry by reducing noise and air pollution generated by aircraft, while also improving the safety and economic efficiency of flight operations.[304]

a. Subsonic Aircraft

For the foreseeable future, the global demand for air transportation will be met primarily by large subsonic aircraft. Although today's subsonic aircraft are considerably more advanced than their predecessors, major developments in range, payloads, environmental soundness, efficiency, and reliability remain to be achieved.[305] A reduction in direct operating costs of up to twenty-five percent is possible if current technological advances are aggressively pursued.[306] Advanced wing designs, improved propulsion systems, high-lift systems, integrated flight and propulsion controls, intelligent controls, and lightweight affordable materials are technologies that can be employed.[307]

Recently developed cleaner gas turbine engine technology demonstrates the technical feasibility of meeting ICAO standards at a reasonable cost.[308] Two technologies in particular provide promise for the

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[300] *See id.* at 4.
[301] *Id.* at 3.
[302] NASA, THREE PILLARS FOR SUCCESS, *supra* note 117, at 2.
[303] NSTC, GOALS FOR A NATIONAL PARTNERSHIP, *supra* note 118, at 3.
[304] *Id.* at 4.
[305] *Id.* at 8.
[306] *Id.*
[307] *Id.*
[308] Control of Air Pollution from Aircraft and Aircraft Engines, Emission Standards and Test Procedures, 62 Fed. Reg. 25,356, 25,359 (May 8, 1997).

immediate future.[309] First, the division of General Electric (GE) that designs and manufactures aircraft engines recently succeeded in obtaining FAA certification for a new low emissions combustor.[310] GE accomplished the emissions reduction by decreasing primary zone HC and CO quenching and increasing secondary zone NO_x quenching.[311] GE asserts HC emissions are reduced to twelve percent of ICAO standards, CO emissions to twenty-two percent, and NO_x emissions to forty-nine percent.[312]

The second promising technology is the double annular combustor (DAC).[313] The DAC divides combustion into two discrete stages.[314] A high temperature/low velocity pilot stage ensures good ignition and low CO and HC formation.[315] A lean (low temperature)/high velocity main stage ensures low NO_x and smoke emissions at high power.[316] CFM International ("CFM"), a fifty-fifty joint venture between GE and Snecma of France, has received certification from the French Direction Generale de l'Aviation Civile for the DAC.[317] The CFM56 DAC reportedly reduces NO_x emissions forty-five percent more than engines with a single annular combustor, engines which are only capable of burning fuel at a single high temperature stage.[318] GE plans to use a DAC on its GE90 engine.[319] The CFM56, which has a double annular combustor, has recently shown reliability problems, however, with airline companies reporting cracking on engine liners.[320] In response, CFM has developed a product improvement package that resolves the cracking problem and reduces NO_x emissions to the initially anticipated levels.[321]

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[309] GE, *GE Aircraft Engines News Release: FAA Certifies New Low Emissions Combustor for CF6 Engines*, <http://www.ge.com/aircraftengines/geae-14.htm> (visited Feb. 1, 1999).

[310] *Id.*

[311] *Id.* Quenching is a fuel combustion process that burns fuel in a more efficient and cleaner manner. *See id.*

[312] *Id.*

[313] *See* Electronic Letter from Willard Dodds, General Electric (Aug. 25, 1998) (copy on file with *The Environmental Lawyer*).

[314] *Id.*

[315] *Id.*

[316] *Id.*

[317] GE, *Aircraft Engines News Release: CFM56-5B DAC Engine Certified On Airbus Industrie A321*, <http://www.ge.com/aircraft engines/cfm-02.htm> (visited Feb. 1, 1999).

[318] *Id.*

[319] GE, *Jet Engine Technology News Release*, *supra* note 77.

[320] *Values Start to Outweigh Cost for Cleaner CFM56 Engines*, AIRCRAFT VALUE NEWS, Mar. 2, 1998, *available in* 1998 WL 7199467.

[321] *Id.*

b. Supersonic Aircraft

The opportunity to produce high speed civil transport (HSCT) aircraft to meet anticipated growth in the long-range commercial transportation market presents the United States with the chance to maintain its global aeronautics dominance.[322] Market studies estimate that by 2015, passenger demand for long, primarily transoceanic routes could reach 600,000 people per day, which would support a fleet of 500 to 1000 HSCT aircraft.[323] While the technical capability of sustained commercial supersonic flight has existed for many years, environmental and market requirements have rendered its widespread implementation infeasible.[324] The technology necessary to meet these requirements is not currently available.[325] Technologies available in the near future, however, may make HSCT aircraft economically and environmentally feasible. These technologies include: (1) lightweight, high-performance engines and ultra-low emission combustors; (2) lightweight materials for airframe construction; (3) advanced subsystems; and (4) advanced aerodynamics.[326]

2. Emission Reduction Goals

NASA asserts that it is imperative for the United States to take a leadership role in setting and meeting environmental challenges related to aircraft emissions.[327] NASA believes that technical solutions will significantly reduce the aircraft emissions that contribute to global warming and ozone depletion.[328]

NASA has set a technological goal to reduce aircraft engine emissions by a factor of three within ten years, and by a factor of five within twenty years.[329] In his message forwarding a technology goals report, NASA's Administrator stated that NASA plans to participate in "pre-competitive research endeavors in long-term, high-risk, high-payoff technologies."[330]

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[322] NSTC, GOALS FOR A NATIONAL PARTNERSHIP, *supra* note 118, at 8.
[323] *Id.* at 8-9.
[324] *Id.*
[325] *Id.*
[326] *Id.*
[327] NASA, THREE PILLARS FOR SUCCESS, *supra* note 117, at 2.
[328] *Id.*
[329] *Id.*
[330] *Id.* at 1.

NASA's goals place the burden on the government to address issues in areas that the private sector does not have an incentive to address because of their size, financial risk, and duration.[331] The NASA Administrator challenged the industry to maintain competitiveness through advancements in their products, while charging NASA with responsibility for providing revolutionary advancements to protect U.S. leadership in the industry.[332] NASA is currently engaged in joint research ventures with industry to develop new technologies that will make aircraft engines burn cleaner and more efficiently.[333] NASA intends to increase and improve the use of experimental aircraft and in-flight tests as research tools to further reduce technology development schedules and costs.[334] This will ultimately cut development cycles in half.[335] NASA has already established the Hyper-X program to increase the validity of in-flight hypersonic aircraft and engine design methods.[336] The Hyper-X program will help NASA meet its goal of producing quiet supersonic engines capable of meeting subsonic noise standards, while at the same time reducing emissions.[337] By using low cost materials and structural concepts, NASA foresees ultimately reducing the time necessary to travel to Europe and the Far East by fifty percent within the next twenty years, without surpassing today's ticket prices.[338]

3. *Other Future Technologies on the Drawing Board*

Several emission reduction alternatives are promising, but, they would require major paradigm shifts in aircraft design and production.[339] The propfan (or unducted fan) engine—essentially a jet engine with a large, enshrouded, curved tip propeller to allow high speed operation—has been developed nearly to commercialization.[340] For a variety of reasons, including development costs, and concerns about noise and safety, the propfan has not been mass-produced.[341] Other engine technologies include

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[331] *Id.*
[332] *Id.*
[333] *Id.* at 2.
[334] *Id.* at 4.
[335] *Id.*
[336] *Id.*
[337] *See id.*
[338] *Id.*
[339] *See* MICHAELIS, *supra* note 71, at 54.
[340] *Id.*
[341] *Id.*

the use of heat exchangers to provide charge cooling to recuperate heat from the exhaust stream.[342]

Airframe technology involves the use of active laminar flow systems.[343] Similar to the propfan engine, cost and safety problems are prohibiting the introduction of active laminar systems.[344] The use of alternative fuel for aircraft is also being considered as a means of reducing greenhouse gas emissions from aircraft.[345] Two alternative fuels under consideration are hydrogen and methane.[346] The use of laminar systems alone could generate long-term energy intensity reductions of approximately forty to sixty percent over the next forty years.[347] Unfortunately, the use of laminar systems and these fuels in existing airframes is not possible, therefore, it is unlikely they will be introduced in the near future.[348]

B. Nontechnical Standards and Practices

1. Ground Operating Procedures

As part of its comments submitted during the development of the proposed California FIP, the FAA supported the reduction of emissions from commercial aviation through various work practices.[349] These included practices to reduce the use of APUs, such as making electricity and air conditioning available at the gates.[350] Additionally, the FAA has taken the initiative in encouraging airlines to operate the cleanest aircrafts possible in FIP areas.[351] The EPA and FAA agreed there was a need to

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[342] *Id.*

[343] *Id.* The area immediately adjacent to an aerodynamic surface (e.g., wing or fuselage) is called the boundary layer. H.C. "SKIP" SMITH, THE ILLUSTRATED GUIDE TO AERODYNAMICS 57 (2d ed. 1997). A smooth, undisturbed boundary layer has laminar flow. *Id.* at 58. Placing the aerodynamic surface at orientations other than parallel to the surrounding airstream introduces disturbances into the boundary layer. *Id.* at 58, 60. These disturbances create a turbulent boundary layer. *Id.* A turbulent boundary layer increases drag on the aerodynamic surface, destroying the efficiency of the surface and increasing the power required to keep the surface in flight. *See id.*

[344] MICHAELIS, *supra* note 71, at 54.

[345] *Id.* at 55.

[346] *Id.*

[347] *Id.* at 54.

[348] *Id.*

[349] *See* EEA, TECHNICAL DATA TO SUPPORT FAA'S ADVISORY CIRCULAR, *supra* note 272, at 1. The FAA also supported the conversion of GSE to alternative fuels. *Id.*

[350] *Id.*

[351] *Id.*

continue to look for ways to reduce emissions from aircraft, thus the FAA plans to develop an Advisory Circular to encourage reduced emissions.[352]

The technical report prepared in support of the planned Advisory Circular recommends reduced use of APUs.[353] APUs generate electricity and provide compressed air to operate the aircraft's electrical and ventilation (heating and cooling) systems and start main engines.[354] APUs are powered by small jet engines that burn jet fuel and create exhaust emissions similar to the main engines, except on a smaller scale.[355] Practices concerning APUs are determined by each participating airline and therefore vary considerably.[356] For example, some airlines start the APU on approach for landing and continue its operation until shutdown at the gate, while others only operate the APU on taxi when they are practicing reduced or single engine taxi.[357]

In the event that both a source of ground power and air for ventilation and engine start are available, the APU may not be needed.[358] Arguably, emissions from ground based power and ventilation systems are lower than the APU because they operate at greater efficiency and are subject to stationary source controls.[359] Additionally, the cost of fuel saved through reduced APU use may be greater than the cost of electricity to provide power to aircraft parked at the gates.[360] Therefore, airlines may have an economic incentive to substitute ground-based systems for APUs. By way of example, it is estimated that an aircraft at LAX uses its APU for roughly 105.34 minutes per landing and takeoff cycle.[361] This includes the average taxi time for aircraft at LAX, which is 23.8 minutes.[362] Subtracting the taxi time from overall time of APU use yields an average APU operating time at the gate of 81.54 minutes.[363] Operating at fuel flow rates ranging from

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[352] Proposed Advisory Circular 34-1, Fuel Venting and Exhaust Emissions Requirements for Turbine Engine Powered Airplanes, 63 Fed. Reg. 51,990, 51,990-52,101 (Sept. 29, 1998).

[353] *See* EEA, TECHNICAL DATA TO SUPPORT FAA'S ADVISORY CIRCULAR, *supra* note 272, at 1.

[354] *Id.* at 29.

[355] *See id.*

[356] *Id.*

[357] *Id.*

[358] *Id.*

[359] *See id.* at 29-30.

[360] *See id.*

[361] *Id.* at 32, 40.

[362] *Id.* at 32, 42.

[363] *Id.* at 32.

102 to nearly 900 pounds per hour (15 to 134 gallons per hour), the fuel savings and emissions reductions are substantial.[364]

2. *Flight Operation Controls*

There are a number of possibilities for reducing emissions by improving the efficiency of flight operations.[365] Aircraft with lower emissions can be scheduled to operate in areas with air quality problems, the number of engines used during taxi operations can be minimized, and the use of reverse thrust upon landing can be reduced.[366] Emissions per unit of engine thrust is a value that engine manufacturers compute as part of the engine certification process.[367] Therefore, the data is available to quantify emissions and devise operational practices to reduce emissions safely.[368] To date, regulatory efforts have been limited to ranking aircraft according to relative emissions.[369]

3. *Traffic Management Controls: Free Flight*

When a commercial aircraft flies from its departure to its arrival point, it follows a flight plan mapped out along prescribed routes in the National Airspace System (NAS).[370] Like freeways and highways used by motor vehicles, flight routes do not provide the shortest distance between two points.[371] Free Flight is an "innovative concept designed to enhance the safety and efficiency of the [NAS]."[372] The Free Flight concept changes flight planning from a centralized command and control approach to one

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[364] *See id.* at 43-44. The study concluded that the combined operations and maintenance costs for a B737-300 running an Allied Signal GTCP 85 series APU (235.28 pounds per hour burn rate) were $45.23. *See id.* at 44.

Using a hypothetical, look at the operations of a regional carrier which flies the 737 at a frequency of 25 flights per day from LAX. The fuel cost savings alone are $1130 per day or $300,000 to $412,000 per year (range depends on scheduling frequency during weekends).

[365] *Id.* at 6.

[366] *Id.* at 6-7.

[367] *Id.* at 7-8.

[368] *See id.* at 6-8.

[369] *See* 40 C.F.R. pt. 87 (1997).

[370] *See* FAA, *What is Free Flight?*, *supra* note 116.

[371] *See id.*

[372] *Id.*

that permits the pilot to choose a more efficient and economical path.[373] Safety, however, is still the central feature of the program.[374] Free Flight limits pilot flexibility in certain high-risk situations: (1) to ensure minimum distances are maintained at high-traffic airports and in congested airspace; (2) to prevent unauthorized entry into prohibited airspace (e.g., airspace used by military aircraft for training); and (3) for any other safety reason.[375]

Free Flight is crucial to safely advancing aviation and accommodating the nation's growing airspace needs.[376] The current U.S. airspace architecture and management would be inadequate to efficiently handle the projected future growth in the nation's air traffic.[377] To fully realize the potential benefits of Free Flight, "current and new ground- and air-based communications, navigation, and surveillance equipment, avionics, and decision support systems (automated)" will need to be used.[378] Free Flight establishes two zones around each aircraft: a protected zone and an alert zone.[379] The protected zone, which is closest to the aircraft, will never be allowed to touch the protected zone of another aircraft.[380] The alert zone extends past the protected zone and provides the pilot freedom of movement until alert zones touch.[381] Once alert zones touch, a controller will provide course corrections to one or both pilots to ensure safe separation of aircraft.[382]

Free Flight will also reduce direct operating costs by providing more efficient routes.[383] These improvements will also result in reduced fuel consumption and, thus, improved air quality.[384] By 2005, for example, it is estimated that Free Flight will save $35 million annually in direct operating

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[373] *Id.*

[374] *Id.*

[375] *Id.*

[376] FAA, *FREE FLIGHT Introduction: Why Free Flight?*, <http://www.faa.gov/freeflight/ff._ov.htm> (visited Feb.1, 1999).

[377] *Id.*

[378] FAA, *FREE FLIGHT Introduction: What's Required for Free Flight?*, <http://www.faa.gov/freeflight/ff.ov_.htm> (visited Feb. 1, 1999).

[379] FAA, *FREE FLIGHT Introduction: How Does Free Flight Work?*, <http://www.faa.gov/freeflight/ff_ov.htm> (visited Feb. 1, 1999).

[380] *Id.*

[381] *Id.*

[382] *Id.*

[383] FAA, *FREE FLIGHT Introduction: What are the Benefits of Free Flight?*, <http://www.faa.gov/freeflight/ff_ov.htm> (visited Feb. 1, 1999).

[384] *See id.*

costs in the Oakland Flight Information Region, by reducing flight and ground time by 9,000 hours and saving 25 million gallons of fuel.[385]

4. *Fiscal Disincentives*

A government measure that has recently gained attention is the imposition of taxes or charges on international civil aviation.[386] The anticipated side effect of taxes or charges is that an increase in the cost of aircraft operations will reduce demand for civil aviation, thereby reducing the harmful environmental effects of flight operations.[387] It has been argued that the revenues generated by such charges should be put toward research in pollution control or environmental cleanups.[388] Proponents of this measure advance the "polluter pays" principle.[389] While fiscal measures can be efficiently and equitably imposed, one unintended consequence of such charges is that they may reduce air traffic demand by causing potential passengers either to forego their trip or shift to a less expensive mode of travel.[390] Ironically, that result could mean a reduction in the revenues the administrating authority intended to collect through the tax or charge and a shift of emissions to another source.[391]

The terms "taxes" and "charges" are often used interchangeably even though they are distinct concepts.[392] Charges are generally defined as assessments on activities that are then earmarked for pollution remediation or control, while taxes are assessments that are returned to the taxing authority's general treasury to be used at its discretion.[393] In practice, the distinction between charges and taxes is blurred because assessing authorities often put charges into their general treasury rather than earmarking them for a particular purpose.[394] Although aviation organizations dislike any form of economic assessment, they maintain that charges are better for protecting the environment than other forms of

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[385] FAA, *FREE FLIGHT Introduction: When Will Free Flight be Implemented?*, <http://www.faa.gov/freeflight/ff_ov.htm> (visited Feb. 1, 1999).
[386] Pablo M.J. Mendes de Leon & Steven A. Mirmina, *Protecting the Environment by Use of Fiscal Measures: Legality and Propriety*, 62 J. AIR L. & COM. 791, 793 (1997).
[387] *Id.*
[388] *Id.*
[389] *Id.* at 793 n.2.
[390] *See id.* at 802-03.
[391] *See id.* at 803.
[392] *Id.* at 794.
[393] *Id.*
[394] *Id.* at 795.

assessment.[395] Environmental charges are consistent with the Chicago Convention and the International Air Services Transit Agreement as long as they are used for a specific environmental purpose.[396] As with any environmental charge for damage to human health, welfare, and the environment, a problem arises in calculating a fair and just amount.[397] This problem stems from the fact that aircraft emissions cannot be confined to a specific area, but often cross state and national borders.

The ICAO Council's interpretations of the Chicago Convention and International Air Services Transit Agreement are that a State party to the Chicago Convention can implement fiscal measures, provided that such measures are nondiscriminatory and have a specific purpose other than the collection of revenue for merely passing through a State's airspace.[398] Bilateral and multilateral air services transport agreements (ASTA) provide a mechanism for a State to impose charges on international air traffic.[399] Bilateral agreements typically include two broad categories of regulation: "hard" and "soft" rights.[400] Hard rights are typically economic

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[395] *Id.*

[396] *See* Chicago Convention, *supra* note 119, art. 15, 15 U.N.T.S. at 306; *see also* International Air Services Transit Agreement, *opened for signature* Dec. 7, 1944, art. 1, 84 U.N.T.S. 390, 390-94 [hereinafter International Air Services Transit Agreement]. The International Air Services Transit Agreement guarantees all member States the privilege to (1) "fly across [another member's] territory without landing" and (2) "land for non-traffic purposes." *Id.* at 390.

[397] Mendes de Leon & Mirmina, *Protecting the Environment by Use of Fiscal Measures*, *supra* note 386, at 795. Messrs. Mendes de Leon and Mirmina propose a series of hypothetical questions for calculating the fair and just amount of charges. *See id.*

[398] *See* Chicago Convention, *supra* note 119, art. 15, 15 U.N.T.S. at 306; *see also* International Air Services Transit Agreement, *opened for signature* Dec. 7, 1944, art. 1, 84 U.N.T.S. 390, 390-94.

[399] *See* International Air Services Transit Agreement, *supra* note 396, art. 1, 15 U.N.T.S. at 392. The Chicago Convention established the "five freedoms" of the air. *See* Randall D. Lehner, *Protectionism, Prestige, and National Security: The Alliance Against Multilateral Trade in International Air Transport*, 45 DUKE L. J. 436, 442 (1995); *see also* Chicago Convention, *supra* note 119. The first two freedoms, the privilege to fly across the territory of a State without landing, and the privilege to land for non-traffic purposes, were exchanged on a multilateral basis among contracting parties to the Chicago Convention. *See* International Air Services Transit Agreement, *supra* note 396, art. 1, 15 U.N.T.S. at 390. "The third, fourth, and fifth freedoms, however, have been the rights . . . exchanged bilaterally between countries in their air services agreements." Lehner, *supra*, at 442. With more than 2000 bilateral agreements in place today, these agreements were, and continue to be, the basis of the international aviation regulatory system. *See* MAREK ZYLICZ, INTERNATIONAL AIR TRANSPORT LAW 1, 136 (1992).

[400] *See* ZYLICZ, *supra* note 399, at 139.

in nature and include routes, airline designation, capacity controls, and pricing.[401] Soft rights cover issues that assist airline operations, including currency exchange, ground and baggage handling, and airport usage.[402]

Whether a tax or charge can be assessed without violating an ASTA cannot be determined without examining national legislation.[403] Generally, the applicable bilateral ASTA will supersede the application of national law.[404] Nearly all of the 2500 bilateral ASTAs rule out the imposition of a fuel tax, so imposing fuel taxes would require amending a vast majority of the bilateral ASTAs currently in existence.[405]

Several nations have implemented fiscal environmental measures to address the harmful impacts of aviation activities.[406] These nations include Sweden, Norway, The Netherlands, and Germany.[407] Compared with similar measures imposed on a global level, these country-specific measures have hindered both the aviation industry and environmental protection.[408] Consequently, major international organizations dealing with international civil aviation oppose unilateral measures to protect the environment.[409]

If found to be necessary, global measures would be the more appropriate tool.[410] The ICAO is currently in the process of refining its position on environmental charges.[411] It recently passed a resolution declaring that it would be impractical to develop an internationally acceptable charge or tax on air transport.[412] The ICAO strongly recommended that member States considering the imposition of environmental levies do so as charges rather than taxes, and that the charges be used to mitigate the environmental impact of emissions.[413] Acceptable uses would include: (1) alleviating the environmental damage caused by

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[401] *Id.*

[402] *Id.*

[403] Mendes de Leon & Mirmina, *supra* note 386, at 800.

[404] *Id.* (citing Vienna Convention on the Law of Treaties, May 23, 1969, art. 27, 1155 U.N.T.S. 331, 339 [hereinafter Vienna Convention]). "A party may not invoke the provisions of its internal law as justification for its failure to perform a treaty." Vienna Convention, *supra*, art. 27, 1155 U.N.T.S. at 339.

[405] MICHAELIS, *supra* note 71, at 19.

[406] Mendes de Leon & Mirmina, *supra* note 386, at 803-06.

[407] *Id.*

[408] *Id.* at 803.

[409] *Id.* at 817.

[410] *Id.*

[411] *See* MICHAELIS, *supra* note 71, at 46-47.

[412] *Id.*

[413] *Id.*

aircraft emissions; (2) providing funds for research to better understand their environmental impact; or (3) funding research aimed at reducing their impact through improvements in technology and new approaches to aircraft operations.[414] The ICAO urges member States to take into account the nondiscrimination principle[415] and use it as a guide, stating "there should be no fiscal aims behind the charges; . . . the charges should [relate] to costs; and . . . the charges should not discriminate against air transport compared with other modes of [transportation]."[416]

VI. CONCLUSION

Past success in reducing the contribution of aircraft exhaust emissions to the nation's air pollutant inventory was the result of both regulatory and economic considerations.[417] On the surface, aircraft emissions do not appear to be a significant factor in the nation's emissions inventory.[418] They are, however, a problem in nonattainment areas struggling to receive credit in their SIPs for reduction of CO, O_3 and NO_x (as both an O_3 precursor and as a separate criteria pollutant).[419] Aircraft emissions can best be classified as having local impacts of national concern.[420]

Emissions from aircraft arguably impact metropolitan areas the hardest,[421] and those areas are the ones with the most intractable nonattainment problems.[422] Emissions from aircraft historically have been minimally regulated.[423] By contrast, emissions from stationary sources and

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[414] *Id.* at 47.

[415] Chicago Convention, *supra* note 119, art. 15, 15 U.N.T.S. at 306.

> Any charges that may be imposed or permitted to be imposed by a contracting State for the use of such airports and air navigation facilities by the aircraft of any other contracting State shall not be higher, . . . [a]s to aircraft engaged in scheduled international air services, than those that would be paid by its national aircraft engaged in similar international air services.

Id.

[416] MICHAELIS, *supra* note 71, at 47.

[417] *See* GE, *Jet Engine Technology News Release*, *supra* note 77.

[418] *See* GAO, GLOBAL POLLUTION FROM JET AIRCRAFT, *supra* note 6, at 1.

[419] *See* NRDC, *Flying Off Course*, *supra* note 1.

[420] *See* discussion *supra* Part II.

[421] *See, e.g.*, Cone, *supra* note 22, at B2; *see also* Pitzl, *supra* note 22, at A1.

[422] *See* GAO, GLOBAL POLLUTION FROM JET AIRCRAFT, *supra* note 6, at 1.

[423] Control of Air Pollution from Aircraft and Aircraft Engines; Emission Standards and Test Procedures, 62 Fed. Reg. 23,356, 23,358 (May 8, 1997) (codified at 40 C.F.R. pt. 87).

mobile sources, such as motor vehicles, increasingly are more stringently regulated.[424] The CAA Amendments of 1990, however, are only now beginning to have an impact on emission levels.[425] Some standards came into effect in 1996 and significant emission reductions will probably not occur until after the year 2000.[426] Meanwhile, aircraft emissions remain minimally regulated and air traffic is projected to increase.[427] Therefore, overall national emissions are likely to decrease while aircraft emissions increase.

Future success in minimizing the contribution of aircraft emissions to NAAQS nonattainment will depend on a combination of factors. Renewed emphasis on command and control emission limitations,[428] cooperative efforts at developing state-of-the-art "high-risk high-payoff technology,"[429] and efficient operational practices[430] will all play a role in reducing the contribution of aircraft emissions to the aggregate national emissions inventory. The various government agencies that are responsible for these matters must work together to develop a comprehensive, coherent, and workable plan for the future.[431]

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[424] *See* Charlier, *supra* note 22, at 4.

[425] EPA, EMISSION TRENDS, *supra* note 64, at ES-2.

[426] *Id.*

[427] *See* 62 Fed. Reg. at 23,358.

[428] *See* FAA, *What is Free Flight?*, *supra* note 116, at 1. EPA and the FAA have apparently entered into an agreement to collaborate on a wide range of topics. *See* Kristin S. Krause, *FAA, EPA Strike Accord*, TRAFFIC WORLD, Apr. 6, 1998, at 32, 32. The agreement leaves the FAA in control of all aviation issues, "but gives the EPA a more active voice on issues where it sees an adverse environmental impact." *Id.* "The EPA pushed for the agreement because it felt it did not have an adequate role in negotiating the U.S. position on international standards." *Id.*

[429] *See* NASA, THREE PILLARS FOR SUCCESS, *supra* note 117, at 1.

[430] NSTC, GOALS FOR A NATIONAL PARTNERSHIP, *supra* note 118, at 3-4.

[431] *Id.*