Realistic Aircraft Greenhouse Gas Emissions Analysis: Achieving Accurate, Scalable, and Robust Surveillance-Derived Modeling Results

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Executive Summary

Aircraft Greenhouse Gas (GHG) emissions inventories form a critical component in accounting for overall transportation-related emissions reporting at the local and state levels. Yet the current reporting and analysis methodologies are largely rooted in static “one size fits all” formulaic calculations and incomplete datasets that provide “best guess” numbers.

In this white paper, ATAC presents an accelerated, scalable, and improved alternative to calculating aircraft emissions. Our approach is based on best-in-class modeling software (the Aviation Environmental Design Tool or AEDT)[1] developed by the Federal Aviation Administration (FAA) and applies ATAC’s industry-leading preprocessing and analysis capabilities using four-dimensional (latitude, longitude, altitude, and time) surveillance track data that achieves unparalleled accuracy by applying more realistic modeling methods. ATAC can produce historical analyses for reporting purposes or forward-looking “what-if” scenario analysis to plan for the future. ATAC firmly believes all airports, airlines, and their communities should strive for report integrity and building public trust in accurate modeling and data analysis. The best method to accomplish this is to combine accurate aircraft track data on the ground and in the air with an analytical approach that yields depth and insight that may be applied in a variety of ways.

ATAC’s industry-leading approach applies analysis-quality, FAA-derived aircraft movement data, an automated engine-to-airframe mapping methodology, and the latest emissions analysis capability to deliver comprehensive aircraft GHG emissions reports to you on a timeframe of your choosing (e.g. hourly, daily, weekly, yearly, etc.).

Problem Statement

The ability for any aviation entity (airport or airline) to accurately report aircraft GHG results from airside and airspace operations and use the reported results as a basis of carbon offset calculations, community engagement, lease negotiations, land use decisions, service initiation or continuity, a political decision-making mechanism, or punitive policy enforcement mechanism should incorporate the most reliable, most accurate, best-in-class methods available to the decision makers. Is that happening currently? Is that happening within the legally defensible realms of litigation and public challenges? ATAC believes the path forward is paved with quickly calculated, automated, defensible data; the FAA’s

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[1] US Federal Aviation Administration, *Aviation Environmental Design Tool*, https://aedt.faa.gov/ Accessed September 2, 2020.

best software; and a modeling approach that represents reality to the maximum extent current practice allows.

In July 2020, US Environmental Protection Agency (EPA) Administrator Andrew Wheeler proposed "…GHG emission standards that would apply to certain new commercial airplanes, including all large passenger jets. These proposed standards would match the international airplane carbon dioxide (CO_2) standards adopted by the International Civil Aviation Organization (ICAO) in 2017. This proposed action would implement EPA's authority under the Clean Air Act and would assure the worldwide acceptance of U.S. manufactured airplanes and airplane engines." This proposed rule includes all domestic and international flights originating in the US and is backed by the EPA's 2016 finding that "…under section 231 of the Clean Air Act, EPA found that: (1) concentrations of six well mixed GHGs in the atmosphere—CO_2, methane, nitrous oxide (N_2O), hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride—endanger the public health and welfare of current and future generations, and (2) GHGs emitted from certain classes of engines used in certain aircraft are contributing to that endangering air pollution." ATAC has taken this large-scale policy direction and charted a path forward that involves both domestic and international flight profiles that would respect the 2016 EPA ruling and the 2017 ICAO ruling, employing the very best in surveillance track analysis and AEDT methodology to produce more realistic modeling methods producing aircraft-specific GHG results that can be confidently defended and used for public engagement efforts without undue concern for legal defensibility.

Background

Aircraft GHG emissions are largely defined as Carbon dioxide (CO_2), Methane (CH_4), Nitrous Oxide (N_2O), and various fluorinated gases.[2] Aircraft-specific GHG inventories have been largely driven by global air emissions and air quality policies affecting aviation, beginning with the 1997 Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC). Reporting emissions inventories[3] under a global framework has been concentrated on six main GHGs[4] that have been affirmed and expounded upon since 1997 by ICAO, which is the aviation arm of the United Nations (UN). Federal regulatory and policy agencies including the FAA and the Environmental Protection Agency (EPA) began driving aviation emissions policy in the early 1970s in response to an influx of Congressional laws and regulations such as the Clean Air Act and National Environmental Policy Act (NEPA). In turn, government agencies and department such as the Environmental Protection Agency and FAA's Office of Environment and Energy (AEE) broke the initial ground propagating guidance, policy, and regulatory structures. Subsequently and with increasing interest over time, the historically active US aviation organizations such as the Airports Council International (ACI), the American Association of Airport Executives (AAAE), the Transportation Research Board (TRB), Airlines for America (A4A), the Airport Consultants Council (ACC), and the National Association of State Aviation Officials (NASAO) have promulgated conferences, committees, panels, calls for research and papers, and in many cases tools to address aviation emissions inventories. Federal, state, and local levels of government have enacted policies, laws, and regulations

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[2] US Environmental Protection Agency. https://www.epa.gov/ghgemissions/overview-greenhouse-gases Accessed September 3, 2020.

[3] https://unfccc.int/process/transparency-and-reporting/reporting-and-review-under-the-kyoto-protocol/overview/guidelines-under-articles-5-7-and-8-methodological-issues-reporting-and-review-under-the-kyoto-1 accessed September 1, 2020.

[4] https://unfccc.int/process-and-meetings/the-kyoto-protocol/what-is-the-kyoto-protocol/kyoto-protocol-targets-for-the-first-commitment-period accessed September 1, 2020.

supporting the need for aviation-specific GHG inventories since the emergence of broad domestic policies for GHG inventories and reporting. Many mechanisms were developed including an individual airport Environmental Management System (EMS), the Global Reporting Initiative (GRI), and a patchwork of local mechanisms that lack standardization. The FAA identified their Aviation Emission Characterization Roadmap in 2008 and has been progressing on this research using a number of public-private research driven contract vehicles employed by the FAA.[5]

GHG inventories can be calculated on many aircraft operational levels whose discriminators may include geography, altitude, and atmospheric mixing dynamics, commercial versus non-commercial service, aircraft type, or trip distances. Throughout the global efforts on aircraft GHG inventory reporting to support climate change policies and reduction strategies, the approach has traditionally been twofold: (1) to adapt air quality models to account for the presence of aircraft GHG emissions and (2) to adapt aviation emissions models to account for atmospheric and engine specific factors to determine GHG amounts. The FAA has clearly moved in the direction to support and develop AEDT as an aviation-specific model that integrates the best-in-class components for air quality, aviation emissions, noise, and atmospheric variables. ATAC is proud to have been a lead development partner with FAA and the US Department of Transportation (DOT) Volpe Center in furthering the software development necessary to push AEDT forward with a GHG emissions reporting capability.

There exist multiple algorithm-driven models that address many aspects of aircraft operations emissions ranging from an engine specific level to broad national geographies. These models include the Advanced Emissions Model (AEM),[6] Aviation Environmental Portfolio Management Tool (APMT),[7] Environmental Design Space (EDS),[8] and as mentioned prior, AEDT. There also exist many atmospheric tools that are used to examine aircraft emissions in complex large scale areas such as Community Multi-scale Air Quality (CMAQ),[9] Pollution and Emission Calculation (PolEmiCa),[10] American Meteorological Society (AMS)/United States EPA Regulatory Model (AERMOD),[11] Sparse Matrix Operator Kernel Emissions

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[5] US Federal Aviation Administration, *Emissions Characterization*, 2020, https://www.faa.gov/about/office_org/headquarters_offices/apl/research/science_integrated_modeling/emissions_characterization/ accessed September 2, 2020.

[6] European Organisation for the Safety of Air Navigation (EUROCONTROL), *Advanced Emission Model*, https://www.eurocontrol.int/model/advanced-emission-model accessed September 6, 2020.

[7] US Federal Aviation Administration, *Aviation Environmental Portfolio Management Tool (APMT)*, 2020, https://www.faa.gov/about/office_org/headquarters_offices/apl/research/models/apmt/ Accessed September 2, 2020.

[8] US Federal Aviation Administration, *Environmental Design Space (EDS)*, 2020, https://www.faa.gov/about/office_org/headquarters_offices/apl/research/models/eds/ Accessed September 2, 2020.

[9] US Environmental Protection Agency, CMAQ: The Community Multiscale Air Quality Modeling System, 2020, https://www.epa.gov/cmaq Accessed September 5, 2020.

[10] Zaporozhets, Oleksandr and Synylo, Kateryna, *New and Improved Local Air Quality Models for Assessment of Aircraft Engine Emissions and Air Pollution In and Around Airports*, 2016. https://www.icao.int/environmental-protection/Documents/EnvironmentalReports/2016/ENVReport2016_pg82-84.pdf Accessed September 4, 2020.

[11] US Environmental Protection Agency, *American Meteorological Society (AMS)/United States Environmental Protection Agency (EPA) Regulatory Model (AERMOD)*, https://www.epa.gov/scram/air-quality-dispersion-modeling-preferred-and-recommended-models#aermod Accessed September 4, 2020.

(SMOKE),[12] and Gas, Aerosol, Transport, Radiation, General Circulation, Mesoscale, and Ocean Model (GATOR-GCMOM).[13] FAA's AEDT incorporates EPA's AERMOD for emissions dispersion analyses. The other models mentioned are all purposefully built to best accomplish complex tasks but are used as stand-alone tools that present risks to GHG calculations in an aviation environment. In one noted instance, modeling granularity at a coarse level (vs fine) results in an overestimate of select pollutants.[14] Study authors recommended "Future global studies quantifying aircraft contributions should consider model resolution and perhaps use finer scales near major aviation source regions."[15]

Recognizing the need for a continuing evolution on aircraft emissions modeling, the EPA Office of Transportation and Air Quality (OTAQ) in concert with the University of Michigan funded a research position in the summer of 2020 focused on "…research and development of databases and modeling methods to improve EPA's aircraft performance and emissions models. It includes researching data, measurements and models to improve emission inventories, conducting rigorous analysis of aircraft and engine emissions data and flight activities to support modeling or regulations…"[16] There is a continuing uncertainty over aircraft GHG emissions calculations that can be complicated by a lack of comprehensive information about specific fuel burn for any given aircraft operation. Recognizing there is substantial complexity and/or data specifics that may deter airports from reporting aircraft-specific GHGs, ACI developed and offers a simplified approach to GHG emissions reporting. The ACI Airport Carbon and Emissions Reporting Tool (ACERT)[17] is employed by numerous airports as a method of measuring and reporting the airport's total GHG emissions at and around an airport, including limited aspects of aircraft operations. It is intended for those airports which are voluntarily reporting GHGs, those airports lacking dedicated staff for reporting purposes, and those airports lacking budgets to obtain GHG emissions calculation services.[18]

Combined with a methodology and model used to generate aircraft GHG results, there have emerged established GHG reporting protocols such as the GHG Protocol, the World Resources Institute (WRI), and the Global Reporting Initiative (GRI). Airports typically divide their emissions across all pollutants into categories or "scopes," and the airport industry has evolved to three specific scopes noted in **Table 1**.

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[12] University of North Carolina at Chapel Hill, *SMOKE (Sparse Matrix Operator Kerner [sic] Emissions) Modeling System*, 2020 https://www.cmascenter.org/smoke/ accessed September 6, 2020.

[13] Jacobson, Mark, *History of, Processes in, and Numerical techniques in GATOR-GCMOM*, 2012 https://web.stanford.edu/group/efmh/jacobson/GATOR/GATOR-GCMOMHist.pdf accessed September 6, 2020.

[14] L. P. Vennam, W. Vizuete, K. Talgo, M. Omary, F. S. Binkowski, J. Xing, R. Mathur, S. Arunachalam, *Modeled Full-Flight Aircraft Emissions Impacts on Air Quality and Their Sensitivity to Grid Resolution*, 2017, https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2017JD026598 accessed September 4, 2020.

[15] *Id.*

[16] US Environmental Protection Agency, *Reference Code EPA-OTAQ-2020-0002*, May 2020, https://www.zintellect.com/Opportunity/Details/EPA-OTAQ-2020-0002 accessed September 3, 2020.

[17] Airports Council International, *Airport Carbon and Emissions Reporting Tool (ACERT) v5.1*, 2020 https://aci.aero/About-ACI/Priorities/Environment/ACERT/ Accessed September 3, 2020.

[18] Airports Council International, *ACERT v5.0 DO-IT-YOURSELF AIRPORT GREENHOUSE GAS INVENTORY TOOL*, 2020 https://aci.aero/Media/e49ff7cf-e154-4554-b8d5-d5222b31520f/b3KlNw/About%20ACI/Priorities/Environment/Publications/ACERT_v5.0_NEW_DESIGN.pdf Accessed September 3, 2020.

Table 1 Airport GHG Emissions Inventory Scopes

Scope 1	Emissions from airport-owned or -controlled sources. Examples include airport-owned power plants that burn fossil fuel, conventional vehicles that use gasoline, or conventional GSE that use diesel fuel.
Scope 2	Indirect emissions from the consumption of purchased energy (electricity, heat, etc.)
Scope 3	Indirect emissions that the airport does not control but can influence. Examples include tenant emissions, on-airport aircraft emissions (typically, after an aircraft is parked on the apron), emissions from passenger vehicles arriving or departing the airport, and emissions from waste disposal and processing.

Source: US Federal Aviation Administration, Airport Carbon Emissions Reduction, 2020, https://www.faa.gov/airports/environmental/air_quality/carbon_emissions_reduction/ Accessed September 3, 2020.
Prepared By: ATAC Corporation, September 2020.

GHG Emissions are also categorized by the degree of control an operator may have, based on ownership and lease provisions. These categories are reported in **Table 2**.

Table 2 Airport GHG Emissions Inventory Categories

Category 1	GHG emissions from sources that are controlled by the reporting entity. In the case of an airport operator these include Scope 1 emissions but can also include some Scope 2 and Scope 3 sources over which the entity can exert some control. Examples of the latter can include on-airport motor vehicles and tenant electrical use.
Category 2	This category comprises Scope 3 emissions associated with sources owned and controlled by airlines and airport tenants. Examples include aircraft, auxiliary power units (APUs), most Ground Service Equipment (GSE), electrical consumption, and other stationary sources controlled by tenants.
Category 3	This category generally comprises Scope 3 emissions associated with public sources associated with the airport. Examples include automobiles, taxis, limousines, buses, and shuttle vans traveling to and from the airport.

Source: US Federal Aviation Administration, Office of Environment and Energy, *Aviation Emissions and Air Quality Handbook Version 3, Update 1, Section 6.3.3. Methodology*, January 2015.
Prepared By: ATAC Corporation, September 2020.

Airports reporting aircraft GHG emissions values under Scope 3 Category 2 typically rely upon a combination one or more of four distinct aircraft operation evolutions that historically resulted from the capabilities of FAA's standalone emissions calculation tool, the Emissions and Dispersion Modeling System (EDMS). The four operational modes EDMS offered were idle, takeoff, climbout, and approach. EDMS was retired and became integral to AEDT upon AEDT's initial release in 2015,[19] and the integration offered a comprehensive change to input and assumption variables in GHG emission calculations and reporting. AEDT features the option to employ user-defined flight profiles, Aircraft Noise and Performance (ANP) database profiles, Base of Aircraft Data (BADA) profiles, altitude and speed controls, or sensor paths. Quantifying aircraft emissions has significant variability in baseline datasets, discretionary modeling methods, default assumptions, and geographical boundaries. For example, airports have differing boundary definitions as to what "the airport" is or is not responsible for reporting. Many commercial service airports only report on-gate emissions for commercial aircraft. Others choose to report emissions from gate pushback to 3,000 feet above ground level (AGL), yielding another variable – altitude. The 3,000-foot AGL reference is prevalent throughout FAA noise, flight,

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[19] US Federal Aviation Administration, *Aviation Environmental Design Tool Outreach*, 2020 https://aedt.faa.gov/news.aspx accessed on September 4, 2020.

weather, environmental, and air traffic procedure regulations. The air quality reference is rooted in, among many other documents in the same era, a 1972 EPA document known colloquially as the "Holzworth" report after the primary author and pioneer of mixing height methodology.[20] The EPA eventually standardized the mixing height recommendation to note that, "If NO_x emissions are unimportant, mixing height will have little effect on the results and the default value of 3000 feet can be used for more generalized results."[21] Were NO_x to be an important primary pollutant of interest, ATAC would conduct the necessary research to determine mixing heights noted by localized state or regional resources known as a State Implementation plan (SIP) or Transportation Improvement Plan (TIP).[22] If no mixing height is noted in the TIP or SIP, then 3,000 feet AGL would still be recommended for analysis and reporting purposes.

The FAA further expounded on the 3,000-foot altitude in a 2000 FAA memo[23] and has historically been used as the upper limit for airport specific emissions reporting from both a voluntary and regulatory perspective.[24] The variability of any model, model inputs, assumptions, and overall integrity is dependent on the track record and demonstrated competence of the modeling staff to gather the information, process it, run the model, and provide defensible results. Understanding and applying the specific FAA recommended regulatory and reporting requirements has been and continues to be ATAC's analytical focus and the primary application of our environmental analysis and software development teams.

While current reporting requirements do not discount a simplified formulaic spreadsheet approach to reporting emissions, the science and methodologies employed by ATAC using FAA's AEDT tool are a significant leap beyond a generalized approach. ATAC has mastered the use and application of quick, accurate, and automated methodologies that consider all available known parameters of aircraft emissions calculations to achieve a fine scale, localized four-dimensional approach whose results can be easily integrated into any number of local or regional air quality analysis tools. This approach includes airline, airframe, trip distance (stage length), airframe specific engine package, analysis-quality aircraft track data, weather data, and many other parameters. Our high-fidelity modeling approach is accomplished efficiently, quickly, and on a cost-sensitive basis to calculate aircraft emissions for airports. This accuracy is in the best interest of governments owning and operating airports and their surrounding communities, as well as aircraft operators who may ultimately bear the ultimate financial and/or societal penalties that will be passed along to a price-sensitive flying public. ATAC's data management, validation, and modeling methodology emphasizes realism, integrity, and defensibility.

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[20] US Environmental Protection Agency, Holzworth, George C., *Mixing Heights, Wind Speeds, and Potential for Urban Air Pollution Throughout the Contiguous United States*, January 1972.

[21] US Environmental protection Agency, *Procedures for Emission Inventory Preparation, Volume IV, Chapter 5, Section 5.2.2*, December, 1992 https://nepis.epa.gov/Exe/ZyPDF.cgi/P1009ZEK.PDF?Dockey=P1009ZEK.PDF Accessed September 9, 2020.

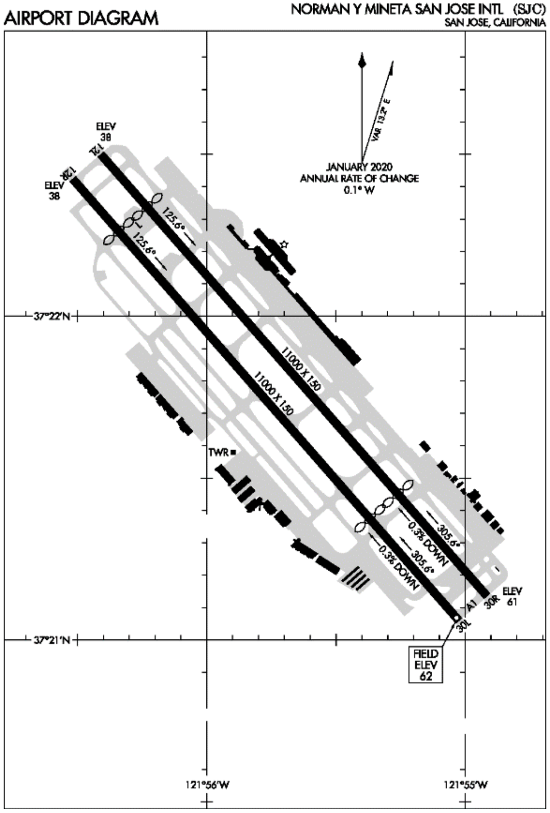
[22] US Code of Federal Regulations, Title 40 Subsection 93.153(c)(xxii).

[23] Wayson, Roger L. and Fleming, Gregg G. *Consideration of Air Quality Impacts By Airplane Operations at or Above 3000 feet AGL*, September 2000, https://www.faa.gov/regulations_policies/policy_guidance/envir_policy/media/catex.pdf accessed September 4, 2020.

[24] US Federal Aviation Administration, Office of Environment and Energy, *Aviation Emissions and Air Quality Handbook Version 3, Update 1, Section 6.3.2. FAA NEPA Guidance*, January 2015.

Solution

Figure 1



ATAC presents the results from an examination of a single day for Norman Y. Mineta San Jose International Airport (**Figure 1**). These results are the product of applying ATAC's proprietary modeling and automation to obtain GHG results. ATAC has conducted extensive research and investigation in FAA policy, existing large-scale modeling, localized scale modeling, aircraft variability, and surveillance data viability to establish the latest modeling and data sourcing capabilities for communities and entities seeking accurate aircraft GHG reporting capabilities. On the data side, FAA has two surveillance track data delivery programs[25,26] that provide analysis-quality aircraft track data for application to emissions calculations. ATAC was awarded the development and implementation of the FAA PDARS program from its inception and uses our Intellectual Property (IP) employed in PDARS to produce analysis-quality aircraft 4D track data from departure to arrival with over one hundred additional data points culled from aircraft track metadata that is not only relied upon by FAA and NASA researchers, but underpins the daily reporting for over 1,500 daily nationwide, regionalized, aircraft-specific, and airport-specific FAA reports that include go-arounds, general sector counts, anomaly metrics, and other FAA safety-defined data. For this white paper, ATAC used our archived System Wide Information Management System (SWIM)-derived trajectory data. As an early user of the FAA's SWIM feed, ATAC has archived over three years of SWIM data that can be accessed without the need for FAA approvals and/or permissions.

Applying expert knowledge of surveillance track data and AEDT, ATAC has developed a process that begins with the data viability at a selected airport. For the purposes of this white paper, ATAC selected the airport out the front door of our headquarters office in Santa Clara, California – San Jose International Airport (SJC). ATAC selected a February 2020 date from which to pull a 24-hour time period of aircraft operations at SJC. This data pull included civilian and commercial aircraft of all types, including those not assigned an Instrument Flight Rules (IFR) transponder code. These aircraft are known as "1200s" after the Visual Flight Rules (VFR) transponder code of 1200 these aircraft use to fly VFR in the congested Bay Area airspace. This resulted in 540 total aircraft that arrived or departed the airfield.

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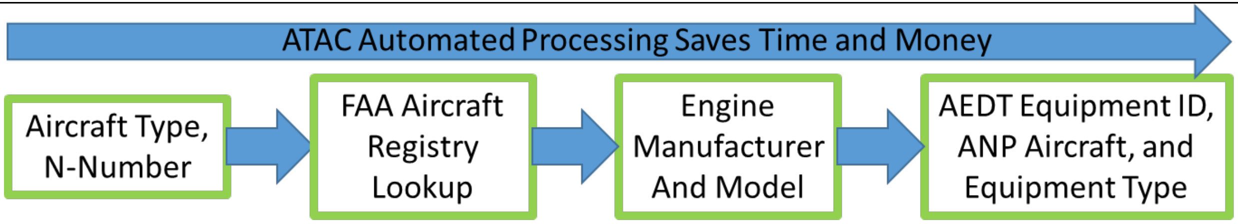
[25] US Federal Aviation Administration, System Wide Information Management System (SWIM), 2020, https://www.faa.gov/air_traffic/technology/swim/ Accessed September 5, 2020.

[26] US Federal Aviation Administration, Performance Data Analysis and Reporting System (PDARS), 2020 https://www.faa.gov/about/office_org/headquarters_offices/ato/service_units/systemops/perf_analysis/perf_tools/ Accessed September 3, 2020.

Throughout history of the environmental modelling software, ATAC served as a lead developer for the FAA's Integrated Noise Model (INM) and currently serves as a lead developer for FAA's AEDT. ATAC is currently engaged with the FAA to support implementation of AEDT version 3d. ATAC incorporates those elements of analysis and data sourcing that indicate an air emissions result relying upon the best underlying data. ATAC does not accomplish this process in a vacuum, instead relying upon the very best science emerging from FAA and Volpe outreach to inform key FAA decision makers.

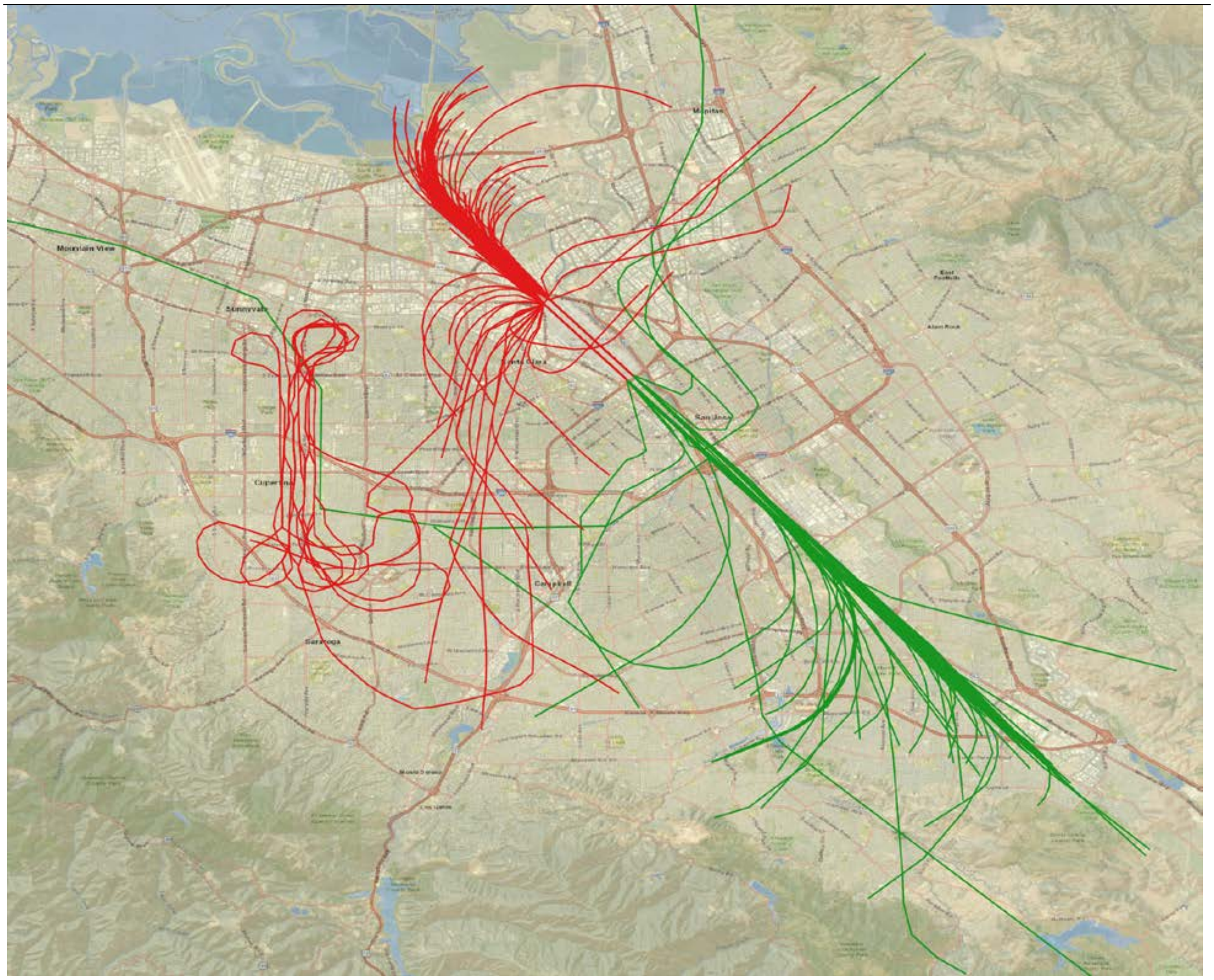
Among the commercial jet fleet in the dataset, ATAC has developed a rapid airframe-engine package matching methodology (**Figure 2**) that uses FAA SWIM data, FAA airframe databases, and AEDT ANP aircraft type and equipment identification to ensure the most accurate and realistic model input for a given FAA tail number. This engine-airframe match is critical to ensuring the taxi time emissions, climb and descent emissions, and runway occupancy times are accurately reflected in the model and may be distinctly different from the default setting AEDT offers for any given aircraft type.

Figure 2 **ATAC Automated Airframe-Engine Mapping**



For the purposes of this analysis, ATAC chose two segments of aircraft operations to analyze: (1) the runway end of the initial takeoff roll to 3,000 feet AGL and (2) 3,000 feet AGL to the end of the landing roll on the runway. Certain aircraft did not exceed 3,000 feet AGL, and for those instances we elected to keep these aircraft in the dataset to represent the whole of the data and to indicate the presence of these anomalous flight tracks without making exceptions to the altitude cutoff. ATAC can certainly exclude, segregate, or filter for any unique or common data points such as altitude, geography, address reference, air carrier, aircraft type, etc. Of particular note for this flight track dataset (**Figure 3**), an aerial survey company conducted extensive overflight runs on a north/south track above the Lawrence Expressway west of SJC. Rather than exclude this flight, ATAC opted to keep this anomaly to illustrate the realistic data that uses the same airport for origin and destination and falls under the maximum altitude for the analysis but was not a flight within the air traffic pattern. Airports can choose to include or exclude these operations on a case-by-case analysis. The distinction is that ATAC can provide your airport the option in the first place. Aircraft city pairs were deduced and used to input assumed aircraft arrival and departure weights. Standard AEDT weather was used, however, ATAC does have the capability and practice in applying AEDT's high definition weather data functionality, if desired. Airports often will not even use surveillance track data, but ATAC uses actual aircraft track profiles to maximize fidelity.

Figure 3 Sample SJC Aircraft Arrival (Green) and Departure (Red) Tracks lower than 3,062’ AGL



Multiple runways were used (SJC has 2 runway surfaces offering north and south departures/arrivals), and the airport remained in a north flow (departures to the north over the Bay) for the selected 24-hour period. The fleet mix dataset included commercial airline, air taxi (charter), and General Aviation (GA) private use aircraft. ATAC “cut” all arrival and departure tracks at 3,062 feet AGL to account for the airport elevation of 62 feet above mean sea level (MSL) plus 3,000 feet.

Given these input and assumptions, the results presented in Appendix A were obtained for one 24-hour period at SJC under real-time conditions with no modification to the raw surveillance data tracks. ATAC has the capability to provide multiple categorical segregations to assist in best matching the client’s preferred data summaries and/or breakdowns. The data was normalized in some cases to illustrate a per-operation (arrival or departure) impact. In other cases, the raw data was broken out to match aircraft types, FAA-defined operator categories, or actual aircraft operators based on 3 letter FAA identifiers.[27] For the case of data simplicity and easy comparison, the data is presented in kilograms (kg) and can be presented in any number of conversions depending on local, state, and federal reporting requirements. The FAA will typically require reporting in metric tons/year, while many localities report GHG in pounds, tons, or metric tons.

Conclusion

The regulatory environment that measures and reports aircraft GHG emissions is going to change with the recent EPA move to normalize technologies against ICAO standards: “The major effect of the proposed standards is to align with ICAO standards in order to provide a level playing field for U.S. manufacturers and to prevent future airplanes from backsliding or incorporating technologies that would have an adverse effect on GHG emissions.”[28] With this change and increasing interest in aircraft GHG reporting, ATAC anticipates a move toward more accurate accounting and reporting for aircraft GHG emissions due to growing calls for integrity and defensibility in all aspects of airport and airline operations. ATAC strongly believes this will combine traditional historic reporting with forward-looking estimates to aid in planning and decision-making at the executive levels of business and government. The recent pandemic experience has fractured aviation industry business models and challenged airport operators in a way that cuts to the heart of the air travel business case. Many airports and airlines are looking to encourage the traveling public back to flying. For these entities, being able to competently and correctly report aviation’s perceived or real impacts, be it emissions, noise, or time savings among many other impacts positive and negative, will be scrutinized by a public that has realized they no longer have an absolute need to fly on a commercial aircraft.

Aircraft emissions at airports are coming under increasing scrutiny as the public and elected officials become more educated and informed through environmental document reviews, noise studies, and other community engagement efforts by airlines, airports, and the FAA. The FAA has unified emissions calculations with aircraft noise, and in doing so has increased public expectation that the use of AEDT’s capabilities be maximized for airports and air traffic. Having the capability to report results displaying a wide variety of formats that offer both raw numbers and normalized results enables analytical insight beyond mere reporting. While aircraft GHG emissions reporting is a historic accounting exercise for most practical applications, ATAC is well-versed in creating normalized, cross-referenced, and integrated current data and future projections for aircraft GHG emissions that enable support for master planning, community development decisions, overall future GHG emissions targeting, airline rates and charges, and community engagement at all levels.

Taking an approach that starts with the best, most reliable, analysis-quality aircraft track data is a necessary first step. Contact Bill Keller via keller@atac.com or 408.736.2822 to accelerate the integrity and defensibility of your aircraft GHG emissions inventories.

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[27] US Federal Aviation Administration, *Order JO 7340.2K, Contractions* https://www.faa.gov/documentLibrary/media/Order/FAA_Order_JO_7340.2K_dtd_9_10_20.pdf Accessed September 11, 2020.

[28] US Environmental Protection Agency, *Draft Airplane Greenhouse Gas Standards Technical Support Document (TSD), Chapter 5.1*, 2020, https://www.epa.gov/regulations-emissions-vehicles-and-engines/notice-proposed-rulemaking-control-air-pollution Accessed on September 1, 2020.

Appendix A – Data Analysis and Selected Aircraft Emissions Results

In the following results, ATAC has produced a number of sample tables and graphs for management level presentation and consideration. The tables and figures are partial samples of the data that could be produced on a raw reporting basis or normalized against other known factors such as kilograms per seat for a given carrier and aircraft type. Other factors are available, and we are ready to discuss the depth and breadth of these factors as they are most appropriate to your specific needs and reporting or presentation requirements.

Table A-1 represents a raw arrival and departure split for the 24-hour period of 12:00am-11:59:59pm for February 5, 2020. These are typical numbers represented in most reports and reflect minimal output from a surveillance track analysis. While this may be the baseline for many reports, the data can be parsed to tell more of the story for community engagement and public relations purposes.

Table A-1 Sum (kg) of Fuel Burn and CO_2 Emissions for February 5, 2020 at SJC

Type of Operation	Sum of Fuel Burn (kg)	Sum of CO_2 (kg)	Flight Count
Arrivals	30,409	95,939	269
Departures	47,697	150,483	271
Total	**78,105**	**246,422**	**540**

Table A-2 is an example of the segregation of results for operational purposes across multiple variables. The insight **Table A-2** provides is to examine underlying land use decisions outside of the noise environment. We included time of day (night is 10:00pm-6:59:59am, following the FAA standard for noise) to illustrate diurnal impact as well. This can help establish the true nature of GHG emissions impacts or any other pollutant impact. To our knowledge, airports are not conducting this finite analysis due to a lack of perceived capability. ATAC can deliver a solution to this need.

Table A-2 Sum (kg) of Fuel Burn & CO_2 by Runway/Time of Day/Op for February 5, 2020 at SJC

	Sum of Fuel Burn (kg)						Sum of CO_2 (kg)					
	Arrivals			Departures			Arrivals			Departures		
Runway	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total
30L	24,106	1,991	**26,098**	3,375	300	**3,674**	76,056	6,283	**82,339**	10,647	946	**11,593**
30R	4,033	278	**4,311**	39,323	4,699	**44,022**	12,725	876	**13,601**	124,065	14,824	**138,890**
Totals	**28,140**	**2,269**	**30,409**	**42,698**	**4,999**	**47,697**	**88,781**	**7,159**	**95,939**	**134,712**	**15,770**	**150,483**

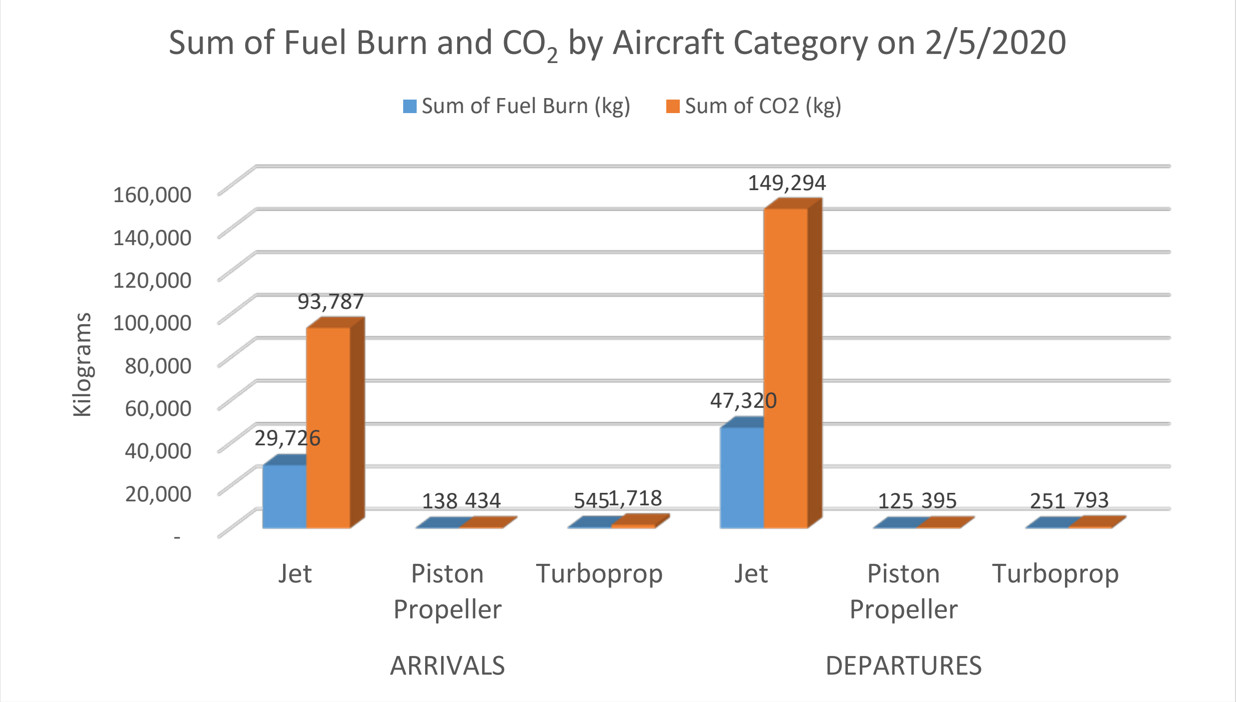
Source: ATAC Corporation, September 2020.
Prepared By: ATAC Corporation, September 2020.

Table A-3 is another multi-variate breakdown of categorized information obtained from the surveillance dataset and calculated through AEDT. While **Table A-3** doesn't state directly, at SJC on February 5, 2020, turboprops were responsible for 2.02 percent of the total CO_2, piston (propeller) aircraft were responsible for 0.34 percent of the total CO_2 and jets were responsible for the remaining 97.46 percent of CO_2. **Figure A-1** is a visual representation of the tabular data that can be used for trend visualization, scalar comparisons, and community outreach. How does this information fit into a rates and charges scheme? Is there consideration for the low CO_2 contribution in tie-downs and hangar rents for piston aircraft? When a community complains about small piston aircraft, do they understand the CO_2 impact comparatively? Many other insights avail themselves to the other end of the scale as to consideration of business model equity and fairness from a CO_2 contribution standpoint or from a societal impact standpoint. In order to gain these insights, ATAC can quickly discern and uncover these relationships.

Table A-3 Sum (kg) of Fuel Burn & CO_2 by Aircraft Category/Op for February 5, 2020 at SJC

	Sum of Fuel Burn (kg)			Sum of CO_2 (kg)			Flight Count		
Aircraft Category	Arrivals	Departures	Total	Arrival	Departures	Total	Arrivals	Departures	Total
Jet	29,726	47,320	**77,046**	93,787	149,294	**243,081**	250	246	**496**
Piston	138	125	**263**	434	395	**830**	9	13	**22**
Turboprop	545	251	**796**	1,718	793	**2,511**	10	12	**22**
Totals	**30,409**	**47,697**	**78,105**	**95,939**	**150,483**	**246,422**	**269**	**271**	**540**

Figure A-1 Sum (kg) of Fuel Burn & CO_2 by Aircraft Category for February 5, 2020 at SJC



If you find yourself asking what aircraft category contributes the most CO_2 for a given period, ATAC has prepared **Figure A-2** with the top ten aircraft types contributing CO_2 on a per-flight basis and **Figure A-3** with the top ten airlines contributing CO_2 on a per-flight basis. The only 787-800 operator on this day was All Nippon Airways (ANA) with an arrival and a departure to/from Tokyo Haneda. Given the overseas origin/destination and a maximum 254-seat configuration, the aircraft has over twice the CO_2 contribution of a Southwest 737-700 in a 137-seat configuration. Does your airport want more overseas flights versus short-haul and medium stage length frequency? What are the trade-offs on the emissions side? ATAC can help you make these air service development decisions while supplying you with scalable time period information by airline, aircraft type, or a dozen other variables to choose from depending on the aircraft and/or airline. Aircraft GHG Emissions reporting can be just as important as noise factors when considering new service or changes in stage lengths and aircraft.

Figure A-2 Sum (kg) of CO_2 by Aircraft Category on a Per-Flight Basis for February 5, 2020 at SJC

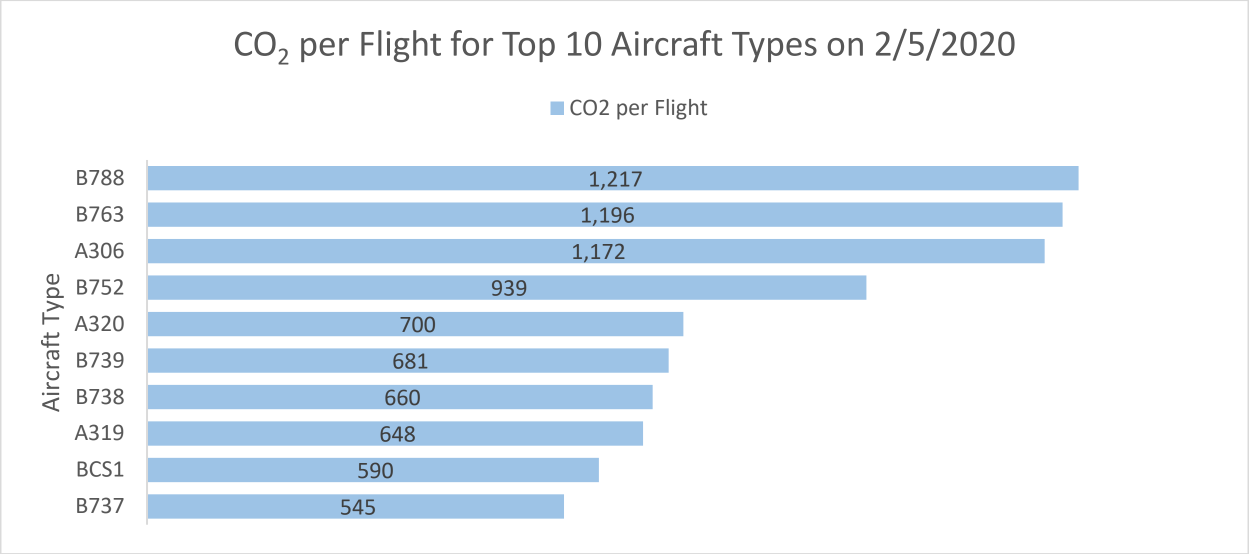


Figure A-3 Sum (kg) of CO_2 by Top 10 Airlines for February 5, 2020 at SJC