

Air Craft Mobile Source Category Calculation Methodology Sheet

<u>I. Source Category:</u> Commercial Aircraft	<u>II. SCC:</u> 2275020000
General Aviation	2275050000
Air Taxis	2275060000
Military	2275001000

III. Pollutants: PM₁₀, PM_{2.5}, VOC, NO_x, CO, SO_x and HAPs

IV. Current Methodology:

The National level activity data on landing and take-off (LTOs) for commercial carriers obtained from U.S. DOT for U.S. flag carriers and from EPA OTAQ internal study for foreign flag carriers. Number of annual aircraft operations (arrivals plus departures) within each non-commercial aircraft category, divided by 2 (data from FAA).

Emission factors for commercial aircraft are derived from Emissions and Dispersion Modeling System (EDMS) from FAA. Used default engines for each aircraft type and default time-in-mode values for takeoff, climbout, approach, and landing roll times. EDMS requires input of time-in-mode for taxiing and idling combined (default value of 26 minutes used for all aircraft types). Does not include emissions factors for PM. For FAA U.S. flag LTO data whose aircraft could not be matched to EDMS aircraft, NEI used an average LTO-based emission factor developed from the U.S. flag aircraft that could be matched.

Criteria pollutant emission estimates for military aircraft, general aviation, and air taxis were calculated by combining aircraft operations data from FAA's Air Traffic and Activity Data System (ATADS) and EPA criteria emission factors (see Mobile Source Emission Inventory Guidance Document reference)

- National aircraft emission estimates were allocated to individual counties using airport activity data derived from FAA Terminal Area Forecast System (TAF) database of over 2,000 airports in the U.S. The percentage of national LTOs represented by each airport was used to apportion the emissions.

V. Emission Calculations:

A. Commercial Aircraft

1. Steps in Creating and Airport Emission Inventory in EDMS:
 - a. Open the EDMS model and create a new study for the airport in question. Enter the parameters (name, mixing height, average yearly temperature, and units of measurement) that are specific to each airport into the study.
 - b. Provide EDMS with information to compute the emissions inventory. Begin by matching engines with aircraft and assigning them to the study. Select the aircraft to be used in the study (data that is collected from the

- airport) by picking the aircraft name from the menus. EDMS automatically associates specific aircraft with certain engine types.
- c. For each aircraft fill in the yearly LTO cycles provided by surveying the airport.
 - d. For each aircraft fill in the average annual taxi time and queue time specific to the airport or use the EDMS provide default values.
 - e. Continue to add each aircraft/engine type, LTO cycle, taxi time and queue time to the study.
 - f. EDMS has tables built into the model that associate aircraft type with the number of engines, auxiliary power units and ground support equipment. The model also assigns default values for Takeoff Time (typically 0.3 minutes), Climbout Time (typically 5 minutes), and Approach Time (typically 6 minutes).
 - g. If emissions from parking lots, roadways, stationary sources, and training fires are also required, complete the dialog boxes associated with each of these subcategories.
 - h. Run the EDMS emission inventory program and view the results.

2. Sample Calculations

The following calculations include aircraft operating at Baltimore/Washington International Airport in Anne Arundel County during 1998. Tabled below is the aircraft, engine assigned to the aircraft, time for each mode of operation, annual LTO operations, average annual taxi time, and the average annual queue time.

Aircraft Name	Aircraft Type	Engine Assigned	Approach Time (min)	Climbout Time (min)	Takeoff Time (min)	Annual LTO	Taxi Time (min)	Queue Time (min)
Falcon 100	GA	TFE731-3	1.60	0.50	0.40	1825	10.50	3.00
P-337P Skymaster	GA	TSIO-360C	4.50	2.50	0.50	9490	10.50	3.00
550 Citation	GA	JT15D-4 (B,C,D)	1.60	0.50	0.40	2190	10.50	3.00
A320	Comm	CFM56-5B4	4.00	2.20	0.70	2555	10.50	3.00
AH-1	Military	T53-L-11D	6.80	6.80	0.00	1825	10.50	3.00
ATR42	Comm	PW120	4.50	2.50	0.50	2190	10.50	3.00
B727-100	Comm	JT8D-7A	4.00	2.20	0.70	8030	10.50	3.00
B737-200	Comm	JT8D-15A	4.00	2.20	0.70	21900	10.50	3.00
B737-300	Comm	CFM56-3B	4.00	2.20	0.70	13140	10.50	3.00
B737-400	Comm	CFM56-3B	4.00	2.20	0.70	3650	10.50	3.00
B737-500	Comm	CFM56-3B	4.00	2.20	0.70	8030	10.50	3.00
B737-700	Comm	CFM56-3C-1	4.00	2.20	0.70	730	10.50	3.00
B747-100	Comm	JT9D-7A	4.00	2.20	0.70	183	10.50	3.00
B757-200	Comm	PW2037	4.00	2.20	0.70	7665	10.50	3.00
B767-200	Comm	CF6-80A (A1)	4.00	2.20	0.70	1095	10.50	3.00
BAE ATP	Comm	PT6A-45	4.00	2.20	0.70	2555	10.50	3.00
BH-1900	Comm	PT6A-65B	1.60	0.50	0.40	3285	10.50	3.00
C-12A/B/C	Military	PT6A-41	3.50	0.80	0.40	730	10.50	3.00
C-130 Hercules	Military	T56-A-16	5.10	1.20	0.40	365	10.50	3.00
C-9A	Military	JT8D-9	5.10	1.20	0.40	365	10.50	3.00
Canadair Reg-100	Comm	CF34-3A1	4.00	2.20	0.70	730	10.50	3.00

Cessna 150	GA	O-200	6.00	5.00	0.30	5110	10.50	3.00
Convair liner	Comm	RDA10	4.50	2.50	0.50	365	10.50	3.00
DC10-10	Comm	CF6-50C	4.00	2.20	0.70	730	10.50	3.00
DC9-10	Comm	JT8D-7A	4.00	2.20	0.70	4380	10.50	3.00
DHC-8	Comm	PW120	4.50	2.50	0.50	3650	10.50	3.00
DHC-8-400	Comm	PW123	4.50	2.50	0.50	18250	10.50	3.00
F-16	Military	F100-PW-100	3.50	0.80	0.40	183	10.50	3.00
F-27 Series	Military	RDa7	4.50	2.50	0.50	365	10.50	3.00
Fokker 100	GA	TAY650	4.00	2.20	0.70	365	10.50	3.00
H-46 Sea Knight	Military	T58-GE-8F	6.80	6.80	0.00	183	10.50	3.00
Kingair B200	GA	PT6A-41	1.60	0.50	0.40	5840	10.50	3.00
Learjet 25B	GA	CJ610-6	1.60	0.50	0.40	1460	10.50	3.00
MD-11	Comm	CF6-80C2D1F	4.00	2.20	0.70	730	10.50	3.00
MD-80	Comm	JT8D-209	4.00	2.20	0.70	4563	10.50	3.00
MD-80-88	Comm	JT8D-217	4.00	2.20	0.70	1825	10.50	3.00
MD-90-10	Comm	V2525-D5	4.00	2.20	0.70	365	10.50	3.00
Porter PC6/B2	Military	PT6A-27	4.50	2.50	0.50	730	10.50	3.00
SF-340-A	Comm	CT7-5	4.50	2.50	0.50	730	10.50	3.00
Swearingen Merlin	Comm	TPE331-3	4.50	2.50	0.50	2920	10.50	3.00
Swearingen Merlin	Comm	TPE331-3	4.50	2.50	0.50	365	10.50	3.00

Once all of the data is entered into the model, the model produces an emission inventory. Annual emission inventory results are listed in the table below:

NAME	CO Tons/year	HC¹ Tons/year	NOX Tons/year	SOX Tons/year	PM10 Tons/year
Aircraft	767.886	128.821	905.493	41.586	
GSE/AGE/APU	2810.992	71.658	221.278	6.027	7.871
Total	3578.878	200.476	1126.771	47.613	7.871

The model will also produce an inventory specific to each aircraft type, which allows the data to be separated into types (commercial, general aviation, and military) of operation. For BWI the separation results in the following:

NAME	CO Tons/year	HC Tons/year	NOX Tons/year	SOX Tons/year	PM10 Tons/year
Commercial Aircraft	546.030	84.833	890.956	40.399	0.000
General Aviation	202.667	34.256	6.699	0.654	0.000
Military Aviation	19.189	9.732	7.838	0.533	0.000
Total	767.886	128.821	905.493	41.586	0.0

¹ Requires a Hydrocarbon to VOC conversion factor of 1.0947.

B. General Aviation

1. Equation:

$$\text{Emiss}_{xx} = \text{LTO (GA)} * \text{EF (GA)}_{xx}$$

2. Variables:

a. Emiss_{xx}. Emissions of a pollutant in pounds.

b. LTO (GA). LTOs for General Aviation. Rough estimates of emissions can be calculated after information on the LTO operations of aircraft operation type is obtained from your states airports, using the alternative fleet-average procedure of Section 5.2.4.2 of Procedures for Emission Inventory Preparation, Volume IV Mobile sources, 1992.

c. EF (GA)_{xx}. Emission Factors for General Aviation

	CO (lbs./LTO)	HC* (lbs./LTO)	NOx (lbs./LTO)	SO2 (lbs./LTO)	PM (lbs./LTO)
General Aviation	12.014	0.394	0.065	0.010	0.2367 ²

* Requires Hydrocarbon to VOC conversion factor of 0.9708 for General Aviation

3. Sample Calculation

This calculation is for Easton Airport/Newman Field in Talbot County, Maryland. The airport had 21,569 General Aviation LTOs over a twelve month period. Performing step 1 Equations (above) the calculations were:

$$\begin{aligned} \text{Emiss}_{\text{VOC}} &= [\text{L(GA)} * \text{EF(GA)}_{\text{HC}}] * \text{CF (VOC/HC)} \\ \text{Emiss}_{\text{VOC}} &= [(21,569 \text{ LTOs / Year} * 0.394 \text{ (lbs. HC / LTO)}) * 0.9708 \text{ (lbs. VOC / lbs. HC)}] \\ \text{Emiss}_{\text{VOC}} &= 8,250.0390 \text{ lbs. VOC / Year} \\ \text{Emiss}_{\text{VOC}} &= 0.0113 \text{ Tons VOC / Day} \end{aligned}$$

$$\begin{aligned} \text{Emiss}_{\text{CO}} &= [21,569 \text{ LTOs / Year} * 12.014 \text{ (lbs. CO / LTO)}] \\ \text{Emiss}_{\text{CO}} &= 259,129.966 \text{ lbs. of CO / Year} \\ \text{Emiss}_{\text{CO}} &= 0.3550 \text{ Tons CO / Day} \\ \text{Emiss}_{\text{NOx}} &= [21,569 \text{ LTOs / Year} * 0.065 \text{ (lbs. NOx / LTO)}] \\ \text{Emiss}_{\text{NOx}} &= 1,401.985 \text{ lbs. of NOx / Year} \\ \text{Emiss}_{\text{NOx}} &= 0.0019 \text{ Tons NOx / Day} \end{aligned}$$

$$\begin{aligned} \text{Emiss}_{\text{SO2}} &= [21,569 \text{ LTOs / Year} * 0.100 \text{ (lbs. SO2 / LTO)}] \\ \text{Emiss}_{\text{SO2}} &= 2,156.900 \text{ lbs. of SO2 / Year} \\ \text{Emiss}_{\text{SO2}} &= 0.0030 \text{ Tons SO2 / Day} \end{aligned}$$

²Documentation for Aircraft, CMV, Locomotive and Other Nonroad Components of the NEI, Vol 1- Methodology.
Note: 69% of PM10 is PM 2.5

$$\text{Emiss}_{\text{PM}} = [21,569 \text{ LTOs / Year} * 0.020 \text{ (lbs. PM / LTO)}]$$

$$\text{Emiss}_{\text{PM}} = 431.380 \text{ lbs. of PM / Year}$$

$$\text{Emiss}_{\text{PM}} = 0.0006 \text{ Tons PM / Day}$$

C. Air Taxis

1. Equation:

$$\text{Emiss}_{\text{xx}} = \text{L(AT)} * \text{EF(AT)}_{\text{xx}}$$

2. Variables:

- a. Emiss_{xx} . Emissions of a pollutant in pounds.
- b. L(AT) . LTOs for Air Taxis. Rough estimates of emissions can be calculated after information on the LTO operations of aircraft operation type is obtained from your states airports, using the alternative fleet-average procedure of Section 5.2.4.2 of Procedures, 1992
- c. $\text{EF(AT)}_{\text{xx}}$. Emission factors for Air Taxis

	CO (lbs./LTO)	HC* (lbs./LTO)	NO _x (lbs./LTO)	SO ₂ (lbs./LTO)	PM (lbs./LTO)
Air Taxis	28.130	1.234	0.158	0.015	0.6033 ³

* Requires Hydrocarbon to VOC conversion factor of 0.9914 for Air Taxis.

3. Sample Calculation

This calculation is for Easton Airport/Newman Field in Talbot County, Maryland. The airport had 4,557 Air Taxi Aviation LTOs over a twelve month period. Performing step 1 Equations (above) the calculations were:

$$\text{Emiss}_{\text{VOC}} = [\text{L(AT)} * \text{EF(AT)}_{\text{HC}}] * \text{CF (VOC/HC)}$$

$$\text{Emiss}_{\text{VOC}} = [(4,557 \text{ LTOs / Year} * 1.234 \text{ (lbs. HC / LTO)}) * 0.9914 \text{ (lbs. VOC / lbs. HC)}]$$

$$\text{Emiss}_{\text{VOC}} = 5,574.9773 \text{ lbs. VOC / Year}$$

$$\text{Emiss}_{\text{VOC}} = 0.0076 \text{ Tons VOC / Day}$$

$$\text{Emiss}_{\text{CO}} = [4,557 \text{ LTOs / Year} * 28.130 \text{ (lbs. CO / LTO)}]$$

$$\text{Emiss}_{\text{CO}} = 128,188.410 \text{ lbs. of CO / Year}$$

$$\text{Emiss}_{\text{CO}} = 0.1756 \text{ Tons CO / Day}$$

$$\text{Emiss}_{\text{NO}_x} = [4,557 \text{ LTOs / Year} * 0.158 \text{ (lbs. NO}_x \text{ / LTO)}]$$

$$\text{Emiss}_{\text{NO}_x} = 720.006 \text{ lbs. of NO}_x \text{ / Year}$$

$$\text{Emiss}_{\text{NO}_x} = 0.0010 \text{ Tons NO}_x \text{ / Day}$$

³ Documentation for Aircraft, CMV, Locomotive and Other Nonroad Components of the NEI, Vol 1- Methodology.
Note: 69% of PM₁₀ is PM 2.5

$$\begin{aligned} \text{Emiss}_{\text{SO}_2} &= [4,557 \text{ LTOs / Year} * 0.015 \text{ (lbs. SO}_2 \text{ / LTO)}] \\ \text{Emiss}_{\text{SO}_2} &= 68.355 \text{ lbs. of SO}_2 \text{ / Year} \\ \text{Emiss}_{\text{SO}_2} &= 0.0001 \text{ Tons SO}_2 \text{ / Day} \end{aligned}$$

$$\begin{aligned} \text{Emiss}_{\text{PM}} &= [4,557 \text{ LTOs / Year} * 0.020 \text{ (lbs. PM / LTO)}] \\ \text{Emiss}_{\text{PM}} &= 91.14 \text{ lbs. of PM / Year} \\ \text{EMISS}_{\text{PM}} &= 0.0001 \text{ TONS PM / DAY} \end{aligned}$$

D. Military Aircraft

1. Equation:

$$\text{Emiss}_{\text{xx}} = \text{L(MA)} * \text{EF(MA)}_{\text{xx}}$$

2. Variables:

a. L(MA). LTOs for Military Aircraft

b. EF(MA)_{xx}. Emission factors for Military Aircraft. Composite emission factors from Procedures for Emission Inventory Preparation, Volume IV: Mobile Sources, 1988 are listed below:

	CO (lbs./LTO)	VOC (lbs./LTO)	NOx (lbs./LTO)	SO2 (lbs./LTO)	PM (lbs./LTO)
Military Aircraft	48.80	27.10	9.160	1.430	15.230 ⁴

3. Sample Calculation:

This calculation is for Patuxent River Naval Air Station in St. Mary's county, Maryland. The airport had 63,852 LTOs in 1999. Using step 1 from Equations (above) the calculations were:

$$\begin{aligned} \text{Emiss}_{\text{VOC}} &= [\text{L(AT)} * \text{EF(MA)}_{\text{HC}}] \\ \text{Emiss}_{\text{VOC}} &= [(63,852 \text{ LTOs / Year} * 27.10 \text{ (lbs. VOC / LTO)}] \\ \text{Emiss}_{\text{VOC}} &= 1,730,389.200 \text{ lbs. VOC / Year} \\ \text{Emiss}_{\text{VOC}} &= 2.3704 \text{ Tons VOC / Day} \end{aligned}$$

$$\begin{aligned} \text{Emiss}_{\text{CO}} &= [63,852 \text{ LTOs / Year} * 48.80 \text{ (lbs. CO / LTO)}] \\ \text{Emiss}_{\text{CO}} &= 3,115,977.60 \text{ lbs. of CO / Year} \\ \text{Emiss}_{\text{CO}} &= 4.2685 \text{ Tons CO / Day} \end{aligned}$$

$$\begin{aligned} \text{Emiss}_{\text{NO}_x} &= [63,852 \text{ LTOs / Year} * 9.160 \text{ (lbs. NO}_x \text{ / LTO)}] \\ \text{Emiss}_{\text{NO}_x} &= 584,884.32 \text{ lbs. of NO}_x \text{ / Year} \\ \text{Emiss}_{\text{NO}_x} &= 0.8012 \text{ Tons NO}_x \text{ / Day} \end{aligned}$$

$$\begin{aligned} \text{Emiss}_{\text{SO}_2} &= [63,852 \text{ LTOs / Year} * 1.430 \text{ (lbs. SO}_2 \text{ / LTO)}] \\ \text{Emiss}_{\text{SO}_2} &= 91,308.36 \text{ lbs. of SO}_2 \text{ / Year} \end{aligned}$$

⁴ For military aircraft, a composite factor was used from section 5.2.5, Table 5-3 of Procedures for Emission Inventory Preparation, Volume IV: Mobile Sources, 1992.

$$\text{Emiss}_{\text{SO}_2} = 0.1251 \text{ Tons SO}_2 / \text{Day}$$

$$\text{Emiss}_{\text{PM}} = [63,852 \text{ LTOs} / \text{Year} * 15.23 \text{ (lbs. PM} / \text{LTO)}]$$

$$\text{Emiss}_{\text{PM}} = 972,465.96 \text{ lbs. of PM} / \text{Year}$$

$$\text{Emiss}_{\text{PM}} = 1.3321 \text{ Tons PM} / \text{Day}$$

VI. Point Source Adjustments:

Emissions for this source category have not been reported in the point source inventory, therefore no adjustment of the area source emissions is required.

VII. Adjustments for Controls:

Data for controls is not available for this source.

VIII. Spatial Adjustments:

Data for spatial allocation is not available for this source.

IX. Temporal Adjustments:

A daily emission inventory was produced assuming an airport activity of 365 days per year.

X. Assumptions:

A. Unless other data is collected, national data on LTOs used for various aircraft categories.

B. National emissions determined using national emission factors either from EDMS or from EPA OTAQ

C. Unless other data is collected, allocation to county level based on total LTOs at individual airports using FAA data.

XI. Rule Effectiveness:

XII. Uncertainties/Shortcomings of Methodology

A. Default engine types and time-in-mode values used.

B. LTO data used to allocate emissions to the county do not generally include military LTO data

XIII. Recommendations to Improve Methods/Data

A. Commercial Aircraft

1. Obtain estimates of LTO data by airport/county, and by aircraft type, to obtain LTOs not covered by FAA data (i.e. foreign flag aircraft).

2. Develop airport specific emission estimates using the new FAA EDMS emission estimation tool in conjunction with local aircraft specific equipment and activity data [local commercial airports (airport master plans or records), Federal Aviation Administration].

3. Information on climbout/takeoff/approach times, as well as taxi/idle times [Local commercial airports (airport master plans or records), Federal Aviation Administration]
4. For PM, match emission factors from EPA's 1992 Volume IV, Mobile Sources Procedures document, to the aircraft engines in the fleet as best as possible.
5. Check EPA OTAQ web page since they are working with FAA to develop better aircraft PM emission factors.

B. General Aviation, air taxi, and military aircraft:

1. Obtain local estimates of LTOs for these categories (to obtain LTOs not covered by FAA data) [Local commercial airports (airport master plans or records), Federal Aviation Administration]
2. Obtain information on the aircraft/engine types that comprise the aircraft fleet for these categories. Apply engine-specific emission factors from EPA's Procedures for Emission Inventory Preparation, Volume IV: Mobile Sources, 1992 (or EDMS, if available) [Local commercial airports (airport master plans or records), Federal Aviation Administration]

XIV. Additional Information/Guidance:

EPA Contact: Ms. Laurel M. Driver
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Additional Information on Emissions from Aviation Source:
www.epa.gov/otaq/aviation.htm

Mobile Source Emission Inventory Guidance Document:
www.epa.gov/otaq/invntory/r92009.pdf

NEI Methodology Description:
www.epa.gov/ttn/chief/net/index.html#doc

XV. References:

Maryland Department of the Environment, *Calculation Methodologies (draft)*, June 2002.

New Jersey Department of Environmental Protection, *PM_{2.5} Area Source Category Calculation Methodology Sheet*, October 2002.

U.S. Environmental Protection Agency. *Current Methods Used to Estimate Emissions, 1985-1999* Procedures Document for National Emission Inventory, Criteria Air Pollutants 1985-1999, March 2001, EPA-454/R-01-006.

U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, *Procedures for Emissions Inventory Preparation, Volume IV: Mobile Sources*, 1992, EPA-450/4-81-026d (Revised).