Supplemental Aviation Noise Metrics: Assisting Communities in Understanding Noise Impacts Relative to Dispersion of Aircraft

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Executive Summary

The FAA was recently tasked with evaluating alternative noise metrics to DNL. When combined with the recent requirement that the FAA analyze dispersion for all new and/or revised departure procedures below 6,000 feet, the use of supplemental metrics to better inform decision makers and the public is more necessary than ever. The FAA encourages the use of supplemental metrics where appropriate,[1] and one of the most significant challenges facing urban airports and the communities they serve is the analysis of the concentration of aircraft which results from the use of Area Navigation (RNAV) and other Performance Based Navigation (PBN) procedures.

ATAC has leveraged our extensive history conducting environmental evaluations (of more than 860 PBN procedures at over 100 U.S. airports) to examine the best uses of supplemental metrics. ATAC's industry-leading approach applies analysis-quality FAA-derived aircraft movement data, an accurate and complete engine to airframe mapping methodology, and the latest noise metrics within AEDT. In this paper we demonstrate supplemental metrics that further define the impacts of shifting noise distribution or concentration of aircraft over specific areas due to the use of RNAV and other PBN initiatives. These supplemental metrics provide information beyond what is available from the standard DNL metric and should be used to empower and better inform decision makers and the general public. Airports and the communities they serve need to fully understand the distribution of aircraft and how the noise associated with aircraft operations is the result of varied factors, including the altitude of aircraft, the phase of flight, and the number of events over a particular point. For skilled analysis of existing conditions, recent or proposed changes, or your own proposed change to airspace procedures utilizing supplemental metrics, contact ATAC, the aviation analysis experts, at 1 (408) 736-2822.

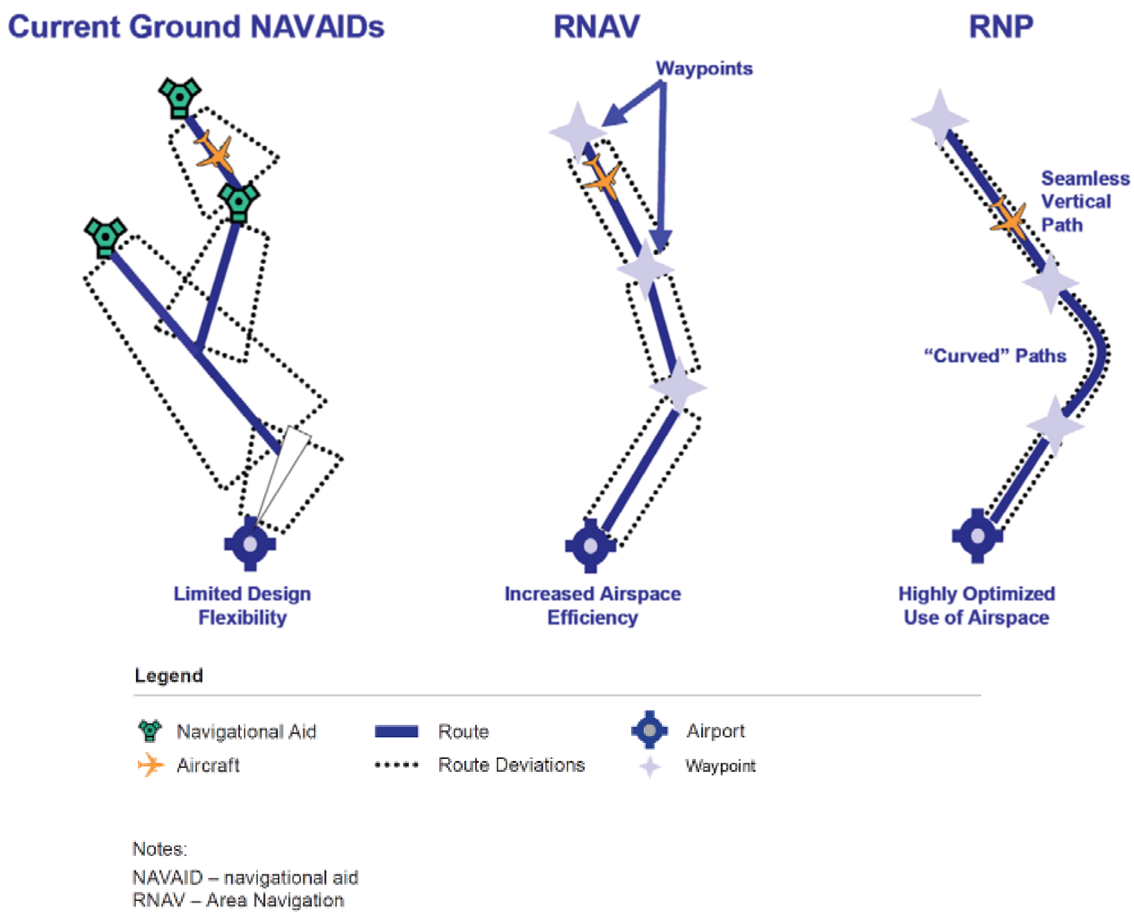
Problem Statement

Area Navigation (RNAV) procedures and other Performance Based Navigation (PBN) are, by their very design, intended to offer more precision, reliability, and predictability than conventional (land-based navigational aid) procedures. RNAV-1 requires aircraft to be not more than 1 Nautical Mile (NM) away from their prescribed routing for 95% of the total flight time.[2] Conversely, conventional procedures generally operate within wider corridors of the defined route.[3] This reduced route deviation associated with PBN procedures is depicted in **Exhibit 1** below. The ability to concentrate aircraft within less space allows the FAA to create a more efficient National Airspace System (NAS). The primary metric utilized by the Federal Aviation Administration (FAA) for aircraft noise exposure continues to be the day-night

[1] U.S. Federal Aviation Administration, Report to Congress, *FAA Reauthorization Act of 2018* (Pub. L. 115-254), Sec 188 and Sec 173, April 14, 2020.
[2] U.S. Federal Aviation Administration, U.S Terminal and En Route Area Navigation (RNAV) Operations, AC 09-100A, change 2.
[3] U.S. Federal Aviation Administration, *Performance Based Navigation*, Workshop for Air Traffic Controllers, June 2017.

average sound level (DNL). DNL may be supplemented with other metrics to further characterize specific noise impacts.[4] However, the day-night average sound level (DNL) used to assess potential noise impacts is, as stated, a noise metric that provides an average noise level for a 24-hour period, and therefore does not directly illustrate the increase in the frequency of events at a specific location that can result from PBN implementation.

Exhibit 1 Navigational Comparison – Conventional/RNAV/RNP



Source: U.S. Department of Transportation, Federal Aviation Administration, "Performance-Based Navigation (PBN) Brochure," October 2009.

In January 2018, the U.S. Senate and House Congressional Representatives reauthorized federal aviation programs. The *FAA Reauthorization Act of 2018* requires the FAA, when proposing a new RNAV departure procedure or amending an existing procedure that would direct aircraft between the surface and 6,000 feet Above Ground Level (AGL), to consider the feasibility of dispersed headings.[5] This is only required if the affected airport operator, in consultation with the communities affected, submits a request to the FAA Administrator. Assessing current and future rates of dispersion requires accurate data and a full understanding of proposed procedure designs. The difficulty in assessing the existing and potential concentration of aircraft over noise sensitive areas is further exacerbated by the number of methods that can be used to disperse aircraft along the route. Divergent headings, manual vector legs,

[4] U.S. Federal Aviation Administration, Order 1050.1F, B-1.6, *Supplemental Noise Analysis*.
[5] U.S. Senate and House of Representatives, *FAA Reauthorization Act of 2018*, January 3, 2018.

and open SIDs all have the potential to disperse aircraft over noise sensitive areas, but the best alternative, allowing for the most effective dispersal while not conflicting with the safe and efficient operation of the NAS, may not be readily identifiable utilizing only the DNL metric. In addition, the concentration of aircraft may reduce the overall noise for communities if the routes are placed over noise-compatible (non-residential) areas, thereby making the concentration of aircraft a desirable outcome.[6]

While no single noise metric can cover all scenarios involving aircraft noise,[7] the current standard DNL metric is influenced by the magnitude, duration, and frequency of aircraft noise events. However, additional information can be gained with the use of supplemental metrics in specific situations.[8] Given the many situations that may arise and the number of supplemental metrics available, it may be necessary to augment the DNL results with other metrics to inform decision makers about the potential impacts to the surrounding communities that are not readily apparent without additional analysis.

In addition, the effect of noise exposure on people can differ due to numerous factors including location (urban versus rural), climb/descent rates, aircraft power settings, time of day, frequency, duration, and altitude. Noise annoyance is more a qualitative understanding based upon many factors[9] and is difficult to quantify as individual perceptions vary. Recently the U.S. Conference of Mayors and National League of Cities have adopted resolutions regarding lowering the 65 DNL threshold for significant impacts and including the use of alternative metrics to DNL. The FAA recently released a Neighborhood Environmental Survey that provides additional evidence that individuals are becoming highly annoyed by aviation noise at much lower volumes than previously recorded.[10] The ability to quantify noise impacts utilizing supplemental metrics beyond the DNL results is critical to proposing or implementing changes to air navigation procedures while addressing community annoyance.

As PBN procedures are implemented to serve airports across the United States, supplemental metrics will better inform the decision makers and surrounding communities regarding the dispersion or concentration of aircraft. The next section provides a background for supplemental metrics and their use and is followed by a solutions-based approach to utilizing supplemental metrics.

Background

Airports and their associated community noise groups (Roundtables) have requested supplemental noise metrics to augment the DNL values found within National Environmental Policy Act (NEPA) documents. The Federal Interagency Committee On Noise (FICON) has endorsed the use of supplemental noise metrics since the early 1990s.[11] Many airport roundtables have also requested the use of supplemental metrics and endorsed this position. In response to the FAA's analysis of supplemental noise metrics, 29 members of the U.S. House of Representatives recently requested

[6] CANSO, *Use of Performance Based Navigation (PBN) for Noise Management*, 2020.
[7] U.S. Federal Aviation Administration, Report to Congress, *FAA Reauthorization Act of 2018* (Pub. L. 115-254), Sec 188 and Sec 173, April 14, 2020.
[8] U.S. Federal Aviation Administration, Report to Congress, *FAA Reauthorization Act of 2018* (Pub. L. 115-254), Sec 188 and Sec 173, April 14, 2020.
[9] Federal Aviation Administration. https://www.faa.gov/regulations_policies/policy_guidance/noise/community/, accessed September 3, 2020.
[10] Federal Aviation Administration.
https://www.faa.gov/regulations_policies/policy_guidance/noise/survey/#results
[11] Ian Waitz, Jessica Townsend, Joel Cutcher-Gershenfeld, Edward Greitzer, and Jack Kerrebrock, Report to the United States Congress, *Aviation and the Environment*, December 2004.

additional study.[12] The demand for supplemental metrics has increased as the NAS has been updated using Next Generation technology including RNAV and other PBN procedures to create more efficient, predictable, and repeatable air routes.

The FAA regulates the maximum noise level that an individual civil aircraft can emit through requiring aircraft to meet certain noise certification standards.[13] As such, aircraft noise footprints have become smaller over the years as engines and airframes have been designed to reduce noise. Conversely, the number of flights in the U.S. has increased significantly over the past decade, and RNAV routes may concentrate those relatively quieter flights over smaller areas of land. The FAA forecast for domestic air carrier traffic shows that it is expected to grow over the next 20 years at 1.8 percent per year.[14]

Noise metrics fall into various categories including exposure, maximum level, time-above, time-audible, and number above. There are also different ways to weight the metrics based upon human hearing characteristics and other factors. For this paper, all results are provided in A-weighted metrics, which is consistent with the weighting used in the FAA's current regulatory metrics. A-weighted metrics have been adjusted to account for the way humans hear, specifically adjusting for the fact that the human ear is less sensitive to lower audio frequencies.

DNL is an A-weighted exposure metric that provides an average value based on the events within a 24-hour period, where the nighttime flights are weighted with a 10dB penalty to account for increased sensitivity to nighttime noise. While many have argued for additional exposure metrics such as Community Noise Equivalent Level (CNEL) and Day Night Evening Noise Level (DNEL), these metrics most often produce similar (albeit slightly higher) noise results to DNL and are therefore not analyzed in this paper. In addition, since these metrics would be applied to both the existing conditions and the proposed alternative(s), the differences (increases and decreases) in the noise results is most often comparable (and often have the same percentage change) to the changes found in the DNL metric. One additional metric that is currently utilized in Europe but not currently included in AEDT is L_{night}[15] which the World Health Organization guidance suggests using to study sleep disturbances for individuals subject to noise above L_{night} 40 dB (note: L_{night} can be manually calculated utilizing the results of an AEDT study). Other AEDT supported supplemental metrics are defined in **Table 1**.

With regard to community annoyance, a question often posed is "are more frequent quieter flights less impactful than louder infrequent flights?"[16] The traditional DNL metric treats both scenarios in a similar fashion by averaging the events over the course of a 24-hour period. In other words, small numbers of loud operations can result in the same DNL as a large number of relatively quiet operations. This can allow an increase in concentration of aircraft flying over RNAV routes without a significant or reportable increase in the DNL noise metric.

A-weighted maximum level (LAMAX) is the maximum sound level of a single event over a point on the ground. Number Above Noise Level (NANL) metrics provide the number of flights over a specific receptor within a study, and the noise threshold provides context for the level of sound associated with

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[12] https://norton.house.gov/media-center/press-releases/norton-bass-and-27-house-members-send-letter-to-federal-aviation?fbclid=IwAR3hFf1ZLyC47MhobdAUSTRahr4Q-krPhyW-lDcHqWu3absdoLII_zRVrJs, accessed September 24, 2020.

[13] www.faa.gov/about/office_org/headquarters_offices/apl/noise_emissions/airport_aircraft_noise_issues/levels/, accessed September 3, 2020.

[14] U.S. Federal Aviation Administration, *FAA Aerospace Forecast Fiscal Years 2019-2039*.

[15] L_{night} is the sound pressure level averaged over the year for the night time period only.

[16] FAA, *Presentation on Noise and Emission Challenges*, UC Davis Aviation Noise and Emissions Symposium, February 25-27, 2018, Long Beach, California.

the event. When LAMAX is combined with a Number Above metric, the output is the number of events (flights) that exceed the defined LAMAX threshold. This operational acoustic metric can provide the public an opportunity to view increases and decreases in the number of events from a given baseline and proposed action scenario that are above a certain threshold, and therefore serves as a good metric for assessing impacts on the human environment due to concentration and/or dispersion of flights.

Time-above and time-audible are additional supplemental metrics that can help the public understand the impacts associated with flights over specific areas by measuring the time aircraft are above a certain noise threshold as measured at a point on the ground, or for how long they are emitting audible noise above the ambient noise level over a single point on the ground.

Supplemental metrics, such as NANL, can identify areas that are subjected to increases and decreases in the frequency of flight operations that may not register a noticeable change with regard to the relative DNL value but still produce a change in noise impacts that is noticeable to the public.

Table 1 Available AEDT Noise Metrics

Metric Type	AEDT Name	Standard Name	Definition/Full Name
A-Weighted Noise Metrics			
Exposure	SEL	L_{AE}	A-Weighted Sound Exposure Level
	DNL	L_{dn}	Day Night Average Sound Level
	CNEL	L_{den}	Community Noise Equivalent Level
	LAEQ	L_{AeqT}	Equivalent Sound Level
	LAEQD	L_{d}	Day-average noise level
	LAEQN	L_{n}	Night-average noise level
Maximum Level	LAMAX	L_{ASmx}	A-Weighted Maximum Sound Level
Time-Above	TALA	TA_{LA}	Time-Above A-Weighted Level
Time-Audible	TAUD	T_{Aau}	Time-Audible
	TAUDSC	T_{AudSC}	Time-Audible with Overlapping Events Method (Statistical Compression)
	TAUDP	T_{AudP}	Time-Audible Percent
	TAUDPSC	T_{AudPSC}	Time-Audible Percent with Overlapping Events Method (Statistical Compression)
C-Weighted Noise Metrics			
Exposure	CEXP	L_{CE}	C-Weighted Sound Exposure Level
	CDNL	L_{Cdn}	C-Weighted Day Night Average Sound Level
Maximum Level	LCMAX	L_{CSmx}	C-Weighted Maximum Sound Level
Time-Above	TALC	TA_{LC}	Time-Above C-Weighted Level
Tone-Corrected Perceived Noise Metrics			
Exposure	EPNL	L_{EPN}	Effective Perceived Noise Level
	NEF	L_{NEL}	Noise Exposure Forecast
	WECPNL	L_{WECPN}	Weighted Equivalent Continuous Perceived Noise Level
Maximum Level	PNLTM	L_{PNTSmx}	Tone-Corrected Maximum Perceived Noise Level
Time-Above	TAPNL	TA_{PNL}	Time-Above Perceived Noise Level
Number Above Noise Level Metric			
Number Above Noise Level	NANL	NANL	Number Above Noise Level

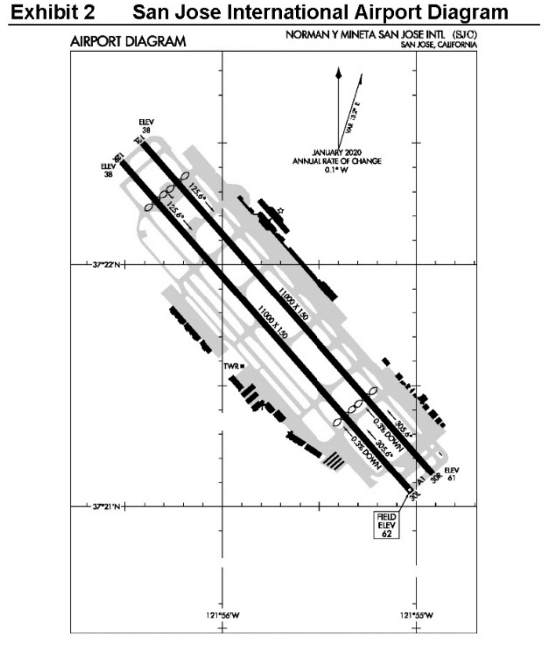
Source: U.S. Federal Aviation Administration, *Aviation Environmental Design Tool User Manual*. March 2020.

Solution

ATAC has extensive experience with FAA policy, existing large-scale modeling, localized-scale modeling, aircraft variability, and surveillance data viability. ATAC has combined this experience to establish the latest modeling and data sourcing capabilities for airports and communities seeking to better understand the noise impacts of PBN implementation via accurate aircraft supplemental noise reporting capabilities. On the data side, the FAA has two widely accepted surveillance track data delivery programs[17,18] that provide analysis-quality aircraft track data for noise and emissions calculations. One is the FAA's System Wide Information Management (SWIM) program, a National Airspace System (NAS)-wide information system that includes surveillance data. ATAC serves as both a provider of data to the FAA's SWIM feed and a consumer of the data products available. The other data source is the FAA's Performance Data Analysis and Reporting System (PDARS) program. From its inception, ATAC has developed PDARS to produce analysis-quality aircraft 3D track data while also employing its own Intellectual Property (IP) to further understand events occurring within the NAS. With over one hundred additional parameters culled from aircraft track metadata, ATAC, NASA, and FAA researchers utilize this data for the daily creation and distribution of over 1,500 FAA aircraft-track-derived nationwide, regional, aircraft-specific, and airport-specific reports that include go-arounds, general sector counts, anomaly metrics, and other FAA safety defined data. Both data sources can be ingested into ATAC's SkyView Data Services platform, a comprehensive set of software tools for gathering aviation performance and supporting data, measuring and baselining operations, and helping to design, implement, and evaluate operational improvements. SkyView contains configurable data collection, air traffic data visualization, analysis, reporting, and management modules that can be tailored to your needs.

ATAC has been involved with the development of aviation noise models for the FAA for several decades, having served as a lead developer for the FAA's Integrated Noise Model (INM) and currently serving as a lead developer for FAA's AEDT. ATAC is currently supporting the FAA to deliver regular updates to AEDT – ATAC's intimate knowledge of the software, combined with our extensive, unparalleled experience with its use, incorporates those elements of analysis and data sourcing that provide high quality aircraft noise results, building upon the best and most valid underlying data. ATAC does not accomplish this in a vacuum, instead relying upon the very best science emerging from the FAA and the Department of Transportation (DOT) Volpe National Transportation System Center (NTSC) outreach to inform key FAA decision makers.

Exhibit 2 San Jose International Airport Diagram



Sources: Federal Aviation Administration, Aeronav, Aeronautical Information Services (Airport Diagram).

Applying this expert knowledge of surveillance data and AEDT, ATAC has developed a process that begins with the data viability from the various sources at a selected airport. For the purposes of this report, ATAC selected the airport

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

[18] U.S. 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]).

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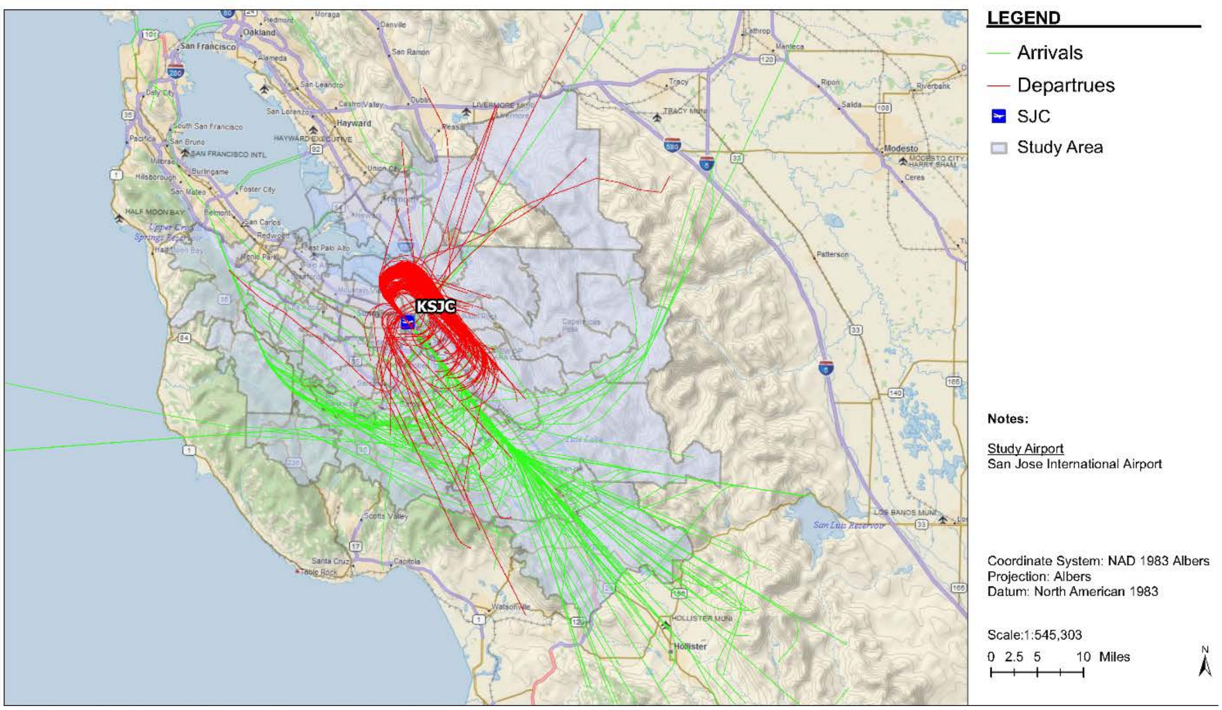
out the front door of our headquarters office in Santa Clara, California: Norman Y. Mineta San Jose International Airport (KSJC). ATAC selected a February 2020 date from which to collect a 24-hour time period of aircraft operations data at SJC. This data pull, derived from FAA SWIM data and augmented by ATAC's SkyView Data Services ADS-B feed, included civilian and commercial aircraft of all types, including those not assigned an Instrument Flight Rules (IFR) transponder code, known as "1200s" after the Visual Flight Rules (VFR) transponder code these aircraft use to fly VFR. This resulted in 269 total arriving aircraft and 271 departing aircraft flights.

For the purposes of this analysis, ATAC analyzed all arrivals and departures into and out of SJC up to an altitude of 10,000 feet Mean Sea Level (MSL). Certain aircraft did not achieve 10,000 feet MSL, and for those instances, the flight tracks were cut at the study area boundary.[19] Aircraft city pairs were determined utilizing the information obtained within the surveillance data, 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. AEDT altitude controls derived from the aircraft trajectory data were used to define the vertical flight profiles to accurately model the real-world flight procedures. SJC has 2 runway surfaces (offering east and west departures/arrivals), and the airport remained in a west flow (departures to the west) for the selected 24-hour period. The fleet mix consisted of commercial airline, general aviation (GA) charter, and GA private use aircraft. The flight operations data was annualized to generate the metrics reported. **Exhibit 3** depicts the flight tracks used for this analysis.

Exhibit 3 San Jose International Airport Flight Tracks

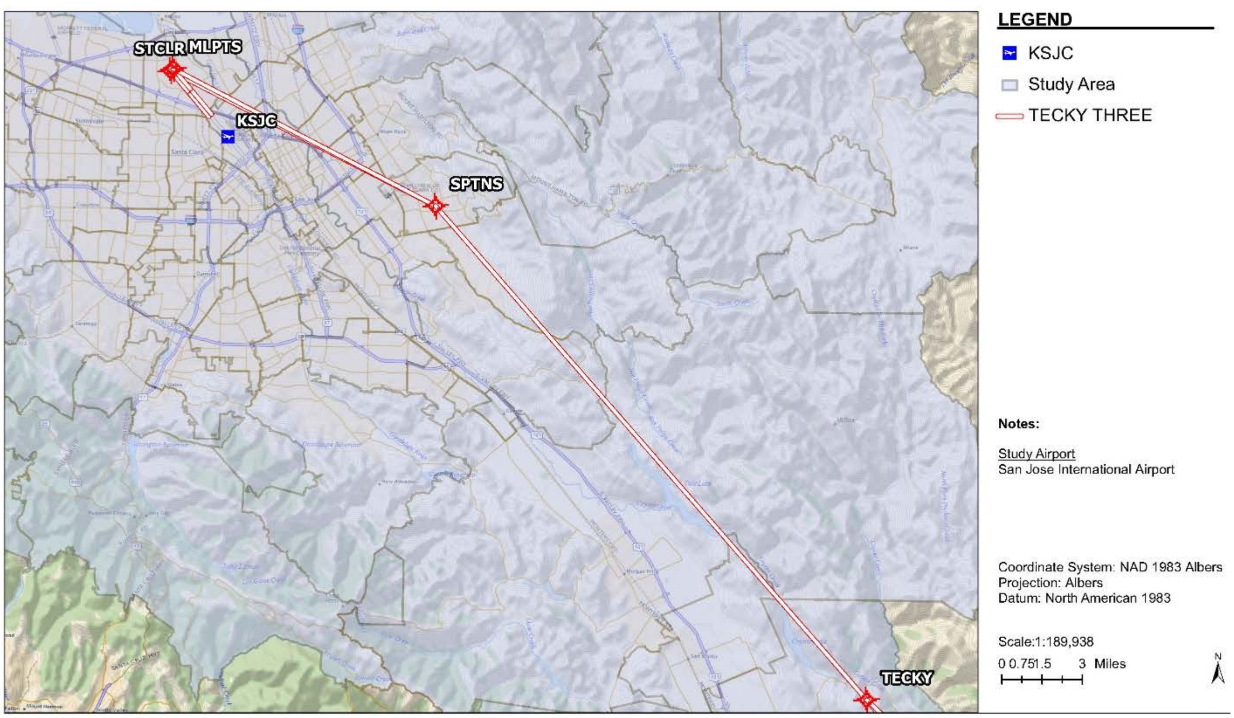


Sources: U.S. Census Bureau, 2019 (TIGER/Line Shapefiles (machine-readable data files), (U.S. states, zip codes, airports); Federal Aviation Administration, 2020 Code of Instrument Flight Procedures (Airspace procedures), Delorme World Basemap, 2020 (Map). ATAC Corporation, 2020, (2020 AEDT Analysis).

[19] The Study Area includes all Census tracts within 15 NM of the airport, an area large enough to encapsulate all results for all metrics within the study area and includes 44,290 unique points.

For this example, the RNAV TECKY THREE departure out of SJC was analyzed. **Exhibit 4** depicts the routing of the procedure as defined by the waypoints. Note that the link and node structure form a direct point-to-point routing that is not synonymous with the actual path aircraft will take while flying the route. Specifically, the routing from MLPTS and STCLR would require aircraft to make an immediate turn of approximately 160 degrees to the south to follow the path to SPTNS. The route legs associated with the TECKY THREE Runway 30L and 30R runway transitions are listed in **Table 2**. The route legs are VA-DF (Vector to Altitude- Direct to Fix), DF-DF (Direct to Fix- Direct to Fix), and DF-TF (Direct to Fix – Track to Fix) legs. The VA-DF legs require aircraft to fly to a certain altitude while flying a certain heading (Vector to Altitude [VA]) (note: this is usually the runway heading when it is the first leg from the runway) before proceeding directly to a fix (Direct to Fix [DF]). The next legs are DF-DF, where aircraft proceed directly from one fix to another. The last legs in the runway transition are DF-TF (Direct to Fix, followed by a Track to Fix [TF]). A TF leg requires an aircraft to track a certain heading to intercept the fix. The VA fix allows for minimal variability due to aircraft type, aircraft weight, and weather impacts on the aircraft's performance causing the aircraft to reach the prescribed altitude at various points along the ground. The DF and TF fixes allow for less variability as the aircraft are either proceeding directly to a fix or flying a track to a fix. Since there are no open portions of the procedure and no manual vectors, aircraft that are directed to fly the procedure will have minimal variation without intervention from Air Traffic Control.

Exhibit 4 TECKY THREE Departure Procedure



Note: The TECKY THREE continues beyond the exhibit in the en route environment beyond the study area to the southeast.

Source: U.S. Census Bureau, 2019 (2019 TIGER/Line Shapefiles (machine-readable data files), (U.S. states, zip codes, airports); Federal Aviation Administration, 2020 Code of Instrument Flight Procedures (Airspace Procedures). Delorme World Basemap, 2020. ATAC Corporation, 2020, (2020 AEDT Analysis).

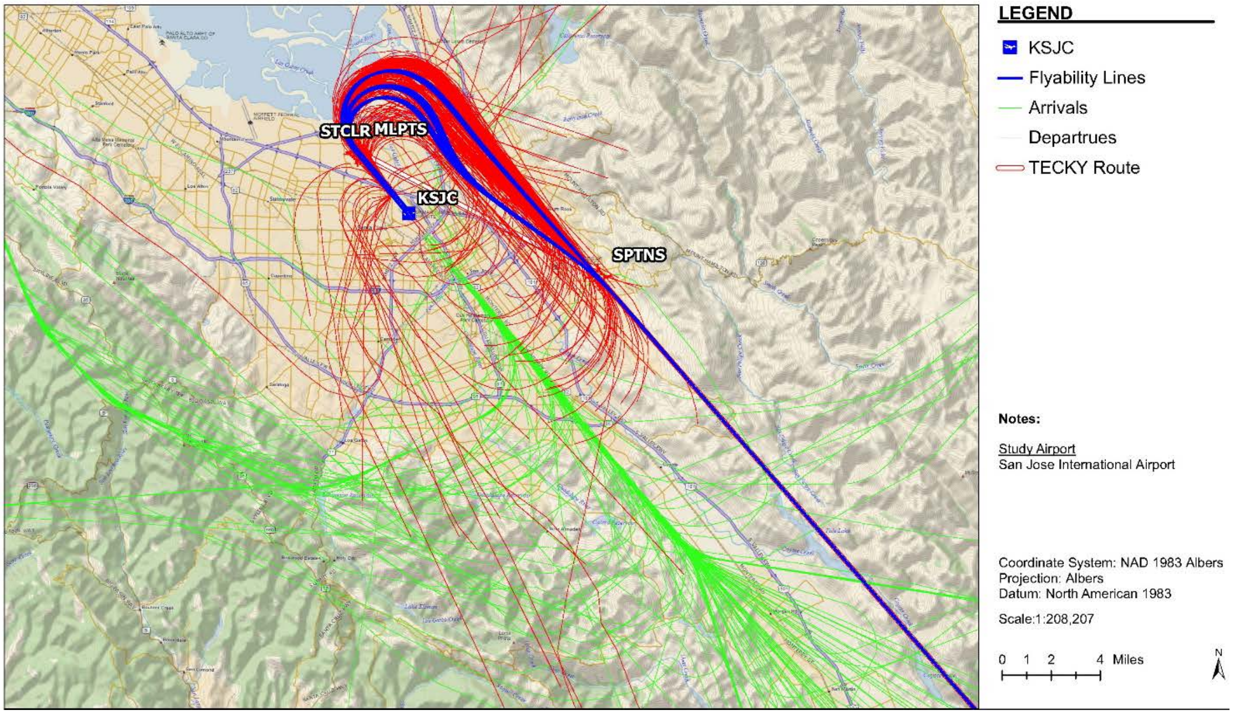
Table 2 TECKY THREE Runway Transitions

Runway	Fix Name	Leg Type	Leg Description
30L	N/A	VA	Fly vector (runway heading) until reaching prescribed altitude
30L	STCLR	DF	Fly directly to the fix
30L	SPTNS	DF	Fly directly to the fix
30L	TECKY	TF	Fly track to the fix
30R	N/A	VA	Fly vector (runway heading) until reaching prescribed altitude
30R	MLPTS	DF	Fly directly to the fix
30R	SPTNS	DF	Fly directly to the fix
30R	TECKY	TF	Fly track to the fix

Source: U.S. Federal Aviation Administration, *Aviation Environmental Design Tool User Manual*. (March 2020), 2020 Code of Instrument Flight Procedures (Airspace Procedures).

To better understand the routing of aircraft, ATAC typically utilizes the flyability feature in the FAA's Terminal Area Route Generation and Traffic Simulation (TARGETS) program to accurately identify the areas where aircraft will be flying. However, in this example, since it is an existing procedure, the flyability routing can be compared with existing flight tracks. **Exhibit 5** depicts the flyability lines superimposed over the flight tracks that were cut at an altitude of 10,000 feet MSL. The flyability lines determine where most aircraft will fly and they vary due to aircraft size and performance. It should be noted that the geometry related to the procedure affects the dispersion of aircraft insomuch as the turning radius can vary among aircraft, leading to greater dispersion along portions of routes with significant turns and less dispersion along straight portions of the route.

Exhibit 5 TECKY THREE Flyability Lines



Source: U.S. Census Bureau, 2019 (TIGER/Line Shapefiles (machine-readable data files), (U.S. states, zip codes, airports); Federal Aviation Administration, 2020 Code of Instrument Flight Procedures (Airspace procedures) (TARGETS Flyability Lines), Delorme World Basemap, 2020 (Map). ATAC Corporation, 2020 (2020 AEDT Analysis).

In addition to the TECKY THREE, the conventional procedures LOUPE FIVE and SJC THREE traverse the same area near the airport. **Table 3** provides the distribution of aircraft among the three procedures. The TECKY THREE accounts for nearly 95 percent of all flights over the area depicted in **Exhibit 5**.

Table 3 Flight Track Distribution by Departure Procedure

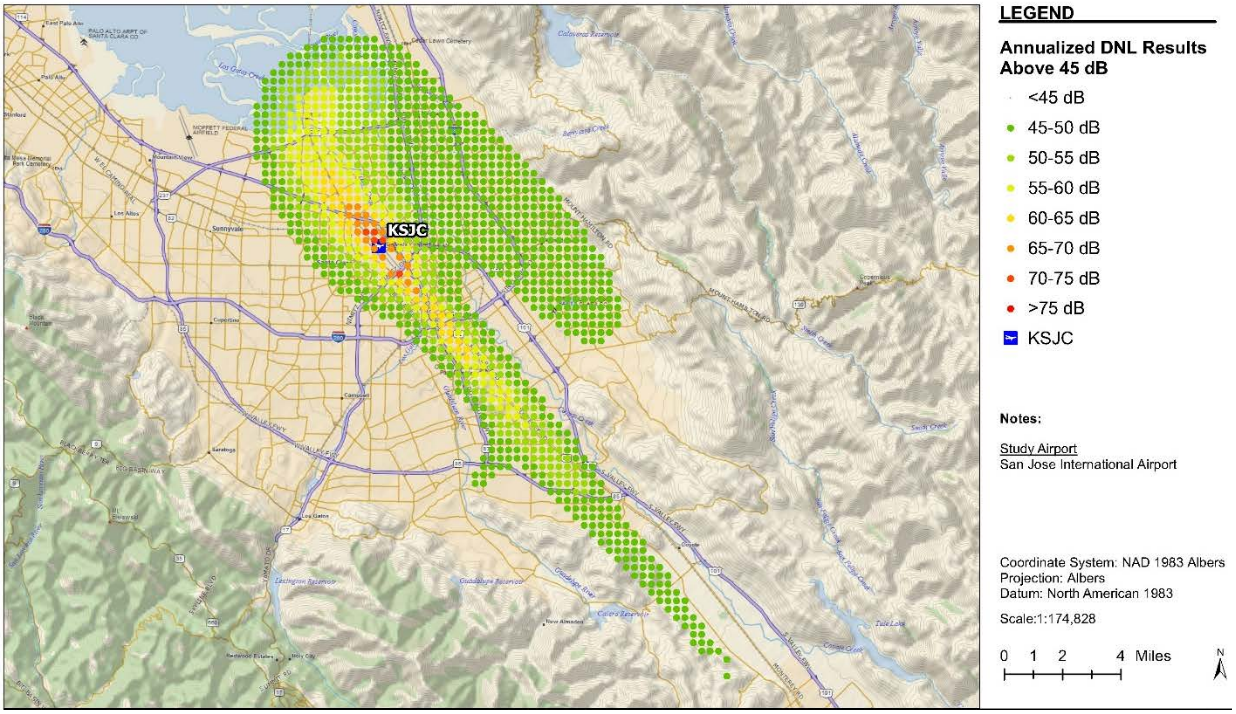
Procedure	Operations Count	Percent of Operations
TECKY THREE	210	94.6%
LOUPE FIVE	3	1.4%
SJC THREE	9	4.1%

Note: Only tracks following the primary departure flow were counted (i.e., left hand turns were not counted).

Source: ATAC Corporation, 2020, (2020 AEDT Analysis) (SkyView Data Services surveillance data).

Utilizing the results from this analysis, ATAC developed a series of exhibits depicting both the DNL values for receptor points within the study area and the Number of events Above Noise Level 60 dBA LAMAX (NANL60). The receptor points consist of an evenly-spaced grid, one quarter NM apart throughout the study area. **Exhibit 6** depicts receptor locations with DNL noise values above 45 DNL, while **Exhibit 7** depicts receptor locations where the NANL60 is greater than one.

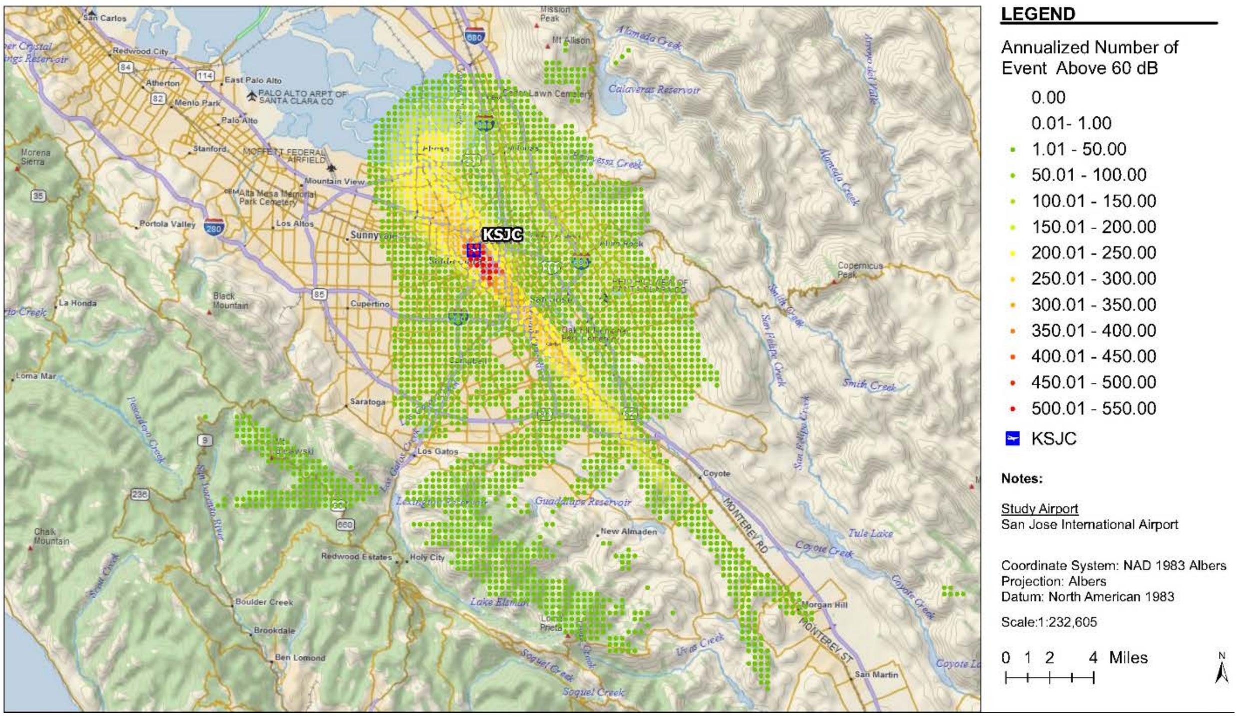
Exhibit 6 DNL Noise Receptors Above 45 DNL



Source: U.S. Census Bureau, 2019 (TIGER/Line Shapefiles (machine-readable data files), (U.S. states, zip codes, airports); Federal Aviation Administration, 2020 Code of Instrument Flight Procedures (Airspace procedures) Delorme World Basemap, 2020 (Map). ATAC Corporation, 2020 (2020 AEDT Analysis).

As evidenced by the larger number of receptors depicted in **Exhibit 7** when compared to **Exhibit 6**, it is possible to have noise events above 60 dB LAMAX and remain below the 45 DNL threshold. Conversely, it is possible to have zero noise events above 60 dB LAMAX but have a DNL value greater than 45.

Exhibit 7 Average Annualized Number of Events Above 60 dB LAMAX



Source: U.S. Census Bureau, 2019 (TIGER/Line Shapefiles (machine-readable data files), (U.S. states, zip codes, airports); Federal Aviation Administration, 2020 Code of Instrument Flight Procedures (Airspace procedures), Delorme World Basemap, 2020 (Map). ATAC Corporation, 2020 (2020 AEDT Analysis).

Table 4 depicts the number of receptors with noise values within each of the given DNL ranges. The NANL60 LAMAX can vary significantly within the same DNL range. In other words, you may have many relatively quiet events, or you may have infrequent loud events that are categorized within the same DNL range. In **Table 4**, we can see that the maximum NANL60 LAMAX value that occurred over a receptor that remained below 45 DNL was 48.98 events. Conversely, there were receptors that had zero NANL60 LAMAX and registered in the 45-50 DNL range. The greatest variation in NANL60 LAMAX events was found within the 60-65 DNL range, which covers DNL values that are typically of great interest for airport noise studies. Within this DNL range the minimum NANL60 value over any receptor was 249.99, while the largest value was 525.02, resulting in a span of NANL60 of 275.03.

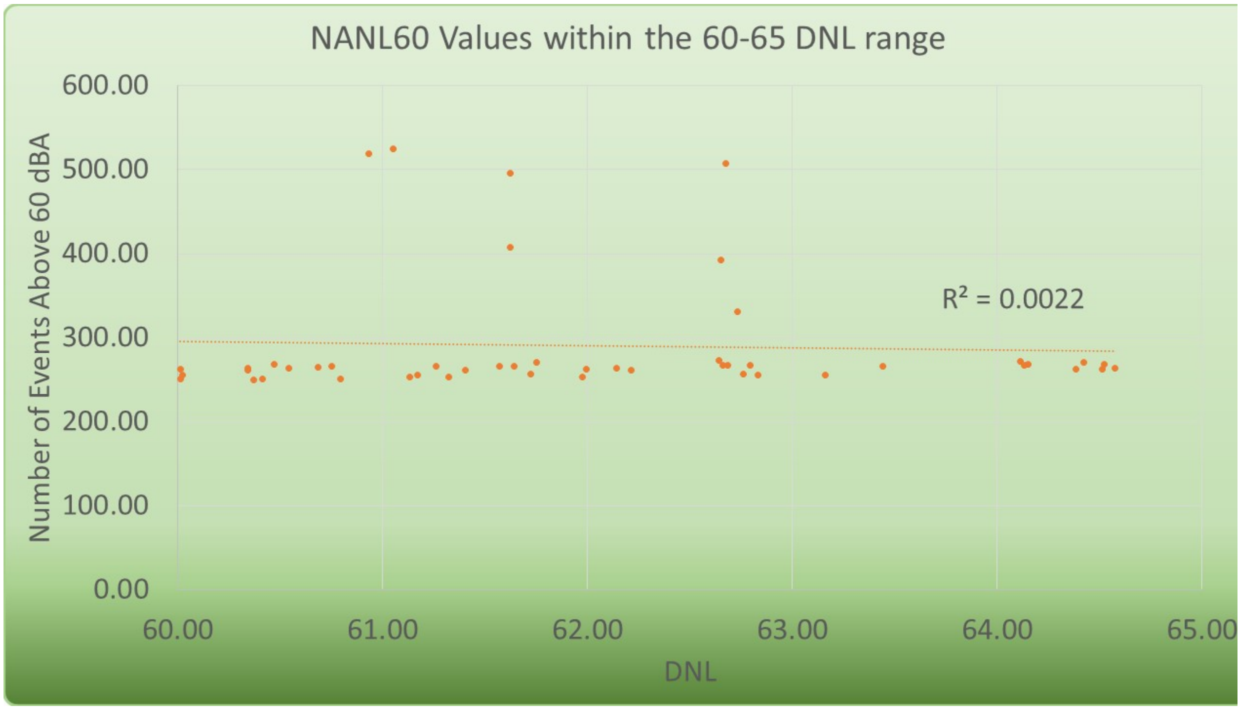
Table 4 DNL Range Comparison to Number of Events Above 60 dB LAMAX

DNL Range	Number of Receptors in DNL Range	Minimum Number of Events Above 60 dB	Average Number of Events Above 60 dB per Receptor	Maximum Number of Events Above 60 dB at a Receptor	Span of Number of Events Above 60 dB
<45 dB	43,023	0.00	0.29	48.98	48.98
45-50 dB	783	0.00	50.77	160.02	160.02
50-55 dB	267	19.02	153.22	257.00	237.98
55-60 dB	141	206.01	244.06	432.01	226.01
60-65 dB	48	249.99	290.15	525.02	275.03
65-70 dB	19	267.00	356.58	539.00	272.00
70-75 dB	5	332.99	439.00	533.01	200.02
>75 dB	4	536.00	537.24	539.00	2.99

Source: ATAC Corporation (2020 AEDT Analysis), September 2020.

While some of the variation can be attributed to the differing DNL values within the range (e.g., 60 dB DNL having less noise and therefore an expected lower number of events versus 65 dB DNL), the scatter plot depicted in **Exhibit 8** shows that there is very little correlation between the variation in the NANL60 LAMAX values and the DNL value within the range for this analysis.

Exhibit 8 Scatter Plot for DNL 60-65 NANL60 LAMAX Values

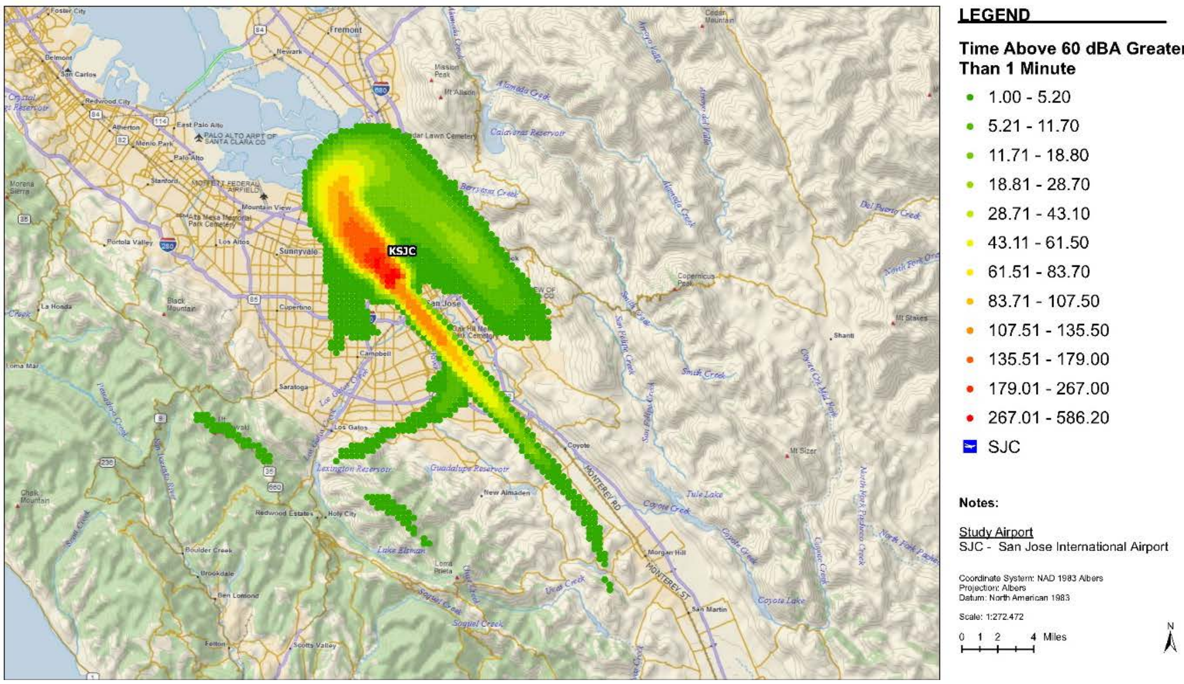


Source: U.S. Census Bureau, 2019 (TIGER/Line Shapefiles (machine-readable data files), (U.S. states, zip codes, airports); Federal Aviation Administration, 2020 Code of Instrument Flight Procedures (Airspace procedures), Delorme World Basemap, 2020 (Map). ATAC Corporation, 2020 (2020 AEDT Analysis).

Additional analysis related to the NANL60 LAMAX metric can be found in **Appendix A** of this paper.

Another metric that provides similar results to the NANL60 LAMAX metric is the Time Above A-Weighted (TALA) metric. While the results of the TALA60 LAMAX metric are similar to the NANL60 LAMAX results, it does provide additional context to the public by defining the time above 60 dB LAMAX over a given receptor. **Exhibit 9** depicts the TALA 60 LAMAX results in minutes above 60 dB LAMAX for each receptor for the AAD. When compared with **Exhibit 6**, we can see that there are areas that fall below the 45 DNL threshold and still have aircraft events that register above 60 dB. Conversely, there are areas that do not register any time above 60 dB and fall into the 45-50 DNL range.

Exhibit 9 Average Annualized Time Above 60 dBA



Source: U.S. Census Bureau, 2019 (TIGER/Line Shapefiles (machine-readable data files), (U.S. states, zip codes, airports); Federal Aviation Administration, 2020 Code of Instrument Flight Procedures (Airspace procedures), Delorme World Basemap, 2020 (Map). ATAC Corporation, 2020, 2020 AEDT Analysis.

Table 5 depicts the minimum, average, and maximum time in minutes that receptors in the various DNL ranges were exposed to noise above 60dB. The minimum time above 60 dB above 45 DNL was 0 minutes and the maximum was 586.2 minutes for a receptor reporting a DNL value above 75 dB DNL.

Table 5 DNL Range Comparison to Time (in minutes) Above 60 dB LAMAX

DNL Range	Number of Receptors in DNL Range	Minimum Time of Events Above 60 dB	Average Time of Events Above 60 dB per Receptor	Maximum Time of Events Above 60 dB at a Receptor	Span of Time of Events Above 60 dB
<45 dB	43,023	0.00	0.04	6.60	6.60
45-50 dB	783	0.00	8.54	27.00	27.00
50-55 dB	267	3.90	39.70	88.00	84.10
55-60 dB	141	62.80	103.59	194.60	131.80
60-65 dB	48	116.10	148.36	242.30	126.20
65-70 dB	19	118.40	214.34	385.10	266.70
70-75 dB	5	206.70	266.58	345.80	139.10
>75 dB	4	183.40	356.63	586.20	402.80

Source: ATAC Corporation (2020 AEDT Analysis), September 2020.

When TALA60 LAMAX is compared to the DNL results of the example, we can see a great amount of variation within the DNL ranges as it relates to the time of events above 60 dB LAMAX. The greatest span is found in the 65-70 DNL range, with a minimum of 118.4 minutes and a maximum of 385.1 minutes. While the average time above increases correspondingly to the DNL ranges, the variability within each DNL range captures significant differences in the way the DNL results are achieved. **Exhibit 10** depicts Google Earth files providing detailed noise parameters developed, including the DNL, NANL60 LAMAX, and the average per event TALA60 LAMAX.

Exhibit 10 DNL, NANL60 LAMAX, TALA60 LAMAX Summary

Source: U.S. Census Bureau, 2019 (TIGER/Line Shapefiles (machine-readable data files), (U.S. states, zip codes, airports); Federal Aviation Administration, 2020 Code of Instrument Flight Procedures (Airspace procedures), Delorme World Basemap, 2020 (Map). ATAC Corporation, 2020, 2020 AEDT Analysis.

In our example analysis, the NANL60 LAMAX metric was able to identify areas that experience high numbers of noise events above the 60 dB LAMAX threshold. The TALA60 LAMAX metric provided additional context related to the duration of events above the threshold. Providing these two additional metrics (NANL 60 LAMAX and TALA 60 LAMAX) with the DNL results allows an individual to compare how the DNL values are achieved, either through a relatively few loud and/or long events or through a relatively large number of quieter and/or shorter duration events. This can help procedure designers and policy makers make informed decisions (e.g., attempting to disperse a relatively low number of flights might not result in the same benefits as dispersing a relatively large number of flights).

The analysis also identified the current leg types associated with the TECKY THREE procedure which dictate the amount of flight track dispersion and, therefore, noise concentration. Additional analysis of potential amendments to the TECKY THREE could include the use of vector to altitude followed by a manual vector (VA-VM) leg, where the ATC controller manually controls the aircraft after reaching a certain prescribed altitude, thereby increasing dispersion. In addition, the use of open SIDS, where the RNAV legs terminate, followed by radar vectors, to rejoin the RNAV route at a later point may be proposed by the airport in an effort to disperse aircraft along the route of travel. Additional analysis of the example above can be found in **Appendix A**.

Additional metrics that may support the further understanding of aircraft noise concentration and warrant additional analysis are currently being explored by ATAC. Metrics related to the number of events above the ambient noise level may help discern what events are disproportionately impactful for communities and also allow for communities and the FAA to better plan aircraft routes that would maintain noise exposure below the surrounding ambient noise levels. Additionally, the NANL and TALA metrics may be further refined to account for the day/evening/night splits, presenting the results with three different values for each time period.

Conclusion

Supplemental metrics empower the FAA, airports, decision makers, and the public by providing additional context to the noise associated with airport operations. Along with the DNL noise values, the public can glean the number of events above a certain threshold in their area of interest, and when combined with the TALA metric, it can provide the public with an average amount of time above a threshold for each event. This additional context can help entities better understand the public's perception of the noise generated by the aircraft and can be used to prioritize the concerns of the public.

The analysis of concentration and dispersion of aircraft operations due to PBN procedures and purposeful design can be further analyzed contextually by utilizing the NANL, TALA, and other supplemental noise metrics as appropriate. The 60 dB noise level used in the NANL60 LAMAX and TALA60 LAMAX noise metrics is associated with normal conversations and background music.[20] Therefore, it can be used to identify areas that will receive increased and decreased activity related to proposed new and amended procedures that may impact people's lives. The analysis would provide the airport and communities an opportunity to work proactively with the FAA, identifying potential areas of concern while informing the public of the existing conditions and any potential changes proposed.

Per the FAA Reauthorization Act of 2018, airports can request that the FAA conduct additional analysis on the potential dispersion of RNAV departure routes below 6,000 feet. During this process, airports can present the findings of a NANL60 LAMAX/TALA60 LAMAX analysis to pinpoint areas impacted by concentration of aircraft in an effort to find where aircraft dispersion may be of benefit. Further, land-use authorities can identify areas that are sensitive to aircraft noise and areas that are not, thereby encouraging the FAA to utilize the flexibility of RNAV procedures to fly routes most compatible with both the existing and planned land uses surrounding airports.

Aircraft noise pollution and its consequences are present today, and ATAC – utilizing the robust AEDT[21] model, its unparalleled expert staff, and its own additional proprietary software built up over the last two decades – can assist airports and the FAA with identifying the most compatible routing while maintaining the safety and efficiency of the NAS. ATAC firmly believes the FAA, all airports, airlines, and the communities they serve should strive for reporting integrity and building public trust in noise modeling and data analysis. In conducting environmental assessments that analyzed over 750 PBN procedures, ATAC has concluded the best method to accomplish these environmental evaluations is to combine accurate aircraft track data with ATAC's modeling and analysis capabilities, including the use of supplemental metrics as appropriate.

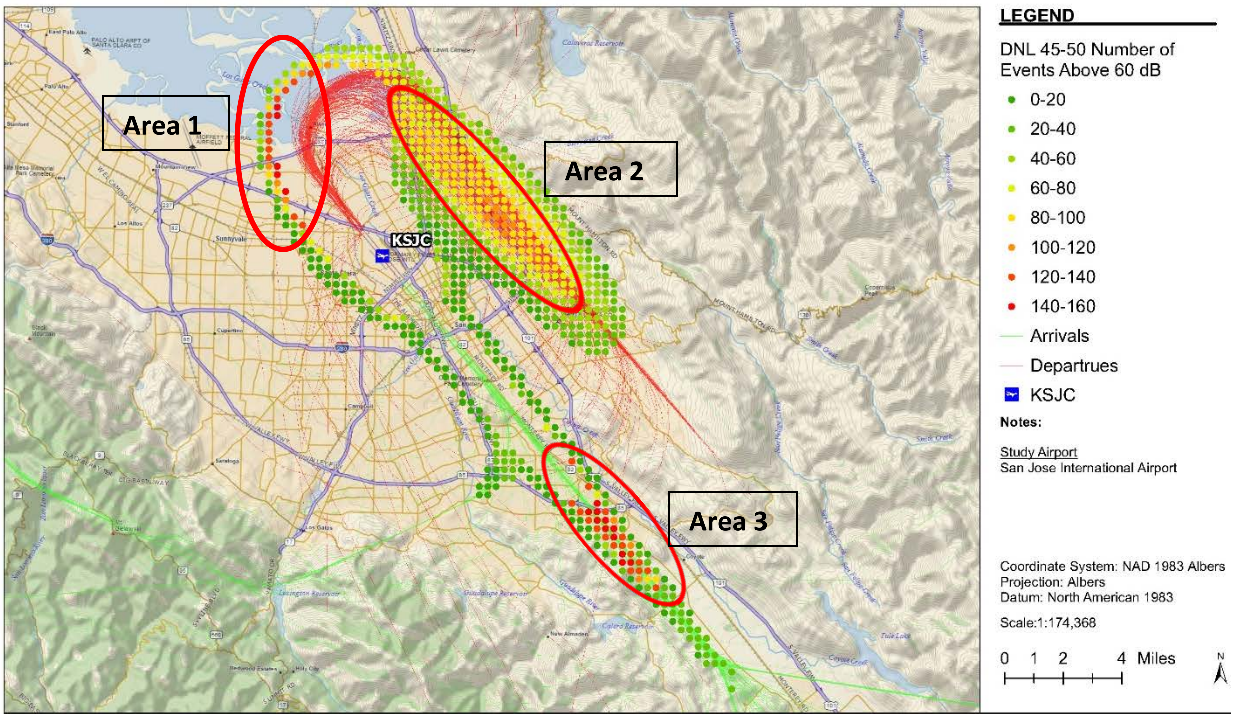
ATAC can provide noise analysis services for airports of all sizes and locations, providing traditional DNL results and robust supplemental analysis. If you or your airport would like to have a noise analysis conducted, call ATAC, the aviation analysis experts, at (408) 736-2822.

[20] Center for Disease Control and Prevention, *Loud Noise Can Cause Hearing Loss.* https://www.cdc.gov/nceh/hearing_loss/what_noises_cause_hearing_loss.html (accessed 09/28/20).
[21] U.S. Federal Aviation Administration, *Aviation Environmental Design Tool*, (https://aedt.faa.gov/ [Accessed September 2, 2020]).

Appendix A – Additional Analysis

Exhibit A.1 depicts the NANL60 LAMAX for the 45-50 DNL range. The range in the number of events spans from 0 to 160. As would be expected, the NANL60 LAMAX directly correlates to the proximity of the noise receptor to the airport, with several registering a relatively large number of events near the upwind leg of the departures (Area 1). There are also a large number of events in the area under the flight tracks further along the route of travel (Area 2). Several of the noise receptors close to the airport's final approach also register a relatively large number of events above 60 dB LAMAX as a result of the aircraft's proximity to the ground and the concentration of aircraft on final approach (Area 3).

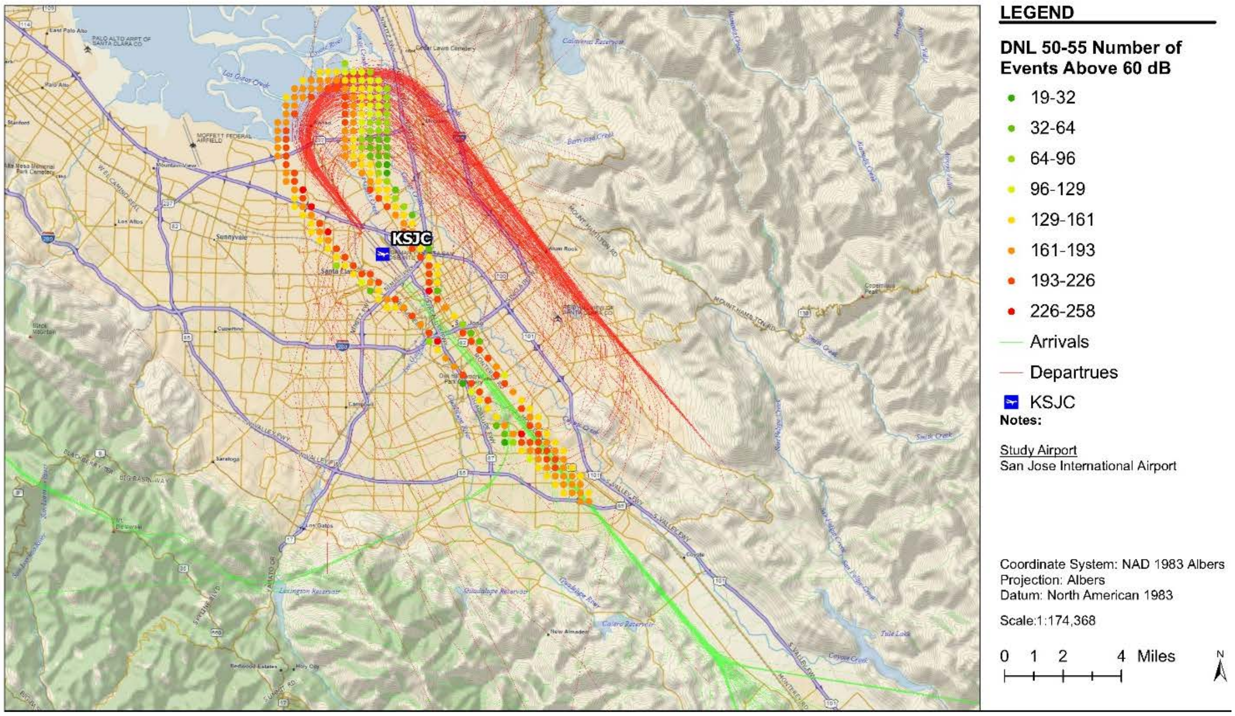
Exhibit A.1 DNL 45-50, Number of Events Above 60 dB



Source: U.S. Census Bureau, 2019 (TIGER/Line Shapefiles (machine-readable data files), (U.S. states, zip codes, airports); Federal Aviation Administration, 2020 Code of Instrument Flight Procedures (Airspace procedures), Delorme World Basemap, 2020 (Map). ATAC Corporation, 2020 (2020 AEDT Analysis).

Exhibit A.2 depicts the NANL60 LAMAX for the 50-55 DNL range centroids. It becomes even more clear that the number of events above 60 dB LAMAX is directly related to the receptor's proximity to the ground (nearness to the airport) and the center of the flow of aircraft. As RNAV increases the number of aircraft operating near the center of the flow, the NANL60 results in this area increase. Noise receptors close to the airport and close to the center of the flight tracks reveal higher values associated with the number above than those noise centroids that are higher in altitude and/or further away from the flow of aircraft. While these increases are similar to those shown by the DNL metric, NANL 60 dB LAMAX provides additional context to the results by quantifying the number of events.

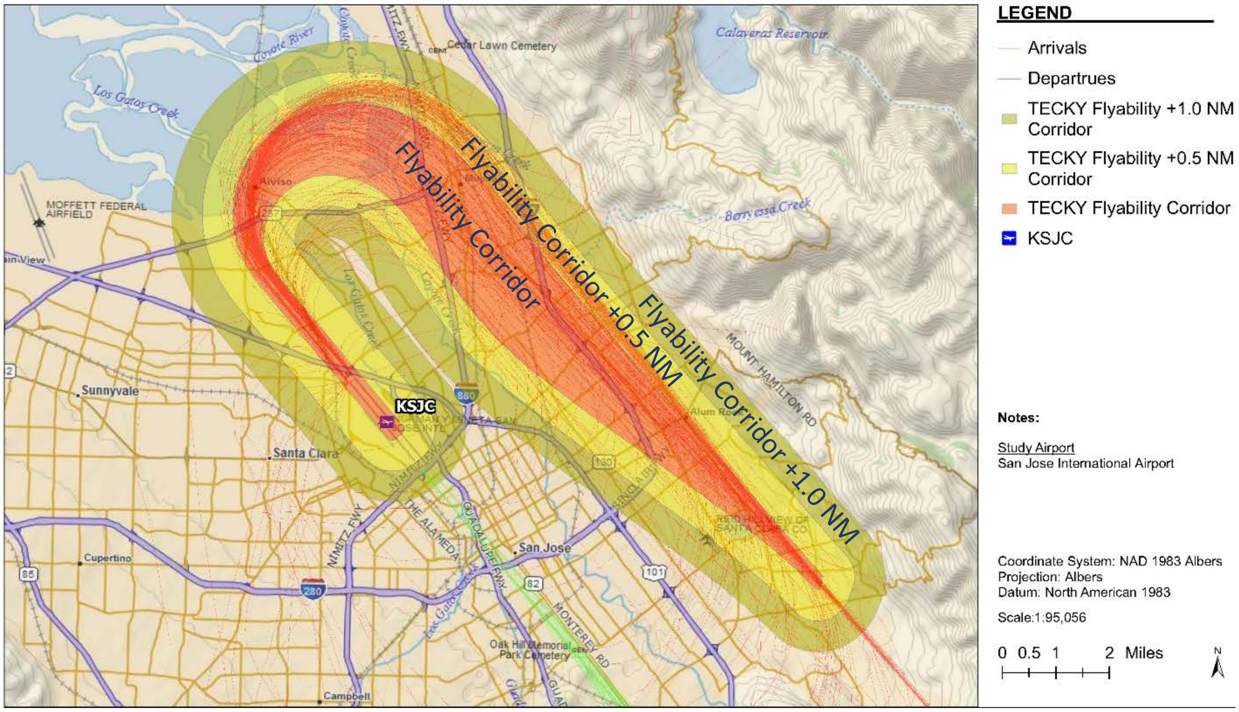
Exhibit A.2 DNL 50-55, Number of Events Above 60 dB LAMAX



Source: U.S. Census Bureau, 2019 (TIGER/Line Shapefiles (machine-readable data files), (U.S. states, zip codes, airports); Federal Aviation Administration, 2020 Code of Instrument Flight Procedures (Airspace procedures), Delorme World Basemap, 2020 (Map). ATAC Corporation, 2020, (2020 AEDT Analysis).

Another means of visualizing the impacts of dispersion as it relates to the number of events above 60 dB LAMAX is to create corridors that encapsulate various areas near a procedure. **Exhibit A.3** depicts three corridors associated with the TECKY THREE procedure. The first corridor represents the area below the flyability lines. The second extends from the flyability corridor 0.5 NM. The last corridor extends an additional 0.5 NM (a total of one NM away from the flyability corridor). A majority of the flights operate within the flyability corridor and the 0.5 NM corridor.

Exhibit A.3 TECKY THREE Flyability Corridors

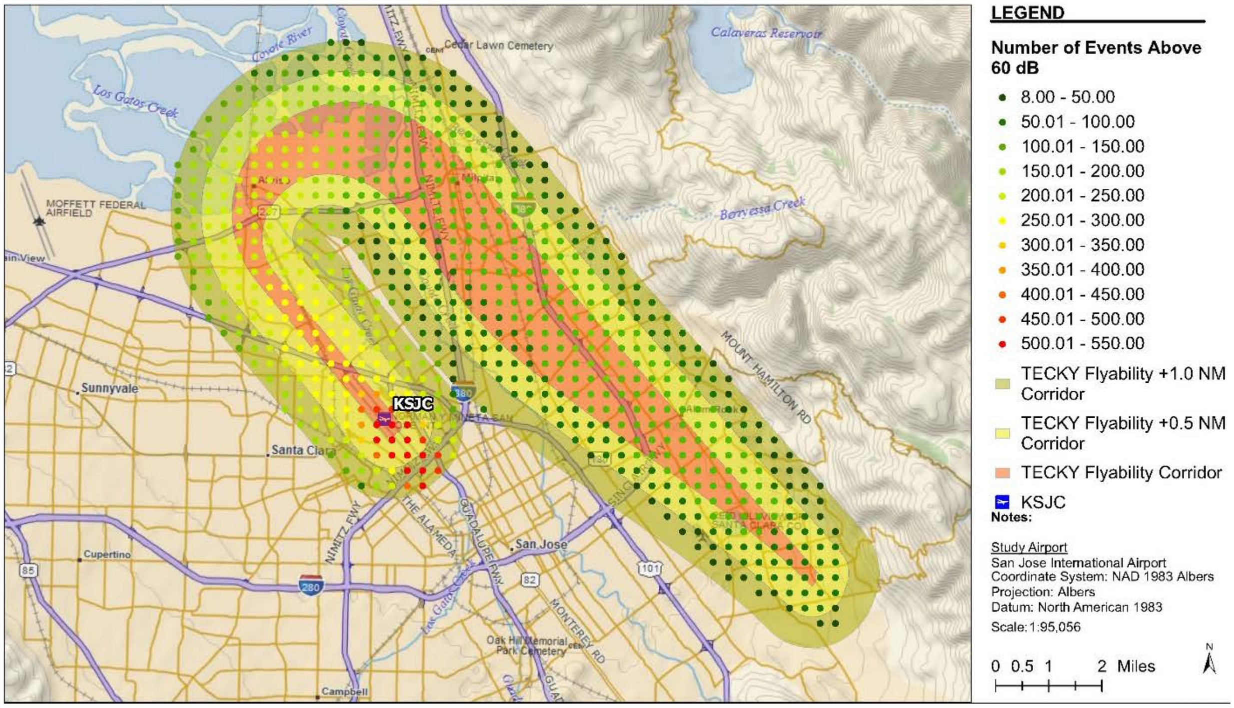


Note: Corridors were cut at the DNL >45 DNL range

Source: U.S. Census Bureau, 2019 (TIGER/Line Shapefiles (machine-readable data files), (U.S. states, zip codes, airports); Federal Aviation Administration, 2020 Code of Instrument Flight Procedures (Airspace procedures), Delorme World Basemap, 2020 (Map). ATAC Corporation, 2020 (2020 AEDT Analysis).

Exhibit A.4 depicts the number of events above 60 dB for the three corridors. Again, we can see that the NANL60 LAMAX is directly correlated to the proximity to the airport and the proximity to the flow of traffic. While **Exhibit A.4** does not provide the same level of granularity of the previous exhibits, it does provide a more complete picture as to the distribution of flights and its relation to the NANL60 LAMAX events.

Exhibit A.4 TECKY THREE Flyability Corridors with Number Above 60 dB Results



Note: Corridors were cut at the DNL >45 DNL range

Source: U.S. Census Bureau, 2019 (TIGER/Line Shapefiles (machine-readable data files), (U.S. states, zip codes, airports); Federal Aviation Administration, 2020 Code of Instrument Flight Procedures (Airspace procedures), Delorme World Basemap, 2020 (Map). ATAC Corporation, 2020 (2020 AEDT Analysis).

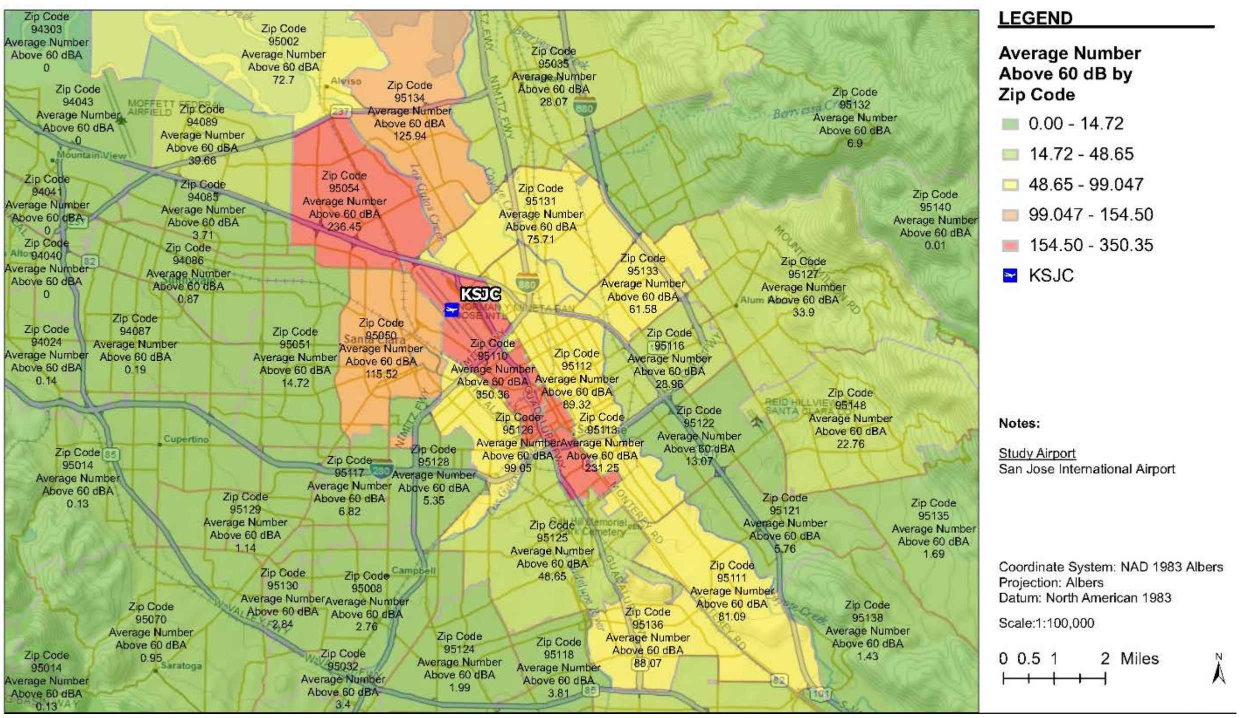
Table A.1 provides a comparison of the NANL60 LAMAX events for each of the corridors. While the median number of events correlates to the proximity of the flight tracks, the average of NANL60 LAMAX events is highest in the first 0.5 NM corridor immediately adjacent to the flyability corridor. The least number of events are found in the outermost corridor. These results are consistent with the RNAV-1 criteria and confirm the predictability of the TARGETS flyability lines.

Table A.1 NANL60 dB LAMAX Results Within the Flyability Corridors

	Minimum Number of Events Receptors	Average Number Events Above 60 dB LAMAX	Maximum Number of Events Above 60 dB LAMAX	Median Number of Events Above 60 dB LAMAX
Flyability Corridor	29.02	116.35	536.99	87.02
0-0.5 NM From Flyability Corridor	17.01	131.92	539.00	82.02
0.5 to 1 NM From Flyability Corridor	7.99	98.24	536.00	60.01

Source: ATAC Corporation (2020 AEDT Analysis), September 2020

Exhibit A.5 Average Number Above 60 dB by Zip Code



Source: U.S. Census Bureau, 2019 (TIGER/Line Shapefiles (machine-readable data files), (U.S. states, zip codes, airports); Federal Aviation Administration, 2020 Code of Instrument Flight Procedures (Airspace procedures), Delorme World Basemap, 2020 (Map). ATAC Corporation, 2020, 2020 AEDT Analysis.

Exhibit A.5 depicts the least granular analysis by providing the average number of events above 60 dB LAMAX by Zip Code. While this does not provide detail for individual properties or areas, it does provide a high-level analysis that can provide context to any DNL analysis that is conducted. In addition, analysis can be conducted by the census tract or block level; however, the general public may not be as familiar with those geographies.