

# ENVIRONMENTAL IMPACT ANALYSIS WITH THE AIRSPACE CONCEPT EVALUATION SYSTEM

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## **Abstract**

The National Aeronautics and Space Administration (NASA) Ames Research Center has developed the Airspace Concept Evaluation System (ACES), which is a fast-time simulation tool for evaluating Air Traffic Management (ATM) systems. This paper describes linking a capability to ACES which can analyze the environmental impact of proposed future ATM systems. This provides the ability to quickly evaluate metrics associated with environmental impacts of aviation for inclusion in multi-dimensional cost-benefit analysis of concepts for evolution of the National Airspace System (NAS) over the next several decades.

The methodology used here may be summarized as follows: 1) Standard Federal Aviation Administration (FAA) noise and emissions-inventory models, the Noise Impact Routing System (NIRS) and the Emissions and Dispersion Modeling System (EDMS), respectively, are linked to ACES simulation outputs; 2) appropriate modifications are made to ACES outputs to incorporate all information needed by the environmental models (e.g., specific airframe and engine data); 3) noise and emissions calculations are performed for all traffic and airports in the study area for each of several scenarios, as simulated by ACES; and 4) impacts of future scenarios are compared to the current NAS baseline scenario.

This paper also provides the results of initial end-to-end, proof-of-concept runs of the integrated ACES and environmental-modeling capability. These preliminary results demonstrate that if no changes are made to elements of the NAS, aviation

growth is likely to be impeded by significant environmental impacts that could negatively affect communities throughout the nation.

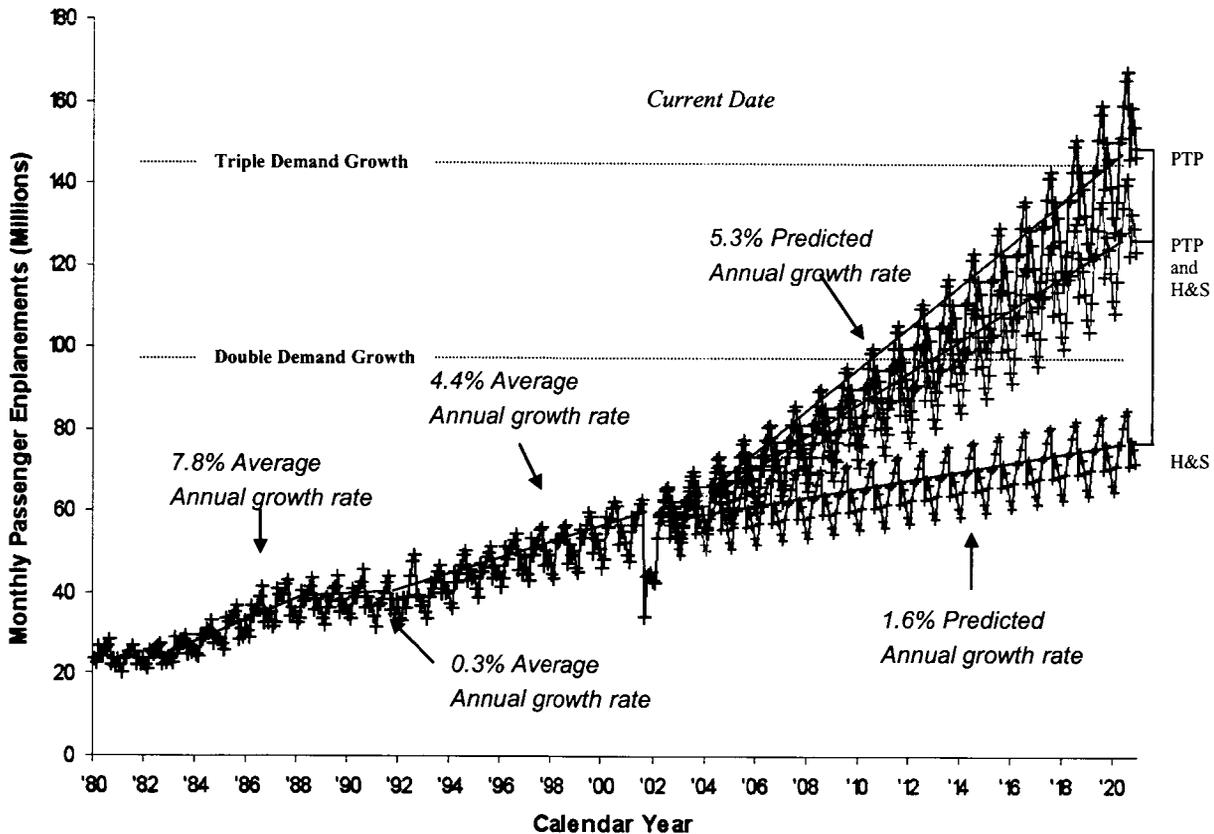
## **Introduction**

Historically, demand in the National Airspace System has grown at rates ranging from approximately 4% up to almost 8% per year for hub and spoke (H&S) and/or point-to-point (PTP) operational paradigms. If this trend continues (Figure 1), future projections point to two to three times (2x to 3x) growth in demand for air transportation services over the next 20 years. The Joint Planning and Development Office (JPDO) is conducting research to understand the requirements for a future NAS that can support this growth. [1] This paper describes methods for estimating potential environmental impacts that, in terms of noise and air quality, such future demand scenarios might have on communities throughout the NAS.

## **Motivation**

A key hurdle to acceptance of a more capable NAS and associated technologies and procedures is the environmental impact of such changes on surrounding communities. Today, under current operations, these impacts are primarily focused on those communities closest to major airport terminals.

Many airports are operating at or near capacity for most of the day, and the number of usable runways is currently the primary constraint on airport capacity. A number of alternatives have been proposed in order to enable greater demand to be



**Figure 1: Historical data and predictions of future growth of domestic enplanements.**  
**Source: Technologies Enabling All-Weather Capacity by 2020: Phase Three Scenarios [2]**

serviced by existing infrastructure, such as a reduction in separation standards, a reduction in runway occupancy time, the introduction of larger aircraft (such as the A380), or the introduction of runway-independent aircraft (such as the civil tilt-rotor). Another option is to increase the number of usable runways, either by constructing new runways at current major airports (as per the Operational Evolution Plan (OEP)), [3] or by shifting some fraction of demand to airports that today do not serve commercial traffic.

Regardless of the ultimate solution to capacity, however, the fact remains that proposed solutions will need to be evaluated not only against metrics related to efficiency, but against metrics related to noise and emissions. Without such vetting of new concepts, they are unlikely to reach implementation. Furthermore, since environmental constraints are likely to be quite stringent, it is important that environmental impacts be part of the design process, so that they can influence the many dimensions of the conceptual design that affect them.

### **Noise and Air Quality Constraints on Aviation**

The reason for inclusion of environmental metrics in multi-dimensional analysis of emerging NAS concepts is the continuing national and international concern with noise and air quality effects of aviation, and the need to address environmental impacts in the context of expected increases in demand for air transportation. FAA, EPA, and ICAO guidelines for control of these environmental impacts continue to evolve and have a long history that is beyond the scope of this paper. However, it is important to note that each metric utilized in our initial modeling effort is one of the standard metrics associated with noise effects (Day-Night Level (DNL)), or with air quality emissions inventories (unburned hydrocarbons (HC), carbon monoxide (CO), and oxides of nitrogen and sulfur (NO<sub>x</sub>, and SO<sub>x</sub>)).

No quantitative environmental constraints on aviation are considered in this paper. In general,

however, it is possible that national and international goals for environmental effects of aviation by approximately 2025 will include required reductions in both noise and air quality impacts, even in the face of continued and substantial growth in air transportation demand and therefore in aviation operations. As these goals become more quantitative, they will be included as benchmarks for comparison of projected impacts associated with each NAS concept explored.

Climatic effects of aviation continue to be studied by the scientific community, and are not included in the present analysis.

## Summary of Initial Scenarios

A large number of future NAS scenarios will be evaluated by the JPDO using ACES. In general, these scenarios span many dimensions, exploring numerous future demand-growth assumptions and various concepts of operation for the NAS. A subset of representative scenarios was selected for purposes of developing and demonstrating a process for evaluating NAS-wide noise and air quality impacts and assessing the relative changes in these impacts across different potential futures. Each scenario is comprised of two components: a future traffic demand set and a corresponding representation of the airspace system capacity. The following points are made with regard to the representation of demand and capacity in ACES Build 2.0.3 used for these initial runs:

- The demand set is limited to flights between airports located within the Continental United States (CONUS) – thus, no international flights are modeled.
- Airport capacity is parameterized in terms of arrival (AAR), departure (ADR), and total acceptance rates at each airport. Each triplet of such values represents an operating point along the airport's assumed Pareto curve defining the optimal tradeoff between arrivals and departures. ACES 2.0.3 allows the user to schedule the airport operating point over the course of the simulated time period to reflect changes due different airport configurations or visibility conditions. Although ACES supports the definition of an arbitrary number of operating points for each airport, for purposes of this initial study we limit our attention to a single airport operating point. This is assumed to correspond to operations under Visual Meteorological Conditions (VMC) in a typical airport configuration.

- Airspace capacity is modeled through the application of sector occupancy limits, expressed in terms of a maximum count of aircraft that can concurrently occupy a given sector within a prescribed time interval.

ACES Version 3 has improved modeling in several of these areas, and will be used in subsequent environmental work. The specific preliminary scenarios evaluated through this initial set of runs are now described.

### ***Baseline 2004 Demand / Constrained Capacity***

The flight data set for this baseline scenario is based on historical data collected from the Enhanced Traffic Management System (ETMS) for February 19, 2004, which may be classified as a high-volume, good weather day. The number of domestic airports included in this dataset is 243. The capacities of airports and sectors in this scenario are set according to the 2001 Capacity Benchmark Study [4] and current Monitor Alert Parameter (MAP) values, respectively. All airports are assumed to operate under Visual Meteorological Conditions (VMC) over the entire simulated day. This scenario serves as a reference point against which environmental impacts associated with future growth scenarios are measured.

### ***Future 2x Demand / Unconstrained Capacity***

The flight data set for this scenario is based on 2004 Terminal Area Forecast (TAF) projections, extrapolating all airports to successive future years until reaching an total growth in operations of 200%, heterogeneously distributed across all 243 modeled airports. Unconstrained capacity, in the context of this scenario, indicates that airport and airspace capacities were modeled with sufficiently high values in ACES such that each flight effectively flies unimpeded through the system according to its schedule. Only minor delays, associated with aircraft attempting to depart or arrive at the same time, occur in this scenario. As such, the environmental impacts obtained in this scenario reflect those that would be obtained in a future world where both airport and enroute capacity issues have all been resolved through some means. A future 2x demand / *constrained* capacity scenario was also simulated; however, the environmental impacts computed in this case were extremely high due to excessive aircraft taxi times as a result of delay that propagated through the airspace simulation. It was determined that these environmental results would never be achievable and

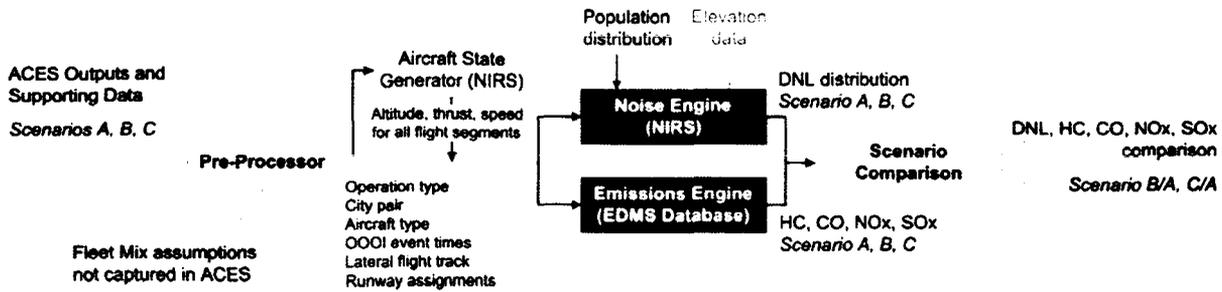


Figure 2: Process for estimating environmental impacts from ACES outputs

were therefore excluded from analysis here.

### ***Future Business Shift 2x Demand / Constrained Capacity***

The flight data set for this scenario is based on a future traffic growth assumption in which a percentage of air traffic that terminates at a hub airport is offloaded to a nearby satellite airport. This represents a shift in business strategy in the NAS. For this scenario, a number of additional airports are modeled in ACES, raising the total number to 315 domestically. Airport capacities in this scenario are set according to the 2001 Capacity Benchmark Study and updated according to planned enhancements provided by the FAA's OEP. For airports not included in the Benchmark Study, FAA Advisory Circular 150/5060-5 is used to approximate the airport's capacity. The capacity of airspace sectors in this scenario is set to twice the current MAP values.

### **Modeling Methodology**

The process used to compute noise and air quality metrics from Airspace Concept Evaluation System (ACES) output data is shown graphically in Figure 2. A key feature of this process is that identical flight data is sent to both the noise and emissions processing engines. This flight data is derived through the combination of the Out, Off, On, and In (OOOI) events and lateral trajectory information from ACES with associated altitude, thrust, and speed profiles generated by the Aircraft State Generator within the Noise Integrated Routing System (NIRS). Industry-standard models are then used for computing noise and air quality impacts. NIRS, which shares its core engine with the Integrated Noise Model (INM), is used to compute noise exposures and the Emissions and Dispersion Modeling System (EDMS) is used to compute emissions inventories.

### ***Airspace Modeling Summary***

ACES is a non-real-time, computer simulation of local, regional, and nationwide factors covering aircraft operations from gate departure to arrival. ACES' overarching objective is to provide a flexible NAS simulation and modeling environment that can assess the impact of new NAS tools, concepts, and architectures, including those that represent a significant departure from the existing NAS operational paradigm. To meet this objective, ACES utilizes an agent-based modeling paradigm to create the large scale, distributed simulation framework necessary to support NAS-wide simulations. [5]

The version of ACES used for this study (Build 2.0.3) has aircraft trajectories modeled in high fidelity in the en route airspace, but with a low fidelity queuing model within the terminal area. For this effort, a geometric technique based on terminal area historical data was used to construct track extensions from the terminal area fixes down to the runways. It is anticipated that future versions of ACES will contain enhancements that will more accurately simulate terminal area trajectories.

### ***Noise Modeling Summary***

All noise modeling was completed within NIRS, following standard FAA procedures for application of this tool. ACES data was processed for loading into NIRS, and decomposed into data files containing all ACES flights data, partitioned into arriving and departing traffic for each airport in the study area. This traffic was further decomposed into day and night traffic. Such decomposition by operation type, time, or other factors such as aircraft class, is essential for determining the causes of changes in noise impact. It is also useful for control of data quality in simulation of complex scenarios.

For purposes of these initial runs, the 2000 U.S. Census data is used as the basis for defining the location points at which noise is computed for each

scenario. The census data provides a set of population centroid locations and a corresponding count representing the size of the population within the area represented by each point. Currently, block-level census data is used.

The following assumptions apply to the initial set of runs performed to date:

- For convenience, we reduced the population data within the study area by a factor of 10 (~1,000,000 points reduced to ~100,000 points) to reduce the run time required for processing each scenario. We have thus sacrificed some fidelity for the ability to complete the evaluation of more scenarios in a very limited period. This is a matter of convenience only, and the next set of runs will be completed using all population centroids.
- No terrain information was used. Thus, all population centroids are assumed to be at the same elevation, namely sea level. This is also a matter of convenience, and terrain data will be used in later runs.
- Flight-profile information from ACES was used in a limited fashion. The vertical profile for each flight was determined on the basis of the standard profile constructed internally by the NIRS aircraft-state generator using approved FAA Office of Environment and Energy (AEE) techniques, with the highest point in the trajectory taken from the ACES data.
- Flight segments with altitudes above 12000 feet AGL (relative to either the arrival or departure field elevation) were ignored. All flight segments associated with overflights (not landing or departing from within the study area) were likewise ignored. In later runs, we can use standard NIRS options to include flight segments at higher altitudes and all overflights, if desired.

Each of these assumptions will be reviewed for later runs.

### ***Emissions Inventory Modeling***

EDMS data and basic procedures are used to estimate the emissions generated due to the aircraft activity at the chosen airports, with some modifications that reflect key characteristics of traffic behavior as simulated by ACES. In generating an emissions inventory, EDMS allows the user to specify an average taxi/idle time by aircraft type at a given airport. However, EDMS does not allow the user to specify a time-in-mode for the other three modes of takeoff, climb, and approach. Instead, EDMS uses default times-in-mode for those aircraft

types based on pre-computed aircraft performance characteristics and a 3000-foot mixing-height threshold that defines the altitude above which aircraft emissions are not included in the inventory. The mixing height defines an altitude above which pollutants released to the atmosphere are fully mixed by dispersive processes. In standard air-pollutant modeling practice, releases occurring above that height are assumed to have no ground-level impact. In the absence of site-specific upper air weather data, EDMS recommends a default mixing height of 3000 feet AGL. Hence the time-in-mode for climb and approach are based on the time taken to climb to 3000 feet AGL, and to descend from 3000 feet AGL, respectively.

For this effort, we utilized the EDMS database of emission factors for the different modes of operation, but we did not use default times-in-mode. Instead, we used simulated times-in-mode for individual flights as derived from each ACES trajectory. The derivation of the times-in-mode was accomplished by segmenting each trajectory into the relevant times-in-mode based on their airport-specific OOOI data, the vertical profiles, and the 3000-foot AGL mixing height. The individual times-in-mode (see Figure 3) were computed as follows:

1. *Taxi/idle Out* is the time from gate pushback to the beginning of the takeoff ground roll;
2. *Takeoff* is the time from the beginning of the takeoff roll to 1000 feet AGL;
3. *Climb* is the time from 1000 feet AGL to 3000 feet AGL;
4. *Approach* is the time from 3000 feet AGL to touchdown;
5. *Taxi/idle In* is the time from touchdown to time into the gate; and
6. In our work, a fifth mode called *Cruise* or *Enroute* is computed and all emissions generated above 3000 feet AGL are attributed to this mode. The emission factors for approach were used for this mode.

In this methodology, the times-in-mode are derived from the simulated trajectories rather than the default values provided in the EDMS database. In this way, the specific traffic behaviors described by the NAS simulation are carried into the emissions modeling. This is important for understanding the environmental sensitivity of different characteristics of emerging NAS concepts, and their complex interactions.

The Landing Take Off (LTO) cycle is the basic unit of aircraft activity used to quantify the pollutants that are generated. In this work, an averaged number

Cruise

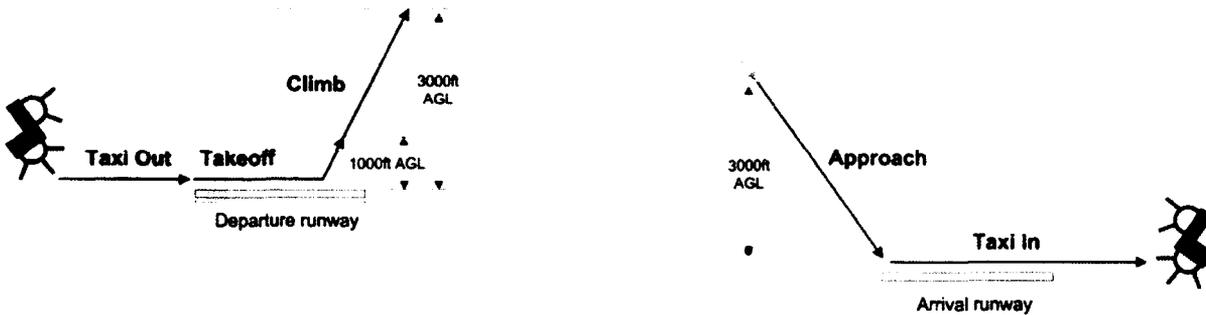


Figure 3: Aircraft modes used for computation of emissions inventories

of LTO cycles is used. Specifically, for each unique aircraft-engine combination we divided the total operation count (departures and arrivals) by two to arrive at the number of LTO cycles for that aircraft-engine combination at each airport for the simulation day. This number of LTO cycles was then multiplied by 365 and rounded to an integer value to obtain the annual count of LTO cycles for each aircraft type at each airport.

Since the ACES simulation data includes OOOI time, the OOOI times of individual flight events were used to calculate an average taxi/idle time for each aircraft/engine type at each airport. For each type at each airport, the taxi/idle time was aggregated by adding the taxi-out time for departures and taxi-in time for arrivals. The average taxi/idle time per LTO cycle was then derived from this aggregate number and the number of LTO cycles as described above. This averaging methodology is simple and direct, but could be altered in later work to reflect additional needs for analysis of emissions impacts. For example, separate averaged departure and arrival taxi times instead of an average of both could be used.

Since emissions inventories are normally presented as values in tons per year, we assumed that the ACES simulation day currently available represented an average day, and we derived the annual emissions inventory by multiplying the daily values by 365. As an example, if all Canadair Reg-100 (CF34-3A1 engine) operations at a given airport generated 2 tons of carbon monoxide on the simulation day, then the annual total for CO generated by this aircraft/engine type at that airport is 730 tons.

In standard emissions inventories, all emissions above the mixing height are discounted. In our methodology we compute all pollutant totals, by

aircraft type, above the mixing height and attribute them to an “enroute” mode. Though we do not include these totals in this paper they are available and may be analyzed in detail in future work.

## Initial Modeling Results

In this section, we present initial results regarding environmental impacts obtained for each scenario, and we discuss how these results may be integrated and compared to emerging air-transportation environmental goals.

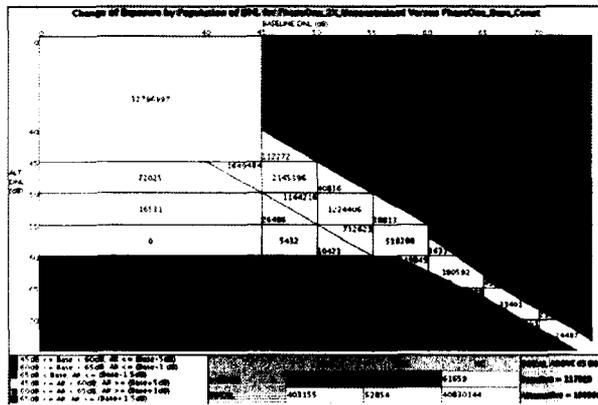
## Noise Results

This section provides an overview of the pilot-run results with regard to noise impact in terms of population with exposure above 65dB DNL. The 2x\_Unconstrained and 2x\_BusinessShift cases were run, and each has been compared to the 1x\_Constrained case as a baseline. Table 1 shows the population above 65dB DNL for each case, and the percent change relative to the baseline value.

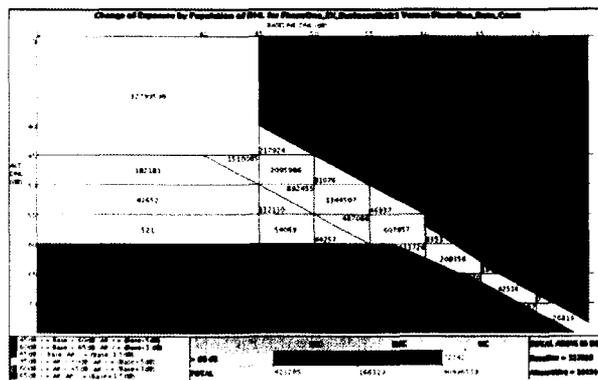
The noise impacts over the study area are presented in the Figures 4 and 5 as detailed breakdowns of the types of noise impacts in all categories, as defined by FAA guidelines [6]. The numbers shown represent the computed number of people that experienced a change (or no significant change) in noise exposure. The “hot” colors (yellow, orange, and red) on the lower left show increases in population impacted by various noise levels and the “cool” colors (purple, blue, and green) on the upper right show decreases. The white diagonal strip of numbers shows population that did not experience significant change in noise impact.

**Table 1 – Pilot Run Results for Population Above 65dB DNL**

Scenario	Change in Regional Traffic Count	Population Above 65dB DNL (thousands of persons)	Change Relative to 1x Constrained Baseline
Baseline 1x Constrained	-	117	-
Future 2x Unconstrained	+74%	190	+62%
Future 2x Business Shift	+80%	165	+40%



**Figure 4 – Impact Graph for the 2x\_Unconstrained Scenario Relative to 1x\_Constrained**



**Figure 5– Impact Graph for the 2x\_BusinessShift Scenario Relative to 1x\_Constrained**

Although these results are preliminary, several observations relevant to their interpretation and to further work can be made:

- Impact reductions in some regions** - In one of the major metropolitan areas within the study, four airports account for approximately 3200 operations in the Baseline 2004 scenario. In both the 2x Unconstrained and the 2x Business Shift scenarios, this number of operations grows to nearly 5400 operations. However, in the 2x Unconstrained case, these operations are focused almost exclusively at two main airports. In contrast, in the 2x Business Shift scenario, a significant fraction of operations is shifted to two smaller airports (~16%) while 84% of the equivalent flights operate in and out of the two major airports. This shift of operations is significant in the sense that the population density around the smaller airports is substantially lower than around the two large ones. As a result, an overall reduction (~13.4%, from 190066 to 164544) in the population above 65dB DNL is seen within study area between the 2x Unconstrained and 2x Business Shift scenarios. Not only are aircraft taking off and departing from the less densely-populated regions around the smaller airports in the 2x Business Shift scenario, but the cumulative number of operations to which any given area is exposed is reduced relative to the 2x Unconstrained scenario where all the operations fly over significantly dense regions around the two major airports.
- Sensitivity to track dispersion** - Results show a high degree of sensitivity to the spatial location of tracks, particularly at airports with relatively few operations. This is an issue due to the technique used (sampling from a normal distribution) for defining dispersion along the nominal track extensions connecting fix to runways. For airports with a large number of operations, the effect is less severe. However, at airports with a small number of operations, this effect can be substantial. Slight shifting of one or two tracks (due to a change in departure fanning angle, for example) can result in tracks that overfly a particular centroid that was avoided in the baseline case or vice versa.
- Sensitivity to population decimation** - The track spatial sensitivity noted above is exacerbated by the decimation of population-location points used for these initial runs. By effectively reducing the population spatial density by a factor of 10, we effectively increased the

possibility that slight variations in track location with respect to the underlying locations can impact the computed noise exposure values.

Each of these effects will be addressed in subsequent work.

**Emissions Inventory Results**

This section provides an overview of the pilot-run results with regard to annual emissions inventory in HC, CO, NO<sub>x</sub>, and SO<sub>x</sub>. As in the case of the noise results, the 2x\_Unconstrained and 2x\_BusinessShift cases were run, and each has been compared to the 1x\_Constrained case as a baseline. Table 2 shows the absolute values for each pollutant and the percent change relative to the baseline.

Although the ACES scenarios thus far processed do not represent the full spectrum of scenarios that will be investigated in the longer term, several general observations can be made at this point:

1. As expected, an increase or decrease in the number of operations (LTO cycles) approximately translates into a proportionate change in the total amount of pollutants generated.
2. Due to the complex NAS effects modeled in ACES, the change in the number of operations

does not remain proportional across different airports within a scenario.

Similarly, due to these complex effects, the change in the number of operations does not remain proportional across different aircraft types at a given airport within a scenario. For example, at DTW the total number of operations in the 2xUnconstrained case has increased by 151% over the 1xConstrained case. However, the number of A319, DC9-30, ERJ-145 operations have almost tripled while the number of DC9-50 operations has stayed about the same.

3. The emission factors for different aircraft engines are highly variable depending on the mode of operation and the specific engine. Hence the rate of pollutant generation can vary widely dependent on the mode, the engine, and the specific pollutant. For example, for the AE3007A engine, during taxi/idle, CO is generated in proportionately greater quantities while NO<sub>x</sub> are generated in proportionately greater quantities during climbout. Hence an increase in taxi time may see the CO burden increase while an increase in climbout time may see the NO<sub>x</sub> burden increase. Additionally, some aircraft-engine combinations generate more of one or two pollutants in all modes of operation. The DC9-30 (with JT8D-9A engines) generates more NO<sub>x</sub> and SO<sub>x</sub> than other aircraft in the same seat-capacity category. At one airport

**Table 2 – Pilot Run Results for Emissions Inventory**

<i>Scenario</i>	<i>Annual LTO Cycles (Millions)</i>	<i>Change in LTO Cycles</i>	<i>Pollutant</i>	<i>Annual Emissions Inventory (kilotons/year)</i>	<i>Change Relative to 1x Constrained Baseline</i>
Baseline 1x Constrained	2.019	-	HC	1.5	-
			CO	11.0	-
			NO <sub>x</sub>	9.5	-
			SO <sub>x</sub>	0.9	-
Future 2x Unconstrained	3.519	+74%	HC	2.6	+ 76%
			CO	18.4	+ 68%
			NO <sub>x</sub>	18.1	+ 92%
			SO <sub>x</sub>	1.7	+ 84%
Future 2x Business Shift	3.626	+80%	HC	2.5	+ 72%
			CO	18.8	+ 72%
			NO <sub>x</sub>	16.0	+ 69%
			SO <sub>x</sub>	1.5	+ 69%

within the study area, the total number of operations has increased by 88% in the 2xUnconstrained case. However the DC9-30 operations have increased almost by a factor of three which contributes to a more-than-proportionate increase in the NO<sub>x</sub> (124%) and SO<sub>x</sub> (123%) totals.

In the 2xBusinessShift case the total number of operations is roughly the same as the 2xUnconstrained case. However, certain airports experience a very significant increase in pollutant totals due to the shifting of traffic from larger airports to smaller regional airports. For example one regional airport receives an additional 122,000 annual LTO cycles of regional jets which have been shifted from one of the major airports in the study area. This represents a 1700% increase in the number of operations and correspondingly produces very large increases in pollutant totals at the regional airport: up to 3500% for SO<sub>x</sub>. The net result of moving the large airport's traffic to the other smaller airports in the area is that the large one sees its annual LTO cycle count dropping by 26% going from the 2xUnconstrained case to the 2xBusinessShift case. Correspondingly the large airport's pollutant burden drops from an aggregate 90% increase in the 2xUnconstrained case to an aggregate 44% in the 2xBusinessShift case.

## Summary and Next Steps

The principal accomplishments of this work to date may be summarized as follows:

1. *Linkage of ACES and environmental models* - End-to-end noise and emissions modeling has been achieved using ACES outputs for future NAS scenarios. Supplementary data necessary for environmental modeling has been integrated into this process, and initial ACES scenarios have been run through the environmental models.
2. *Integrated data stream for noise and emissions calculations* - NAS simulator outputs are integrated into a single data stream feeding both the noise and emissions models, thus reducing costs associated with data preparation and quality assurance.
3. *Environmental output exhibits constructed* - Exhibits of graphical and tabular outputs from the environmental models have been produced, and they have been integrated into the process.

This work provides the basic capability required to support multi-dimensional system analysis of emerging NAS concepts as they are developed by the JPDO. Environmental modeling can now be performed as an integrated part of the complex technical and operational trade-offs necessary for development of future concepts encompassing innovations in ATM, airport operations, weather, and security.

Principal areas of further effort are as follows:

- Population data - Full-scale runs will be undertaken using all population points in the study area, and use of population projections for 2025 will be explored.
- Terrain data - Full-scale runs will be undertaken using geographic terrain data.
- Terminal-area data - ACES Version 3 outputs for terminal-area trajectories will be incorporated in later runs.
- Technology evolution - Both airframe and engine technology evolution will be included in future runs to evaluate noise and emissions impacts of this evolution
- Fleet evolution - We will incorporate latest FAA data and guidelines for estimating future fleet composition.
- Sensitivity analyses - The sensitivity of environmental results to different assumptions for technology and fleet evolution will be evaluated.
- Extend baseline-establishment methods - We will further address the best means of establishing credible baselines for airports that are not modeled in the ACES baseline.

## References

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[6] Federal Aviation Administration (AEE-110), December 1986, FAA Order 1050.1D, Policies and Procedures for Considering Environmental Impacts.

## Author Biographies

Stephen Augustine is a Senior Analyst at Metron Aviation. He has a B.S. in Physics and Computer Science from St. John's University in Minnesota. Since joining Metron in 1998, Mr. Augustine has been directly involved with research and development related to noise quantification and reduction of noise impacts in the several regional projects. He has been an integral part of the development team for the FAA's Noise Integrated Routing System (NIRS) with key work on noise mapping modules. Mr. Augustine currently leads all development activities related to NASA's NAS-wide Environmental Model (NASEIM) and has also contributed several noise-optimization related features to Metron Aviation's Airspace Design Tool (ADT).

Dr. Brian Capozzi is a Senior Analyst at Metron Aviation. He has a Ph.D. in Aeronautics and Astronautics from the University of Washington in Seattle, WA. Since joining Metron in September of 2001, Dr. Capozzi has been directly involved with research and development related to reduction of noise impacts in the terminal area. This includes a study using Metron Aviation's Airspace Design Tool (ADT) and Noise Integrated Routing System (NIRS) to quantify the impacts of postulated noise-aware decision support tools (RTO61). Dr. Capozzi was all involved in the development of a noise-aware decision support tool under a Phase II SBIR titled Dynamic Noise Avoidance Planner with NASA.

John DiFelici is a Principle Software Engineer at Metron Aviation. He has an M.S. in Physics from the University of Maryland at College Park. For the past nine years, Mr. DiFelici has been involved with the development and application of software used to

model terminal-area and en-route airspace noise and to the design of alternative routes for noise reduction. Mr. DiFelici is the lead developer of the FAA's Noise Integrated Routing System (NIRS) which is used to show changes in noise impacts associated with airspace changes. He was the lead developer for Metron Aviation's Airspace Design Tool (ADT) which is used to create models of current terminal airspace routes.

Michael Graham is a Senior Analyst at Metron Aviation. He has a B.S. in Computer Science from Brigham Young University in Provo UT. Since joining Metron in May of 2002, Mr. Graham has assumed project lead responsibilities for all noise analysis projects. Currently he oversees the analysis of several National Airspace Redesign (NAR) projects. Mr. Graham is the primary contact for Metron Aviation in discussing all technical aspects of the project with the FAA and other sub-contractors. He currently leads day-to-day operations that include radar data analysis from a variety of sources, understanding the current and alternative airspace designs, and finally developing technical documentation that describes the analysis.

Dr. Terry Thompson is Vice President for Aviation Technology at Metron Aviation. He has a Ph.D. in Computational Biophysics from the University of Rochester. With 13 years of experience in aviation systems, Dr. Thompson is a subject matter expert in Environmental Modeling, Noise Abatement Procedures, Airspace Design, Route and Schedule Optimization, and NAS Simulation. He is technical director of development for the FAA's Noise Integrated Routing System (NIRS) for regional and nationwide noise-impact assessments. He is technical director of development of the Airspace Design Tool (ADT) for data integration and airspace-design construction and evaluation. He was technical director for NASA's Benefits Analysis of Noise-aware Decision Support Tools.

Raymond M.C. Miraflor is a researcher at NASA Ames. He has an M.S. in Mechanical Engineering from Stanford University. Mr. Miraflor is also the Environmental Sub-Team Lead for the JPDO Evaluations and Analysis Office. He is the NASA technical lead on integration of environmental modeling capabilities with airspace simulation environments. Mr. Miraflor led the requirements definition for ACES Build 4 and was the focal point for development of the NASA Virtual Airspace Modeling and Simulation Laboratory, which includes ACES, NIRS, EDMS, and INM. He is also technical monitor for several industry and university contracts for airspace and environmental impact research.