Evaluation of LAX North Downwind Arrivals

Technical Memorandum

HMMH Report No. 306430_LAWA_003
September 1, 2016

Prepared for:

Los Angeles World Airports
Environmental Programs
7301 World Way West
Los Angeles, CA 90045
&
Environmental Science Associates
2600 Capitol Ave, Suite 200
Sacramento, CA 95816

Prepared by:

Mary Ellen Eagan

Gene Reindel

Hugh J Enxing

Dominic Scarano

Adam Scholten

HMMH

77 South Bedford Street

Burlington, MA 01803

Contents

Figures

Tables

1 Overview

Los Angeles World Airports (LAWA) undertook this analysis of the north downwind arrival route in response to concerns raised by residents under or near the north arrival routes into Los Angeles International Airport (LAX). The analysis assessed whether changes have occurred to published arrival procedures, flight track locations, aircraft altitudes, aircraft types, the time of day aircraft flights occurred, the number of arrivals, the time those arrivals occurred, and the noise levels of aircraft on the north downwind arrival. The analysis independently examined six years of flight operations data beginning in 2010 to identify and report on any changes in these eight factors. This Technical Memorandum presents the methodology and findings of the analysis within the scope and timeframe of the study.

1.1 Background and Schedule of Events

Increasing concerns raised by residents under the north downwind arrival route into LAX, which has been in use for decades, prompted this analysis. Specific milestones are outlined below:

- 2012: A resident of Culver City contacts LAWA about low, loud, frequent aircraft noise events over their residence, which lies beneath the north downwind arrival route into LAX.
- 2014: Culver City becomes a member of the LAX/Community Noise Roundtable and residents begin to attend Roundtable meetings and submit complaints to express concerns about low, loud, and frequent aircraft noise events.
- 2015: Complaints start to increase from communities under the north downwind arrival route. Culver City residents note changes in aircraft flying over the area, some as early as summer 2014 and others in summer 2015. In October, residents from Santa Monica Canyon/Pacific Palisades observe aircraft as lower, louder, and more frequent and begin to submit noise complaints. In November, LAWA examines flights over the Santa Monica Canyon/Pacific Palisades area and finds no obvious, permanent changes in aircraft altitudes and flight track locations.
- January 2016: FAA SoCal TRACON staff present their analysis of north downwind arrivals to the LAX Roundtable; FAA finds no obvious changes in aircraft flight track locations.
- March 2016: LAWA initiates the analysis of the north downwind arrival route.
- May 2016: The LAX/Community Noise Roundtable adopts Work Program Item A13 - North Downwind Arrival Study.
- June 2016 - The LAX/Community Noise Roundtable holds a special meeting to review and discuss the North Downwind Arrival Study results.

1.2 Scope of Work

The goals of the North Downwind Arrival Study were to: (1) evaluate flight track and altitude data in new ways, focusing on visual images and data trends; (2) analyze the data in a granular manner, looking at both month-over-month and year-over-year trends to identify changes; and (3) determine whether the data reveal any new insights into the origin of the community's aircraft noise complaints. Specific tasks, which are documented here, include the following:

- Review historic arrival procedures and fixes
- Identify up to ten locations for data analysis generally associated with areas of increased noise complaints or navigational fixes
- Analyze data from 2010 through 2015 on a monthly basis, as follows:
  - Prepare Flight Track Density Plots

    - Analyze Changes in Aircraft Fleet Mix
    - Compare Average Sound Exposure Levels
    - Prepare Altitude Distribution Graphs
    - Analyze Time of Day Distribution
    - Assess Changes in Slant Distance
- Prepare a Technical Memorandum
- Present the Study Results at a Special LAX/Community Noise Roundtable Meeting

2 Review of Published Arrival Procedures

The primary Federal Aviation Administration (FAA) arrival procedure for jet aircraft arriving from the west and northwest of LAX is the "SADDE" Standard Terminal Arrival Route (STAR). Based on a review of the FAA Facility Aeronautical Data Distribution System (FADDS), this arrival procedure has been published and in use by aircraft for many years.[1] The SADDE STAR is a conventional STAR, which utilizes ground-based equipment for navigation.

The published SADDE STAR arrival procedure is as follows (see Figure 1):

- From SADDE INT via Santa Monica Airport (SMO) Radial 261 to SMO Very High Frequency (VHF) Omni-Directional Range/Distance Measuring Equipment (VOR/DME), then via SMO Radial 068 to SMO 9 DME for Runways 24 and 25.
- From SMO 9 DME expect vector to final approach course for LAX.

Based on LAWA-observed communications[2] between the FAA Air Traffic Control (ATC) and pilots following the SADDE STAR, the typical instructions include heading changes before reaching SADDE to turn to BAYST or even directly to the SMO VOR/DME. From BAYST they are instructed to descend and maintain 7,000 feet until reaching the SMO VOR/DME. When near the SMO VOR/DME, the FAA ATC usually gives another instruction to descend and then provide a new heading such as 070 or 065 degrees. Further instructions are usually provided by FAA ATC as to when the aircraft should start their U-turn to line up for the final approach to a specific LAX runway.

On September 20, 2012, the FAA published two additional arrival procedures for LAX.[3] The FAA called the procedures the "SYMON" and "KEACH" Standard Terminal Arrival Routes (STARs). These are shown in Figures 2 and 3 below. The SYMON was intended for use by jet aircraft arriving at LAX from the west and northwest, while the KEACH was intended for use by jet aircraft arriving at LAX from the west. The SYMON and KEACH arrival procedures were intended to use Area Navigation (RNAV) performance standards (rather than relying on ground-based navigation aids), which allowed for greater navigational accuracy and greater repeatability of aircraft flight track navigation on the published flight procedures. The SYMON and KEACH arrivals were published as "Not Available" in the FAA Notice to Airmen (NOTAM) system from September 19, 2012 until September 16, 2015, indicating the procedures were not to be utilized by aircraft. Therefore, the SYMON and KEACH arrival procedures do not appear to be a factor in the findings of this study.[4] Both procedures were removed from publication in the FAA Digital Terminal Procedures Publication (DTPP) after September 17, 2015.

[1] Our review of FAADS data downloaded from the FAA December 17, 2009 indicates the SADDE arrival procedure has been published since at least 2009, and may have been published as early as 2004 (Not verified).
[2] LAWA's Airport Noise and Operations Management System, ANOMS™, records tower/pilot communications and maintains the recordings for playback.
[3] From FAA Digital Terminal Procedures Publication (DTTP). http://www.faa.gov/air_traffic/flight_info/aeronav/digital_products/dtpp/search/results/?cycle=1210&Ident=LAX
[4] FAA AIM NOTAM Search. https://notams.aim.faa.gov/notamSearch/nsapp.html#/details

Figure 1. SADDE SIX Arrival Plate - Published Procedure Currently in Use

(Source: FAA DTPP July 21, 2016)

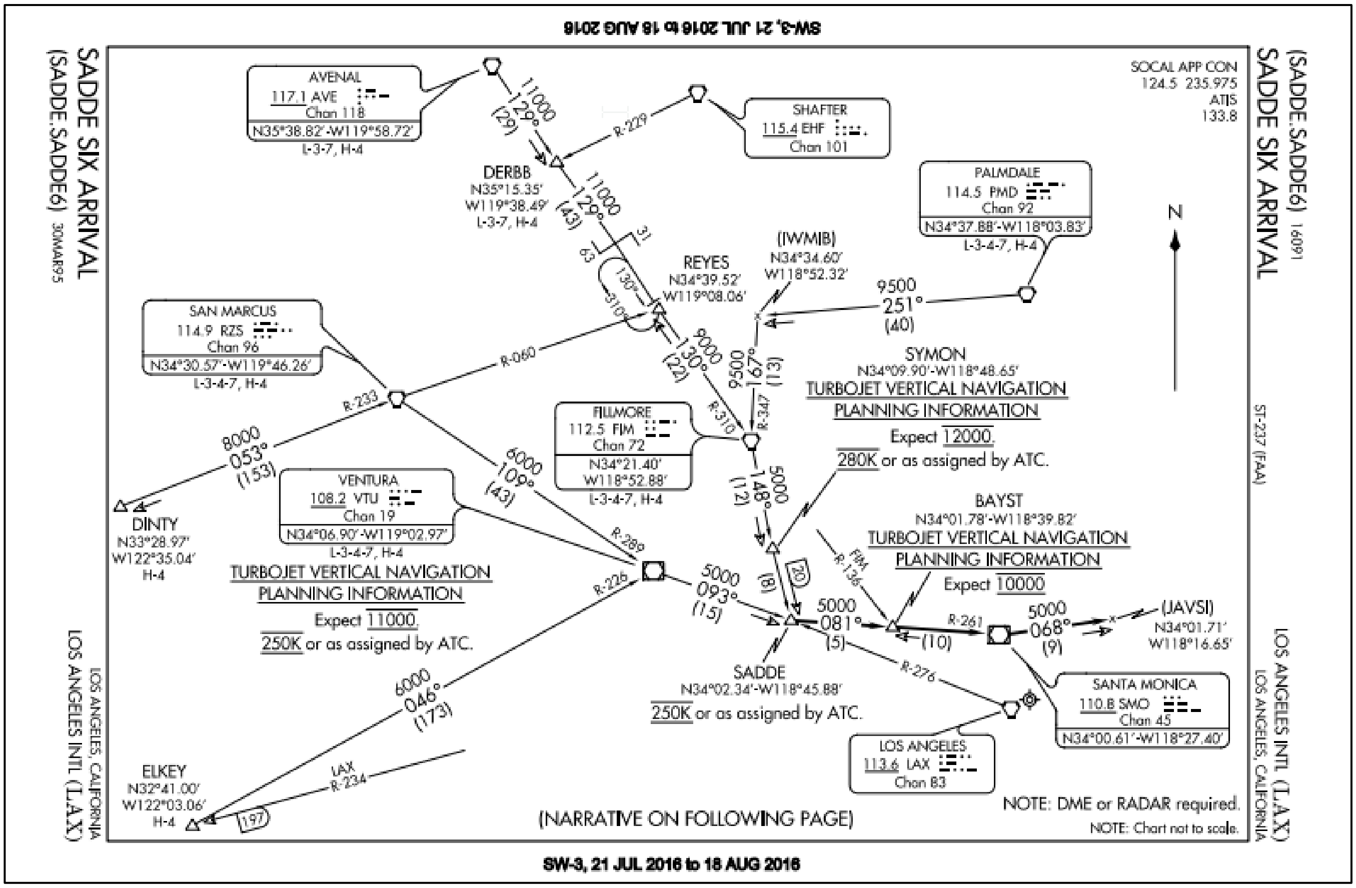


Figure 2. SYMON ONE Arrival Plate - Procedure Published as "Not Available" per FAA NOTAM
(Source: FAA DTPP September 20, 2012)

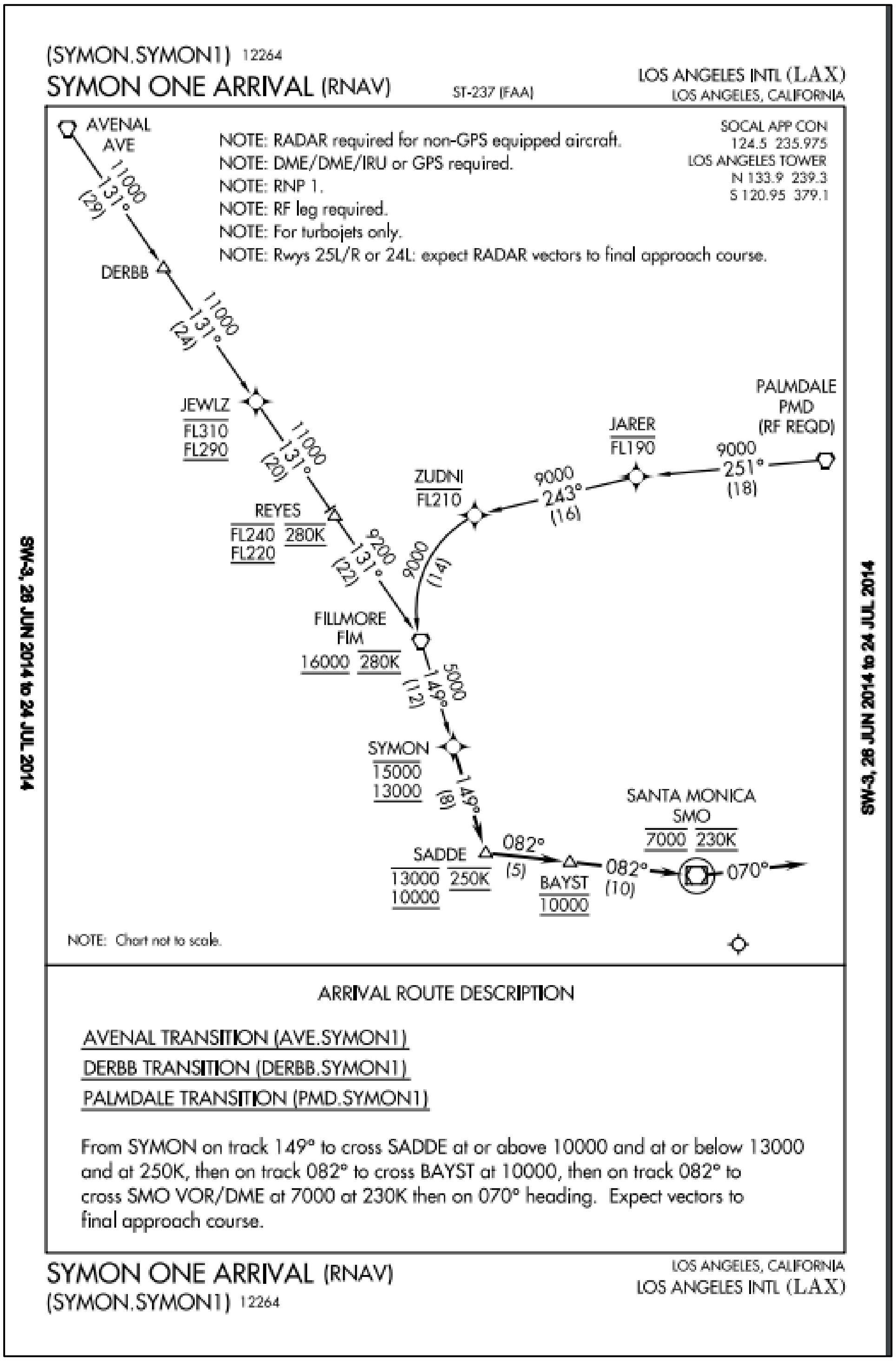
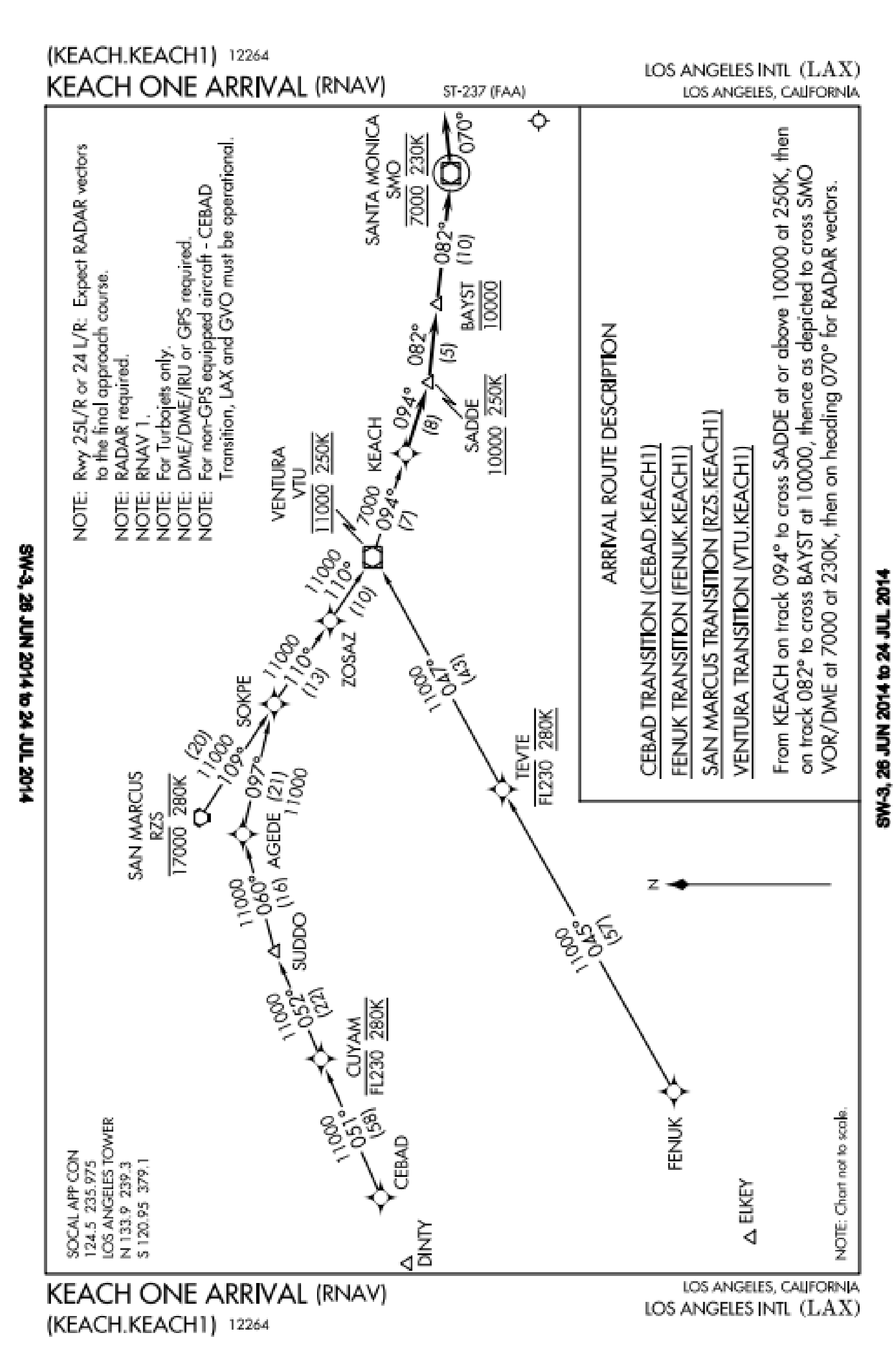


Figure 3. KEACH ONE Arrival Plate – Procedure Published as "Not Available" per FAA NOTAM
(Source: FAA DTPP September 20, 2012)



3 Data Preparation

This section details how the radar flight track data was obtained, processed, identified, and categorized for use in this study.

3.1 Data Source

HMMH has been receiving radar flight track data files prior to 2010 for use in developing contours for LAX, ONT and VNY using RealContours™ and the FAA's Integrated Noise Model (INM)[5]. These data files have been provided by LAWA's noise monitoring system vendor, Bruel & Kjaer. HMMH re-processed all flight track and operations data into new, "clean" databases, in order to remove any possibility of filtering/processing errors caused by program settings that may have changed over the years. This resulted in a consistent database from which the technical analyses were conducted.

3.2 Study Area - Analysis Locations and Gates

Ten locations were identified for in-depth analysis of LAX arrivals entering from the West and Northwest (Northerly) directions. Three are navigation fixes along the SADDE-SIX arrival procedure (SYMON, SADDE, and SMO VOR/DME), and the rest are located in or near various residential community areas from which noise complaints have been received.

A computer-generated vertical "gate" was created using GIS software to capture the density of flight tracks (position and frequency) as they crossed that particular plane in space. The gates were anchored at each of the analysis locations, and assigned a specified width, height and orientation (heading), designed to capture the entire arrival stream at each analysis location. The table below identifies these configuration parameters.

[5] Radar data is received in the form of a LT6 file which is generated from the LAWA Airport Noise and Operations Management System (ANOMS) and provided by the LAX ANOMS vendor, Bruel & Kjaer. LT6 files contain aircraft flight plan data including the aircraft type, airline, arrival runway, departure runway, arrival and departure airport, operation time, and registration if available. In addition to aircraft flight plan data, LT6 files also include aircraft flight track data for each operation recorded by the radar system based on a collection of track point locations defined by a distance, direction, and elevation from the location of the ANOMS system in a Cartesian coordinate system. Radar data for processing by the ANOMS system and inclusion in LT6 files is provided through outside data connections to FAA radar systems, and are subject to the accuracy and coverage limitations of the FAA radar systems used to provide data to the ANOMS system.

Table 1. Configuration of Gates and Locations
(Source: HMMH 2016)

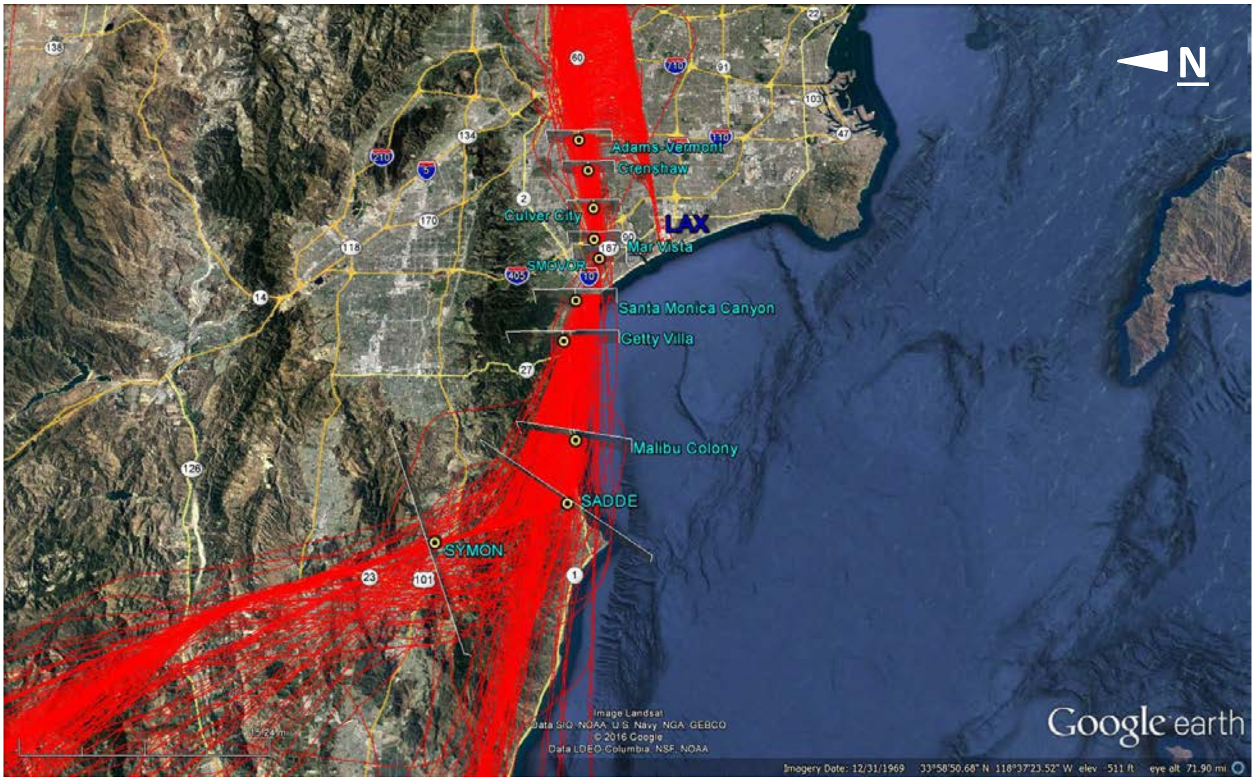
Analysis Locations	Longitude	Latitude	Elevation (ft)	Heading (deg)	Lwidth (ft)	Rwidth (ft)	Floor (ft)	Ceiling (ft)
SYMON	-118.8108333	34.1650000	1141	160	40000	40000	1141	20000
SADDE	-118.7646667	34.0390000	571	125	35000	35000	571	20000
Malibu Colony	-118.6887937	34.0319918	1	100	20000	20000	1	20000
Getty Villa	-118.5647522	34.0454549	177	90	20000	20000	177	15000
Santa Monica Canyon	-118.5122185	34.0338314	90	90	15000	15000	90	15000
Mar Vista	-118.4302354	34.0158952	102	90	10000	10000	102	10000
SMO VOR	-118.4566667	34.0103333	117	95	10000	10000	117	15000
Culver City	-118.3879914	34.0167442	83	90	10000	10000	83	10000
Crenshaw	-118.3350940	34.0226190	112	90	10000	10000	90	10000
Adams-Vermont	-118.2915360	34.0327643	194	90	12500	12500	194	10000

The figure below is a map in Google Earth showing the positions of the analysis locations, as well as the position, size and orientation of each gate.

Figure 4. Analysis Locations and Gates on Map
(Source: LAWA, Google Earth 2016)

Radar flight track data and gates over analysis locations were used to isolate west and northwest arrivals for this evaluation. Only radar flight tracks that passed through both the "SADDE" and "SMO VOR" gates were included in analysis since nearly all northerly arrivals pass through these two locations. Arrivals approaching LAX from other directions and all departures were excluded from the study.

Figure 5. Sample of Northerly Arrivals through Gates
(Source: LAWA, Google Earth 2016)



4 Flight Track Density Plots

The initial portion of this section details the methodology used to develop flight track density plots and concludes with the findings from the analysis of these plots.

4.1 Development of Flight Track Density Plots and ArcGIS Plot Generation

Flight track density plots are a convenient way to show a visual representation of the distribution (spread) of flight track data points and reveal clusters and/or variations that cannot otherwise be discerned from standard flight track distribution maps. The software program used to generate these plots comes from ESRI, and is called ArcGIS. Flight tracks of interest to this study for each month were exported in an ESRI Shapefile format, (a geospatial vector data format), which was then loaded into ArcGIS for processing.

ArcGIS uses a technique called “line density spatial analysis” to generate these images from the flight track data. ArcGIS does this by developing a grid (a 2-dimensional array of “cells”), and calculating the magnitude (number of overflights) per unit area from polyline features that fall within a radius around each cell (i.e., the “search radius”). For these density plots, the cell size was set to 200 feet on each side, and a search radius of 300 feet.

Once plotted, the polylines are assigned to color gradations to depict the flight track geometry, dispersion, and relative frequency of overflights in areas of interest. The color ranges are assigned based on the relative density of aircraft operations, with “warm” colors (e.g., red and orange) indicating areas with higher levels of overflights and frequency relative to the number of flight tracks in the data sample, and “cool” colors (e.g., blue and light blue) indicating areas of lesser levels of overflights and frequency.

4.2 Flight Track Density Plots and Results

In order to quickly identify possible changes in flight paths and procedures, flight track density plots were generated for each month of the six-year study period. By loading these images into a “flip-book” format (e.g., Microsoft PowerPoint), one can advance or retreat in time at varying speeds, and the human eye will pick up subtle changes between images. For example, this phenomenon can be seen over the Getty Villa and Santa Monica Canyon areas as the density plots transition from lighter to deeper blues as more arrivals are vectored directly from the navigational fix SYMON to the SMO VOR/DME and overfly those communities. Though these overflights account for a small percentage of the overall traffic, these subtle month-to-month fluctuations may contribute to the residents’ increased perception of aircraft activity, especially in communities with low ambient noise levels.

A review of the flight track density plots throughout the six-year study period indicate that during the period from January 2010 to May 2014 the flight track density of LAX Northerly Arrivals remained largely consistent on a month to month basis. Aircraft primarily flew along the published SADDE arrival procedure and overflew the navigational fixes of SYMON, SADDE, and BAYST before overflying the SMO VOR/DME and entering the downwind for LAX.

During the period from June 2014 to June 2015, flight track density east of the SMO VOR/DME on the downwind leg of the SADDE arrival procedure reduced in dispersion and became more concentrated. Aircraft flight tracks became concentrated around approximately the 068 degree radial of the SMO VOR/DME over the communities and neighborhoods of Mar Vista, Culver City, Crenshaw, and Adams Vermont. Prior to this period, aircraft flight tracks were more widely dispersed and not focused in the vicinity of the SMO VOR/DME 068 degree radial. After June 2015, tracks east of the SMO VOR/DME increased in dispersion and returned to levels consistent with density in the months prior to June 2014 and showed little change throughout the remainder of the study period. Flight track density to the west and north of the SMO VOR/DME over the communities of Malibu Colony, Getty Villa, and Santa Monica

Canyon showed little change between June 2014 and June 2015 and remained consistent with other months during the six-year study period.

The increase in track density east of the SMO VOR/DME during the period from June 2014 to June 2015, when compared to other months during the study period, is demonstrated in Figure 6 and Figure 7 below. Figure 6 shows the flight track density of LAX northerly arrivals during the month of April 2014, which exhibits flight track density east of the SMO VOR/DME consistent with the months before June 2014 and after June 2015. Figure 7 shows the flight track density of LAX northerly arrivals during the month of April 2015, which exhibits flight track density east of the SMO VOR/DME consistent with the reduction of track dispersion that occurred during the period of June 2014 to June 2015 on the downwind portion of the SADDE arrival procedure. Flight track density to the north and west of the SMO VOR/DME shows only slight variations between April 2014 and April 2015 in both figures, and is consistent with other months throughout the six-year study period.

Although only the plots for April 2014 and April 2015 are presented in this section, plots for each month from January 2014 through December 2015 are provided in Appendix C of this report. Plots for additional months throughout the entire six-year study period not included in Appendix C can be found in the Supplemental Data appendices.

As demonstrated in Figure 6 and Figure7 below, there was a noticeable increase in flight track density east of the SMO VOR/DME during the period from June 2014 to June 2015 over the communities of Mar Vista, Culver City, Crenshaw, and Adams Vermont. This indicates aircraft during this period were flying with greater frequency over a smaller area, and likely contributed to the perception of residents of increased aircraft overflights in the areas of the greatest shift in flight track density. After June 2015, when the flight track density returned to levels consistent with the period from January 2010 to May 2014 east of the SMO VOR/DME, residents who may have benefitted from the concentration of flight tracks apparently noticed this increase in aircraft activity as the flight tracks became more dispersed again. Even though these communities had previously experienced overflight traffic with relative frequency prior to the concentration of track density in June 2014, the reduction in track density followed by a subsequent increase over a twelve-month period likely resulted in a greater perception by residents of aircraft operations in the areas north and south of the north downwind arrival route.

Figure 6. LAX Northerly Arrivals - Flight Track Density April 2014

(Source: HMMH, LAWA ANOMS Data 2010-2015, ESRI ArcGIS)

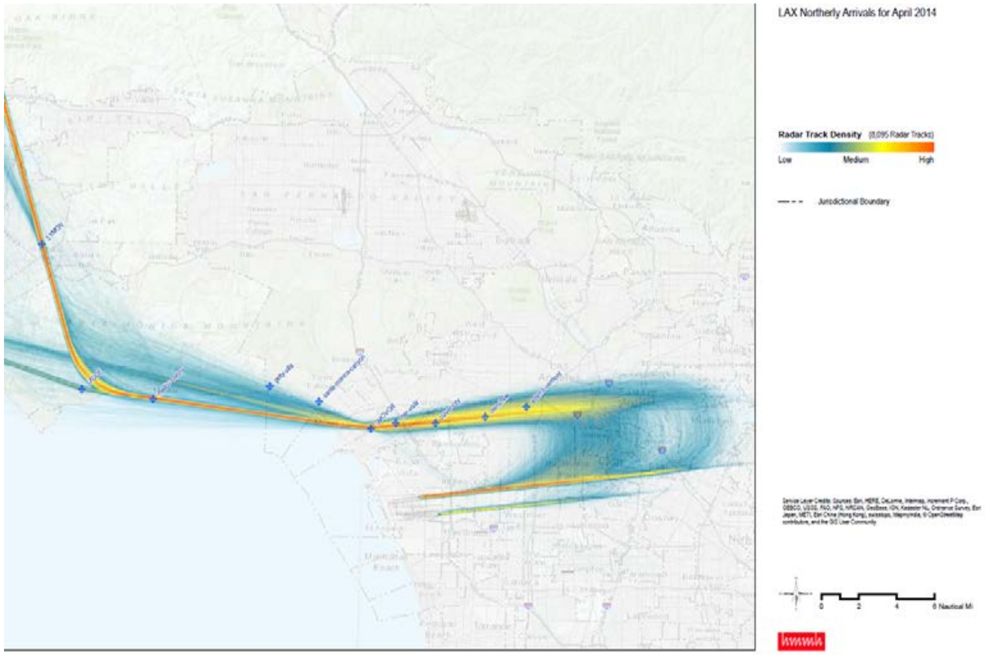
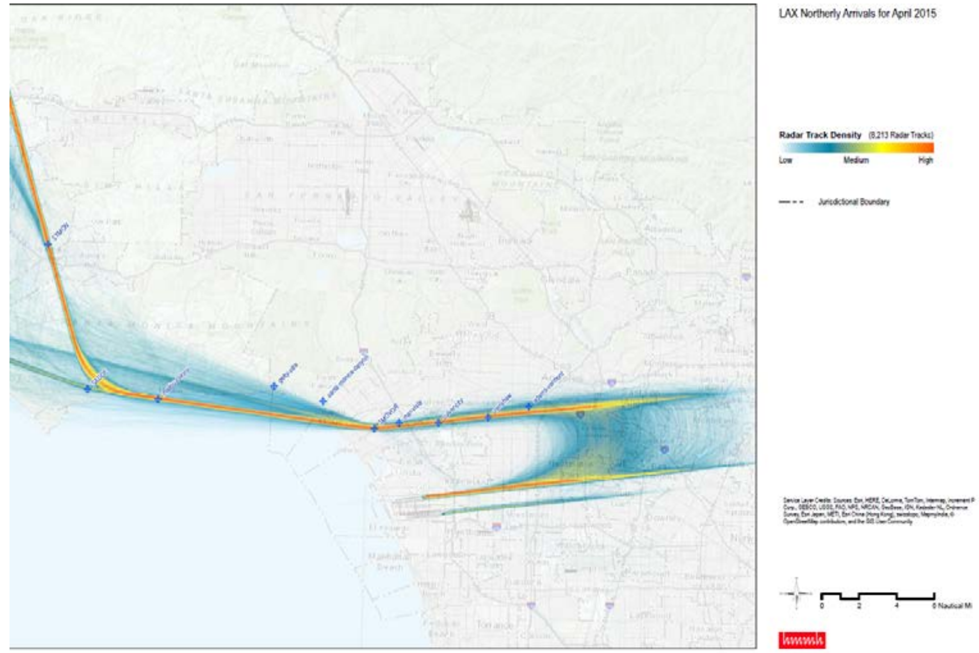


Figure 7. LAX Northerly Arrivals - Flight Track Density April 2015

(Source: HMMH, LAWA ANOMS Data 2010-2015, ESRI ArcGIS)



(Note: Each flight track in Figure 6 and Figure 7 is represented by a single continuous line. When lines overlap and become layered, the color shift from cool (blue) to warm (red) indicates a greater degree of flight track concentration.)

Prior to June 2014, tracks to the east of the SMO VOR/DME over the communities of Mar Vista, Culver City, Crenshaw, and Adams Vermont were well dispersed to the north and south of the 068 degree radial. This track dispersion is consistent with the expected behavior of aircraft vectored from the SMO VOR to the final downwind leg of the SADDE arrival procedure and the reduced navigational performance associated with conventional ground-based arrival procedures. From June 2014 to June 2015, tracks became less dispersed around the 068 degree radial east of the SMO VOR/DME.

LAWA reviewed FAA Air Traffic Control (ATC) radio communications at periodic intervals during the June 2014 to June 2015 period and noted that ATC personnel began issuing aircraft instructions to fly the 068 degree radial east of the SMO VOR/DME instead of issuing a radar vector for a heading to be flown after reaching the SMO VOR/DME.

When an aircraft is issued a radar vector, the aircraft will fly a heading specified by air traffic control, which will not be corrected for the effects of wind. Radar vectors lack the repeatability and consistency in execution of flying a radial from a ground based navigational aid due to the variability of the heading issued by air traffic control, the effects of wind drift, and the inability for the radar vector to be programmed into aircraft navigational systems in advance of execution by aircraft flight crews. When aircraft are instructed to fly a radial from a ground based navigational aid such as the SMO VOR/DME, the aircraft will navigate on a defined path within the tolerances of the aircraft navigational system performance corrected for the effects of wind. This path is highly repeatable and can be entered into the aircraft navigational system prior to the aircraft flying the radial portion of the procedure.

This increase in predictability and repeatability in flight paths when flying a radial from a ground based navigational aid when compared to flying a radar vector issued by air traffic control is consistent with the increase in concentration and reduction in flight track dispersion observed from approximately June 2014 to approximately June 2015 in the vicinity of areas to the east of the SMO VOR/DME. Although the observed dispersion decrease from June 2014 to June 2015 was consistent with the behavior of aircraft flight paths associated with increased navigational performance associated with aircraft navigating on RNAV procedures, there were no published RNAV procedures in use during this time.

After June 2015, and throughout the remainder of 2015, aircraft flight tracks increased in dispersion north and south of the SMO VOR/DME 068 degree radial and returned to similar dispersion levels that occurred prior to June 2014. This is consistent with the behavior of aircraft flying a radar vector issued by ATC personnel and corresponds to observations by LAWA staff that controllers were no longer issuing instructions to pilots to fly the 068 degree radial from the SMO VOR/DME.

Apart from dispersion changes east of the SMO VOR/DME, there were also some subtle changes that were observed in the flight track density plots throughout the study period. The most noticeable of these subtle changes is the shift in deviation at Malibu Colony in July 2011, which is discussed in Section 7.2.3.

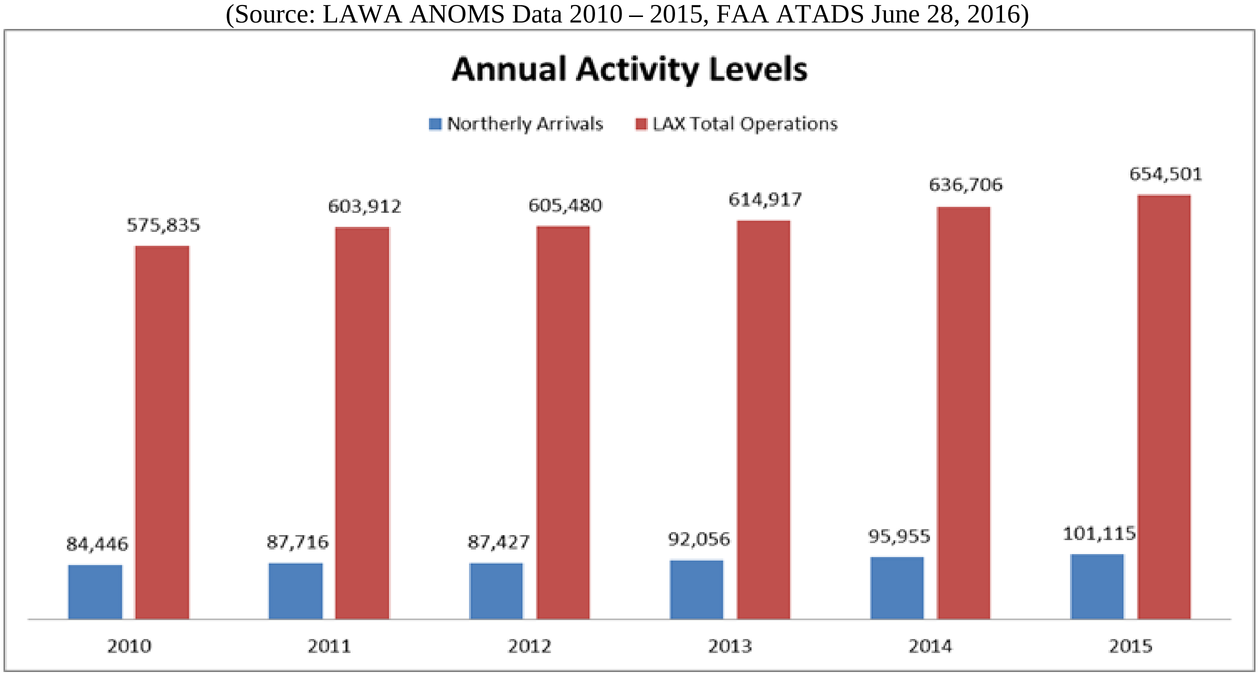
5 Operations and Activity Trends

This section examines the changes in aircraft activity levels throughout the study period. Specifically, the section examines whether there was a disproportionate increase in use of the northerly arrivals course compared with other growth in activity at LAX during the study period.

5.1 Activity Levels

Analysis revealed an overall growth trend in the number of northerly arrivals into LAX during the study period. There were 84,446 northerly arrivals in 2010 compared to 101,115 in 2015. This represents an overall 20% increase in the number of northerly arrival operations over the six-year period. The number of northerly arrivals grew steadily throughout the period with the exception of 2012 when there was a very slight decrease. The overall number of operations at LAX grew nearly 14% over the same 2010 – 2015 time period.[6] Therefore, the increase in northerly arrivals was 6% greater than the overall growth in operations at LAX over the same time period. All northerly arrival counts for each year of the study period are listed in Figure 8 below.

Figure 8. Annual Activity Levels for Northerly Arrivals
(Source: LAWA ANOMS Data 2010 – 2015, FAA ATADS June 28, 2016)



The increased activity levels from 2010 through 2015 would explain the perception of residents under the path of LAX northerly arrivals that overflights became more frequent throughout the study period. Independent of other flight path changes, as the number of aircraft operations over the same flight path corridor increase, so will the probability the community under that flight path will experience a greater

[6] Data from FAA Air Traffic Activity System (ATADS), retrieved June 28, 2016, https://aspm.faa.gov/opsnet/sys/Airport.asp.

frequency of overflight operations. The increase in operations between 2010 and 2015 may continue as total 2016 traffic levels at LAX are expected to exceed 2015 totals[7].

5.2 Aircraft Arrival Counts by Category and Aircraft Groups

Due to the very large number of aircraft types, it is sometimes convenient for analysis to group aircraft into categories. For this study, specific aircraft were grouped into categories based on similar characteristics such as aircraft size, weight, and engine type. Aircraft types are first broken down by what is called "NEM groups", which are consistent with the groupings of aircraft types used for the LAX Noise Exposure Map (NEM) Update in the fall of 2015 and is a methodology accepted by the FAA. The seven principal NEM Groups are shown in Table 2, below:

Table 2. Aircraft Groups

(Source: LAX 2015 Noise Exposure Map)

NEM Group	Aircraft Group	Sample Aircraft Type
Large Wide-Body	A330	A330, A332, A333, etc.
	A340	A340, A340-500, A340-600, etc.
	B747	B747, B747-400, etc.
	B777	B777, B777-200, B777-200LR, B777-300ER, etc.
	MD11	MD11
Large Narrow-Body	B727	B727, B727-200
	B757	B757, B757-200, B757-300
	B787	B787
New Large	A380	A380
	B748	B748
Small Wide-Body	A300	A300
	A310	A310
	B767	B767, B767-200, B767-300

[7] Comparison of FAA ATADS 2015 LAX airport operations to FAA Terminal Area Forecast (TAF) LAX airport operations.
FAA ATADS data retrieved June 28, 2016, https://aspm.faa.gov/opsnet/sys/Airport.asp
FAA TAF data retrieved June 28, 2016, http://taf.faa.gov/

NEM Group	Aircraft Group	Sample Aircraft Type
Small Narrow-Body	A320	A320, A318, A319, A321
	B737	B737, B738, B739, etc.
	MD80	MD80, MD81, MD83, etc.
	MD88	MD88, MD87
	MD90	MD90
Small Jet	B717	B717
	CRJ7	CRJ7, CRJ9, etc.
	E145	E145, E135, etc.
	Business Jets	GV, CL30, F2000, etc.
Non-Jet	Wide Range of Piston-Driven Aircraft	Various

(Note: Helicopters are excluded from the analysis because they do not follow the north downwind arrival route to LAX.)

Within the NEM groups, subgroups of aircraft types called AC groups were used for additional analysis. Of all the AC groups available, 11 groups were used for drill-down in this analysis. These 11 groups represent the majority of flights (between 80% and 85%, depending on year), and also represent the top 20 most frequently flown aircraft types for each year during the study period. These 11 groups are:

- A320
- A330
- A340
- A380
- B737
- B747
- B757
- B767
- B777
- B787
- CRJ

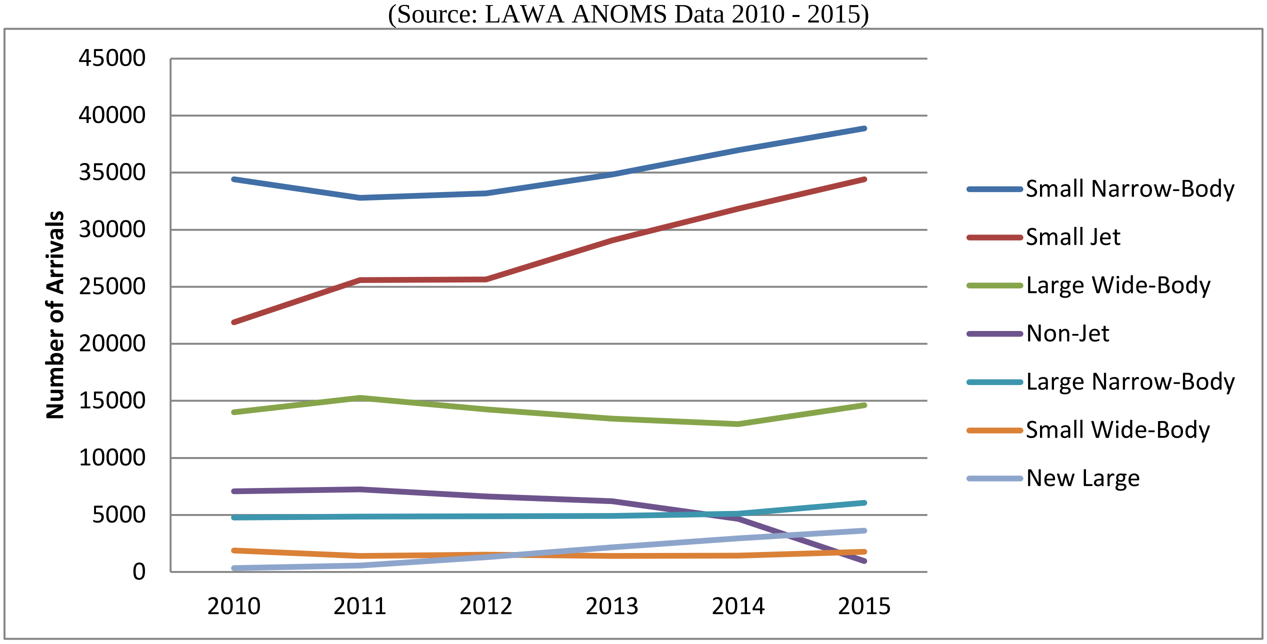
These grouping schemes and aircraft types are detailed in Appendix A.

Annual and monthly counts of northerly arrivals by aircraft type were calculated and several interesting trends were discovered. While on the whole, operations increased over the years, some aircraft type categories saw large swings in usage within each NEM and AC group.

- Small Narrow-Body Jets: Aircraft such as the Boeing 737 and Airbus A320 increased 13% in usage over the period especially since 2012. This category is also the category with the largest arrival count, so this increase is substantial, and likely noticeable by residents.
- Small Jets: This category, which includes corporate jets and regional jets, saw a sizable increase in operations during the period. There were nearly 22,000 operations in 2010 and this jumped to just over 34,000 in 2015. Small jets have the second highest arrival count, just below small narrow-body jets. This also was probably noticeable.
- Large Narrow-Body Jets: Aircraft like the Boeing 757 remained fairly steady throughout the study period with a small amount of growth after 2013, though there are few large-narrow body operations on the whole.
- Small and Large Wide-Body Jets: Small wide-body jets like the Boeing 767 and large wide-body jets like the Boeing 747, 777, Airbus A330, and A340 showed little variation in counts over the study period though large wide-body jets accounted for many more arrivals than their smaller counterparts.
- New Large Jets: Aircraft such as the Boeing 747-800 and the Airbus A380 were a very small portion of the overall number of west and northwest arrivals in 2010 with just 340 operations. This number grew steadily over the next several years with just over 3,600 arrivals in 2015. This is still a very small number of the total arrivals, but there is a definite growth trend and these are very large and noticeable aircraft.
- Non-Jets: Propeller planes represented a large portion of arrivals in 2010 with just over 7,000 operations. This number remained fairly consistent until 2014 when it dropped to around 4,600 arrivals. A much more dramatic drop occurred in 2015 when there were just fewer than 1,000 non-jet arrivals.

All annual counts by aircraft category type are presented in Figure 9 below.

Figure 9. Annual Arrival Count by Aircraft Category Type
(Source: LAWA ANOMS Data 2010 - 2015)



Figures 10 and 11 below provide an alternative representation of the change in aircraft fleet mix from 2010 to 2015 through providing the percentage of aircraft arrivals by aircraft category type for 2010 and 2015 respectively.

Figure 10. 2010 Arrival Percentage by Aircraft Category Type
(Source: LAWA ANOMS Data 2010 - 2015)

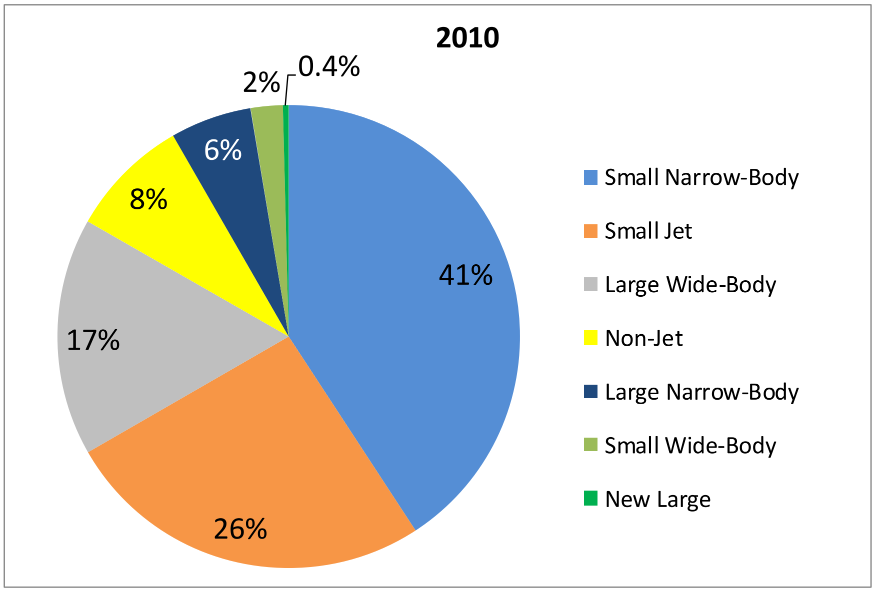
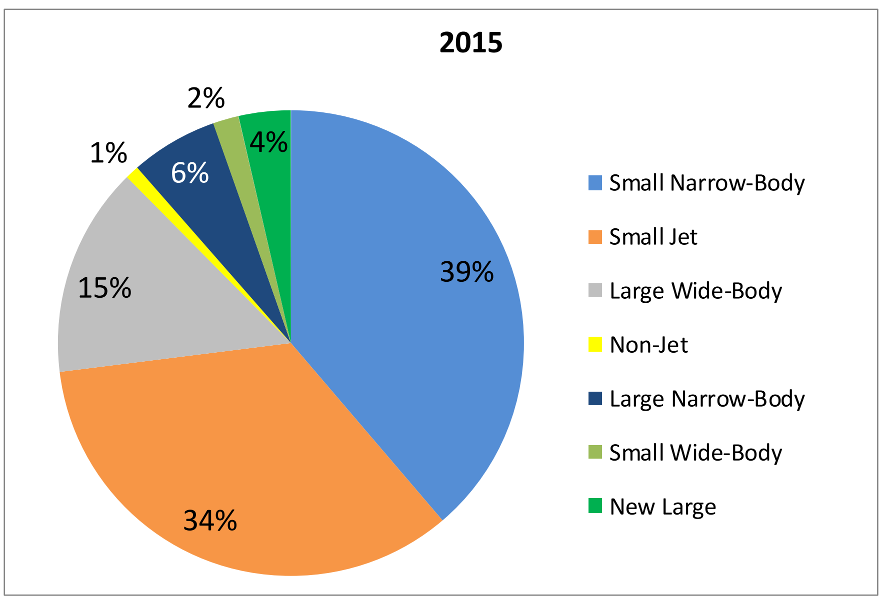


Figure 11. 2015 Arrival Percentage by Aircraft Category Type
(Source: LAWA ANOMS Data 2010 - 2015)



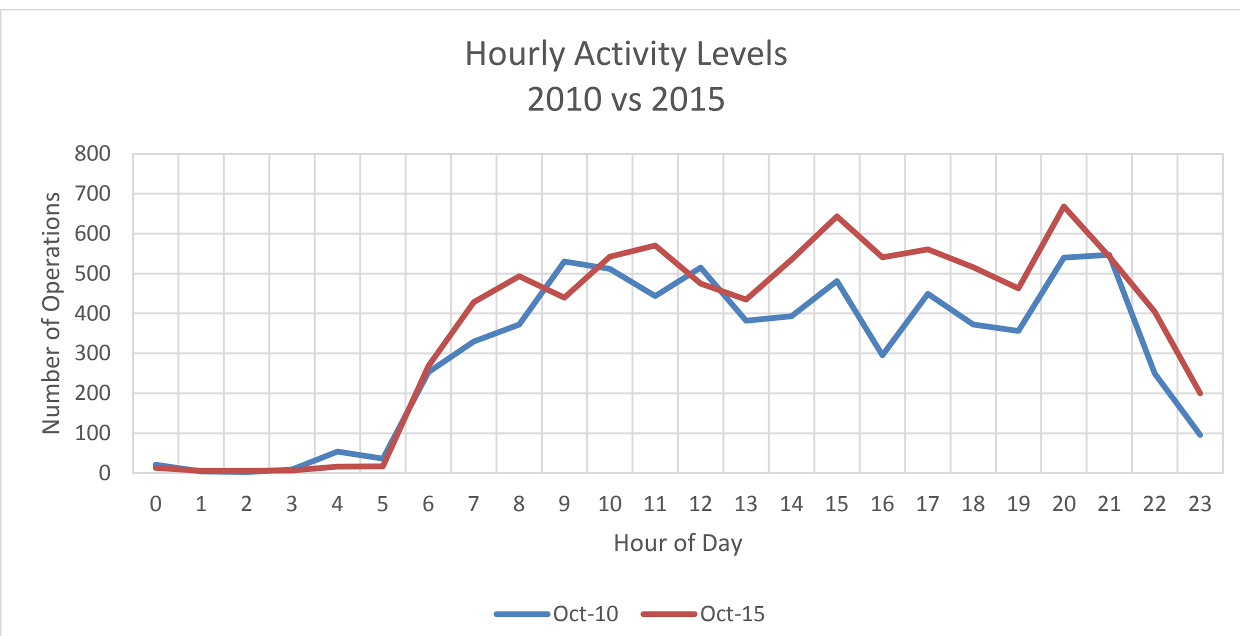
As noted in Section 5.1 and detailed in Figure 9 above, LAX operations increased throughout the study period. This overall increase in operations and changes in the fleet mix of some aircraft types within the NEM groups may have contributed to the perception by residents of greater aircraft noise levels and aircraft operation frequency over the communities under the flight path of the LAX northerly arrival corridor.

The changes in fleet mix, specifically within the New Large Jet NEM group, may have also contributed to the perception of increased noise and operations levels by residents under the LAX northerly arrival corridor. In general, large aircraft are more noticeable visually than smaller aircraft due to larger airframes and may generate higher single event noise levels when compared to smaller aircraft depending on aircraft model, engine type, and the number of aircraft engines. From 2010 to 2015 the proportion of New Large Jet NEM group increased by approximately tenfold, while other jet categories grew at lesser rates throughout the same period. Although the number of New Large Jet operations represents a small number of the total operations at LAX during the study period, the large increase in operations between 2015 and 2010 may have caused residents to perceive these aircraft as lower and louder since they are much larger than other aircraft.

5.3 Hourly Arrival Counts

Arrival counts for each analysis location were calculated by hour of the day for every month for the years 2010 and 2015. The results of this analysis were consistent with the results of earlier arrival count analysis: there was an overall increase in operations throughout the busiest time periods during the day in 2015 when compared to 2010. There were slight variations in the specific time of day at which peak morning and afternoon traffic hours occurred, but there were no discernible shifts in the specific time of afternoon and evening peaks. There were increased operations within the daytime (7AM – 7PM), evening (7-10 PM) and certain night time hours (10-11PM) throughout the day. The only time period in which arrival counts remained steady during both years was the very early morning between midnight and 6 AM. There were very few flights during these hours in both 2010 and 2015.

Figure 12. Hourly North Downwind Activity Levels October 2010 vs. October 2015
(Source: LAWA ANOMS Data 2010 - 2015)



The figure above shows a comparison of the number of operations per hour for the months of October 2010 and October 2015. Although only the month of October in 2010 and 2015 are shown, other months throughout the study period exhibited similar results although there may be variations within any given month. Data for other months can be found in the Supplemental Data Appendices.

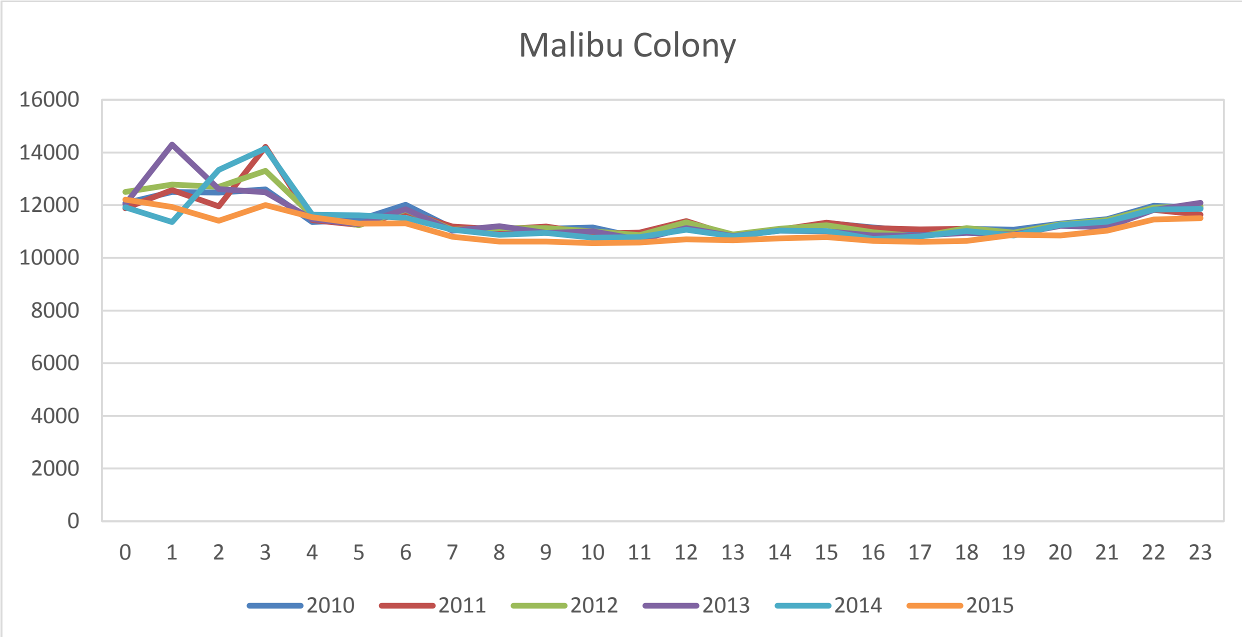
Table 3, below, shows the same months and values used in Figure 12 above, but set side-by-side, with the additional "percent" columns providing another way to visualize this comparison.

Table 3. Hourly North Downwind Activity Levels October 2010 vs. October 2015
(Source: LAWA ANOMS Data 2010 - 2015)

October 2010			October 2015		
Hour	Number of Operations	Percent	Hour	Number of Operations	Percent
0	21	0.3%	0	13	0.1%
1	4	0.1%	1	6	0.1%
2	3	0.0%	2	6	0.1%
3	9	0.1%	3	7	0.1%
4	54	0.7%	4	16	0.2%
5	36	0.5%	5	17	0.2%
6	253	3.5%	6	268	3.0%
7	330	4.6%	7	428	4.9%
8	372	5.1%	8	493	5.6%
9	530	7.3%	9	440	5.0%
10	512	7.1%	10	542	6.2%
11	444	6.1%	11	570	6.5%
12	515	7.1%	12	475	5.4%
13	382	5.3%	13	435	4.9%
14	393	5.4%	14	535	6.1%
15	481	6.6%	15	643	7.3%
16	295	4.1%	16	541	6.2%
17	449	6.2%	17	561	6.4%
18	372	5.1%	18	516	5.9%
19	356	4.9%	19	463	5.3%
20	540	7.5%	20	668	7.6%
21	547	7.6%	21	542	6.2%
22	250	3.5%	22	404	4.6%
23	96	1.3%	23	200	2.3%

The average altitudes for each hour were evaluated at each analysis location for all six study years. In the example provided in Figure 13, there were no substantial variations from year to year, with the notable exception of the early morning hours, which show variable altitudes for several years. However, these operations only amount to one percent of the total daily operations. The early morning hours are expected to have more variability due to the fact that there are far fewer operations during those times and, therefore, more flexibility for FAA in managing air traffic. The same variations during the early morning hours are seen on a daily, weekly and monthly basis throughout the study period.

Figure 13. Average Altitudes by Hour at Malibu Colony
(Source: LAWA ANOMS Data 2010 - 2015)



After reviewing the average aircraft operations and altitudes for each hour of the day throughout the study period, and for each of the gates, there were only slight variations in the frequency and altitude of operations between 2010 and 2015. Aircraft in 2015 were flying at a slightly lower (approximately 200 feet) altitude on the whole when compared to other years, which is within 2% of the altitude at approximately 11,000 feet above ground level. At the altitudes shown in Figure 13 (generally above 10,000 feet), this would translate to a change in noise level of less than 0.1 dB. The reasons for this observed change in altitude are unclear, but could be related to the increased level of traffic, or changes in fleet mix. The example showing Malibu Colony is representative of the other gates in this study. Data for other gates are available in the Supplemental Data Appendices.

6 Single-Event Noise Analysis

In order to determine whether noise levels due to northerly arrivals have changed over the study period, sound exposure levels (SEL) for each analysis location were modeled using the standard grid calculation feature of the FAA's INM Version 7.0d. HMMH uses a proprietary software system that turns each actual radar flight track into a model track for the INM for use in calculations. This software system is called RealContours™.

SEL is one of the most common measures of cumulative noise exposure for a single aircraft flyover. Mathematically, SEL is the sum of the sound energy over the entire duration of a noise event – one can think of it as an equivalent noise event with a one-second duration. Because the SEL is normalized to one second, it will almost always be larger in magnitude than the maximum noise level (Lmax) for the event. In fact, for most aircraft events, the SEL is about 7 to 12 dB higher than the Lmax. The fact that it is a cumulative measure means that when comparing two SEL values, a higher SEL results from either a louder event (i.e., higher maximum noise level) or a longer event (in duration), or a combination (both louder and longer). California law[8] specifies the use of SENEL, which is a slight variant of SEL, in that it considers the noise level over a period during which the noise level exceeds a threshold level, rather than over its entire duration. In most situations, the SEL and SENEL are identical.

The INM SEL metric computed for standard grids represents the total sound energy for all aircraft flown during a single model run. These total SEL values are normalized so the SEL represents the average of all flights flown during that modeling run. This was accomplished in the following manner:

$$\mathrm{SEL}_{\mathrm{DailyAverage}} = \mathrm{SEL}_{\mathrm{DailyTotal}} - 10 * \log_{10}(\ 1.0\ /\ \#\ \text{of operations for that day}\ )$$

This yielded daily average SEL values for a given group during a given month at a given location. These daily average numbers were arithmetically averaged to yield the monthly SEL value used for final analysis and comparison.

$$\mathrm{SEL}_{\mathrm{MonthlyAverage}} = \left(\sum_{d=1}^{\#\ of\ days} \mathrm{SEL}_{\mathrm{DailyAverage}}\right)\ /\ (\ \#\ \text{of days}\ )$$

This SEL value is referred to as the average daily SEL for the month.

Daily SELs were computed by the INM at each analysis location for the NEM Groups as well as the AC groups as detailed in Section 5. These daily SELs were then averaged to compute an average monthly SEL value for each aircraft group or category at each analysis location. Monthly SELs were calculated for April 2010-2015 as well as October 2014 and October 2015.

There are 10 analysis locations, but another 20 locations were added for modeling exposure 1000 feet to the left and to the right of the center of the gate at each analysis location.

For 16 groups (11 AC groups and 5 NEM groups), over a 30-day period requires 480 INM standard grid modeling runs. Modeling six April months between 2010 and 2015, plus two October months in 2014 and 2015 required a grand total of 3,840 total INM modeling runs.

6.1 Same-Month Comparison over Study Period

The figures below show the average daily SEL values during the month of April in years 2010 through 2015 for all aircraft and each of the NEM aircraft groups described in Section 5: non-jets, small narrow-body, large narrow-body, large wide-body and new large aircraft.

[8] California Airport Noise Standards, California Administrative Code, Title 21, Public Works, Chapter 2.5, Subchapter 6.

Figure 14. Average Daily SEL Values (dB) for All Aircraft

(Source: HMMH RealContours™ and LAWA ANOMS data 2010-2015)

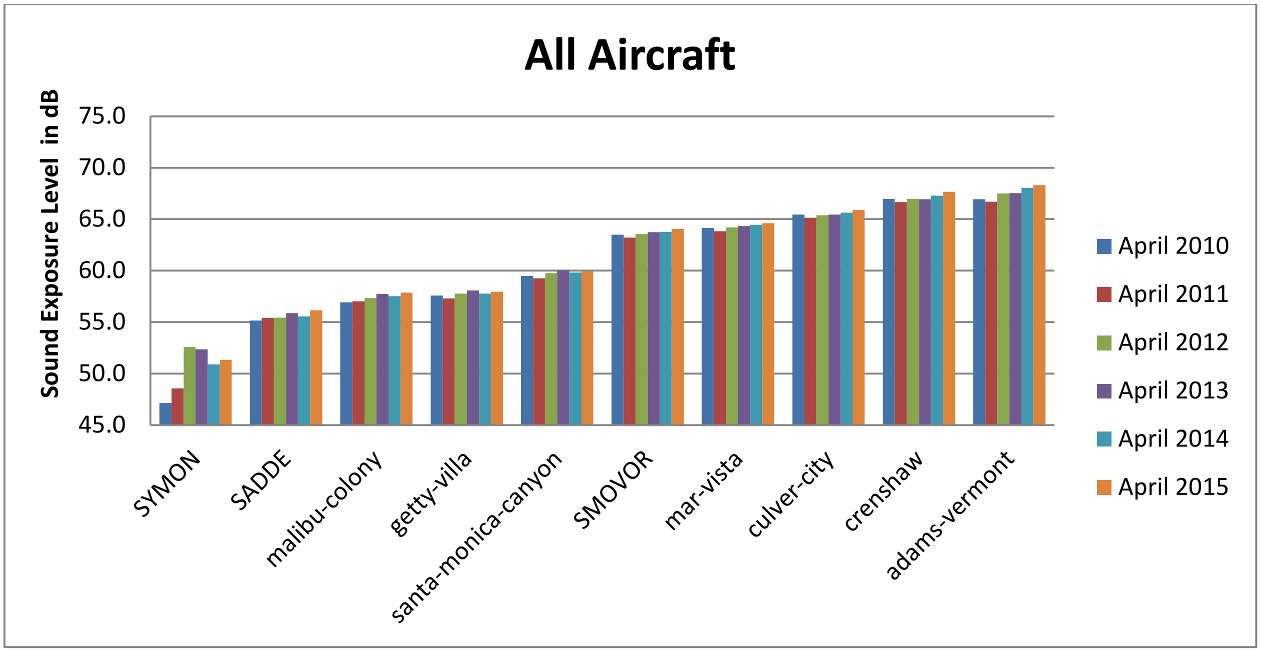


Figure 15. Average Daily SEL Values (dB) for Non-Jet Aircraft

(Source: HMMH RealContours™ and LAWA ANOMS data 2010-2015)

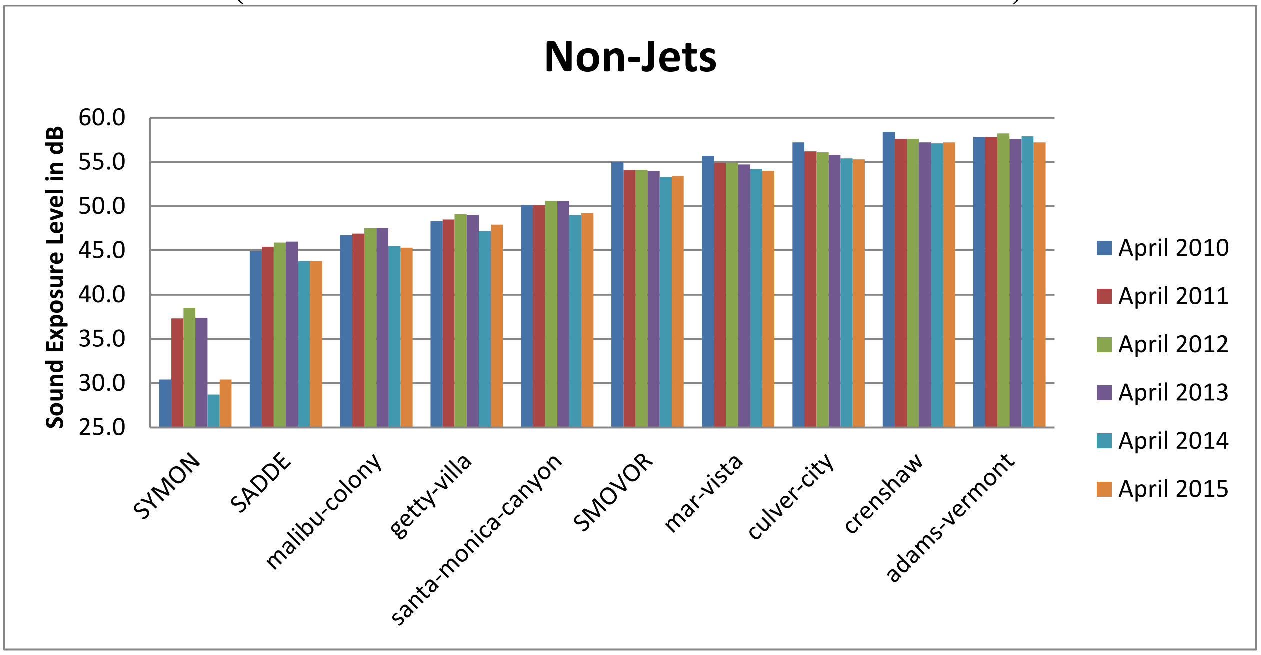


Figure 16. Average Daily SEL Values (dB) for Small Narrow-Body Aircraft
(Source: HMMH RealContours™ and LAWA ANOMS data 2010-2015)

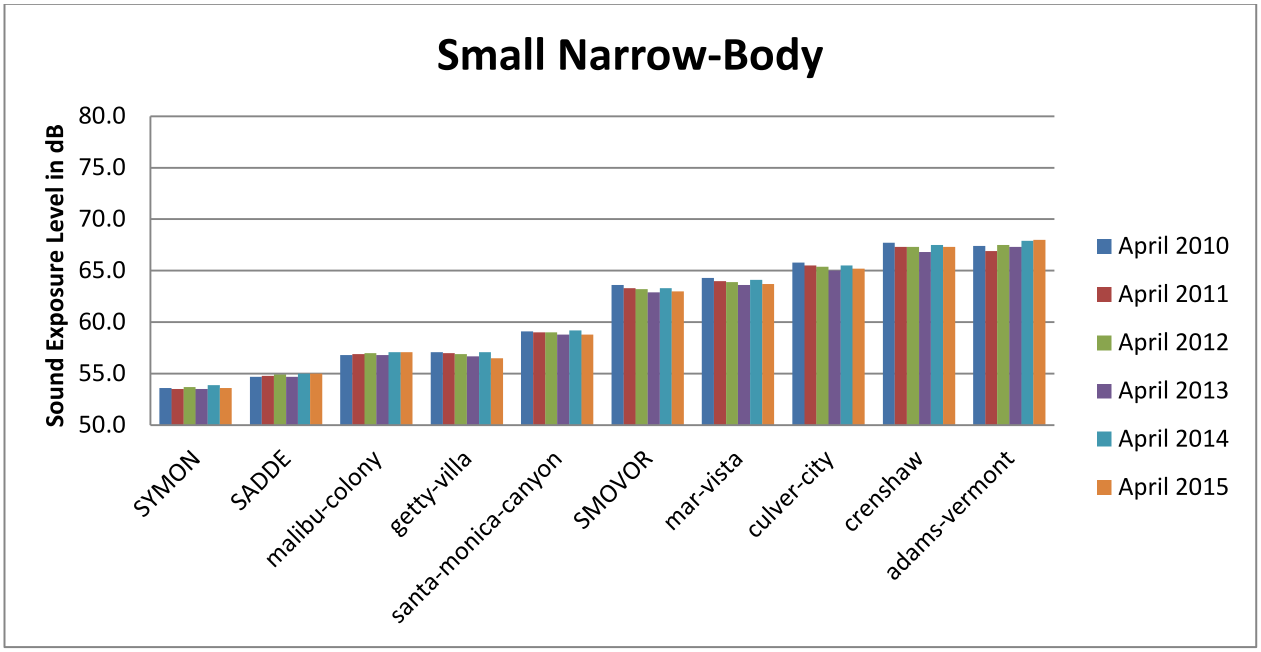


Figure 17. Average Daily SEL Values (dB) for Large Narrow-Body Aircraft
(Source: HMMH RealContours™ and LAWA ANOMS data 2010-2015)

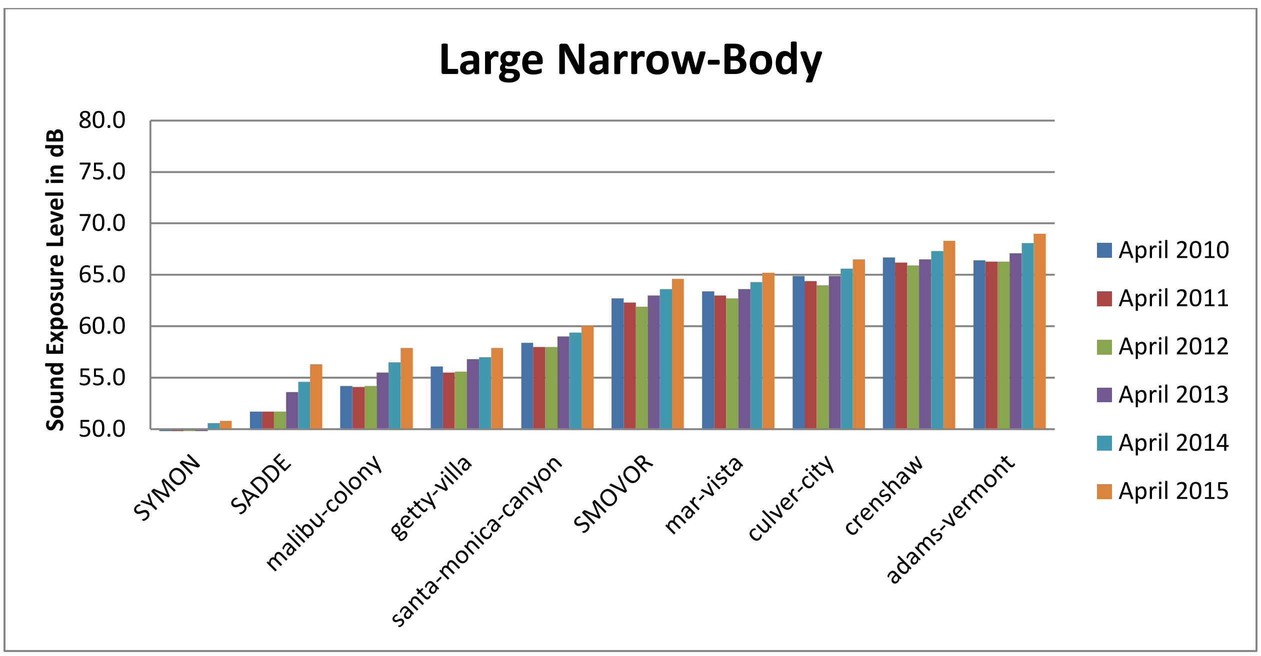


Figure 18. Average Daily SEL Values (dB) for Large Wide-Body Aircraft
(Source: HMMH RealContours™ and LAWA ANOMS data 2010-2015)

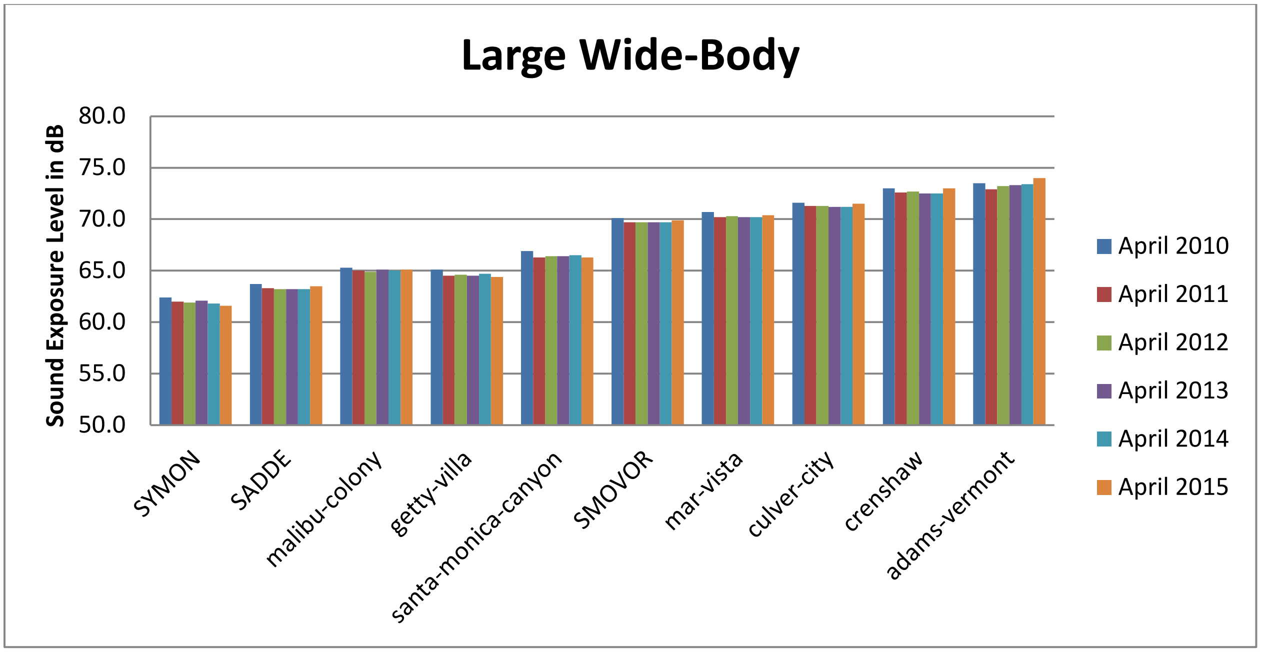
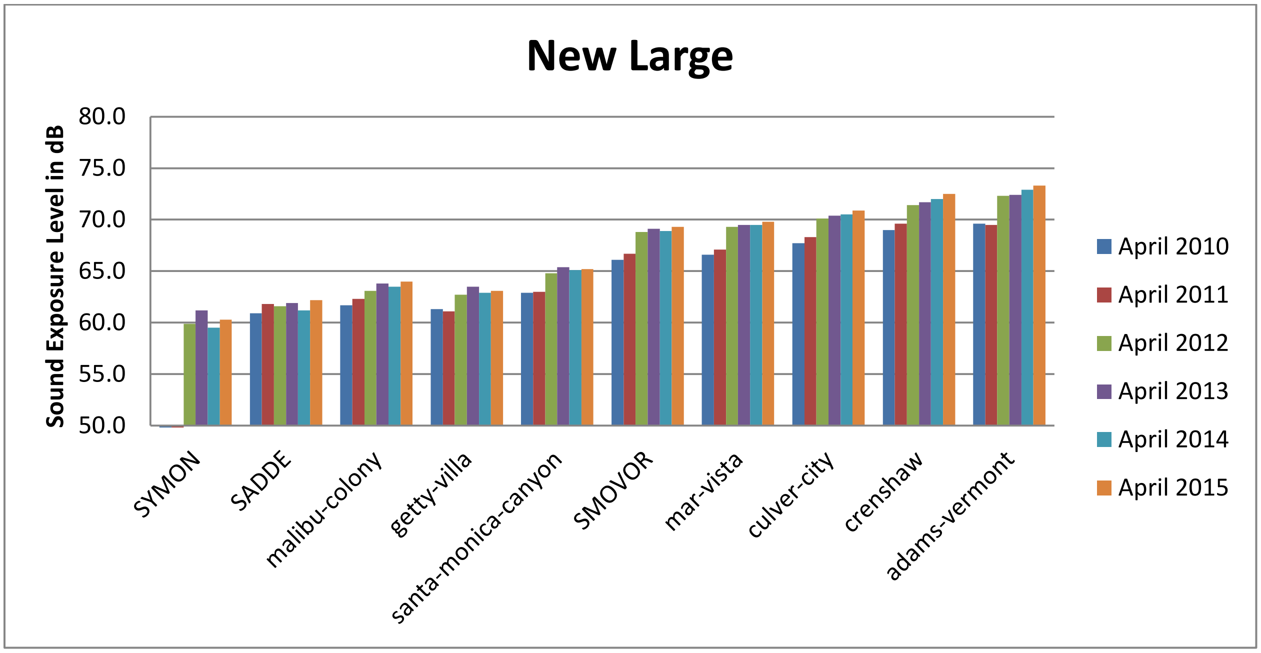


Figure 19. Average Daily SEL Values (dB) for New Large Aircraft
(Source: HMMH RealContours™ and LAWA ANOMS data 2010-2015)



The data from these plots suggest the following:

- Figure 14 shows that average daily SEL values for all aircraft flying the north downwind arrival route into LAX showed an increase from April 2010 to April 2015, ranging from an average of 0.5 dB at the Culver City gate to as much as 1.6 dB at the Adams-Vermont gate. This is most likely a result of changes to fleet mix that have resulted in larger aircraft in several categories (i.e., the 757-300 is both larger and louder than the 757-200). And while aircraft technology trends have driven average aircraft noise levels down over the last decade, most of the benefit has been achieved in reduced noise levels for departures, not arrivals.
- The review of non-jet aircraft (Figure 15) indicates up to a 3 dB reduction in average SEL (except at the SYMON gate, which shows wider variability in values and overall very low noise levels).
- Figure 16 shows that changes in average SEL for the small narrow-body aircraft group (such as the 737), were generally small, ranging from a 0.6 dB reduction at some locations (SMOVOR and Culver City) to a 0.6 dB increase at others (Adams Vermont). This is likely a result of fleet evolution as well.
- The biggest changes were observed in the large narrow-body aircraft group. Figure 17 shows that there was a 2 to 4 dB increase in average SEL at most locations. Additional analysis is provided below.
- The large wide-body aircraft group showed increases of as much as 1 dB, which is likely the influence of the new large aircraft (discussed below).
- The new large aircraft group includes the A380 and 747-800 aircraft. It shows an increase in SEL of up to 4 dB at some locations. This group was also tagged for further analysis by individual aircraft type (discussed below).

Further analysis was completed for the large narrow-body and new large aircraft that showed an average SEL increase greater than 1 dB. Figures 20, 21, 23 and 24 provide the same average daily SEL results as shown above, but for the aircraft that make up the large narrow-body aircraft group (Boeing 757 and 787 aircraft types) and the new large aircraft group (Airbus A380 and Boeing 747-800 aircraft types).

Figures 20 and 21 indicate that the increased average SEL values observed in the large narrow-body group is primarily due to the change in Boeing 757 noise levels and to the addition of Boeing 787 to the fleet mix in 2014. Figure 22 shows the monthly activity levels of these aircraft in 2014 and 2015 and it shows a marked decline in the use of Boeing 757-200 aircraft near the end of summer 2015, which is after the April 2015 analysis timeframe for the average daily SEL analysis. Prior to the marked decline in the use of 757-200 aircraft at LAX, there was an increase in use of all three large narrow-body aircraft types through the summer of 2015, coinciding with the narrowing of the downwind leg. Given that Boeing 757-300 aircraft are larger and also louder, the increase in the number of Boeing 757-300 aircraft operations at LAX in April 2015 (approximately 150 operations), compared to April 2014 (approximately 60 operations), is likely a contributing factor to the rise in average daily SEL values.

Large narrow-body aircraft type analysis:

Figure 20. Average Daily SEL Values (dB) for Boeing 757 Aircraft
(Source: HMMH RealContours™ and LAWA ANOMS data 2010-2015)

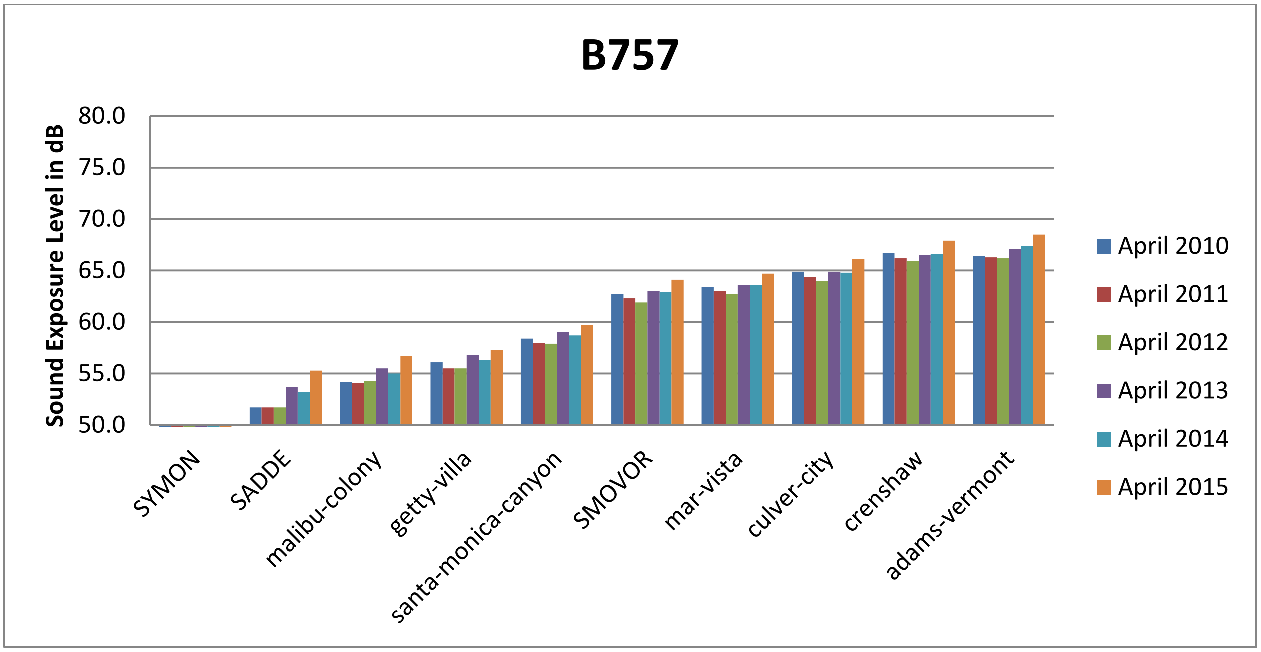


Figure 21. Average Daily SEL Values (dB) for Boeing 787 Aircraft
(Source: HMMH RealContours™ and LAWA ANOMS data 2010-2015)

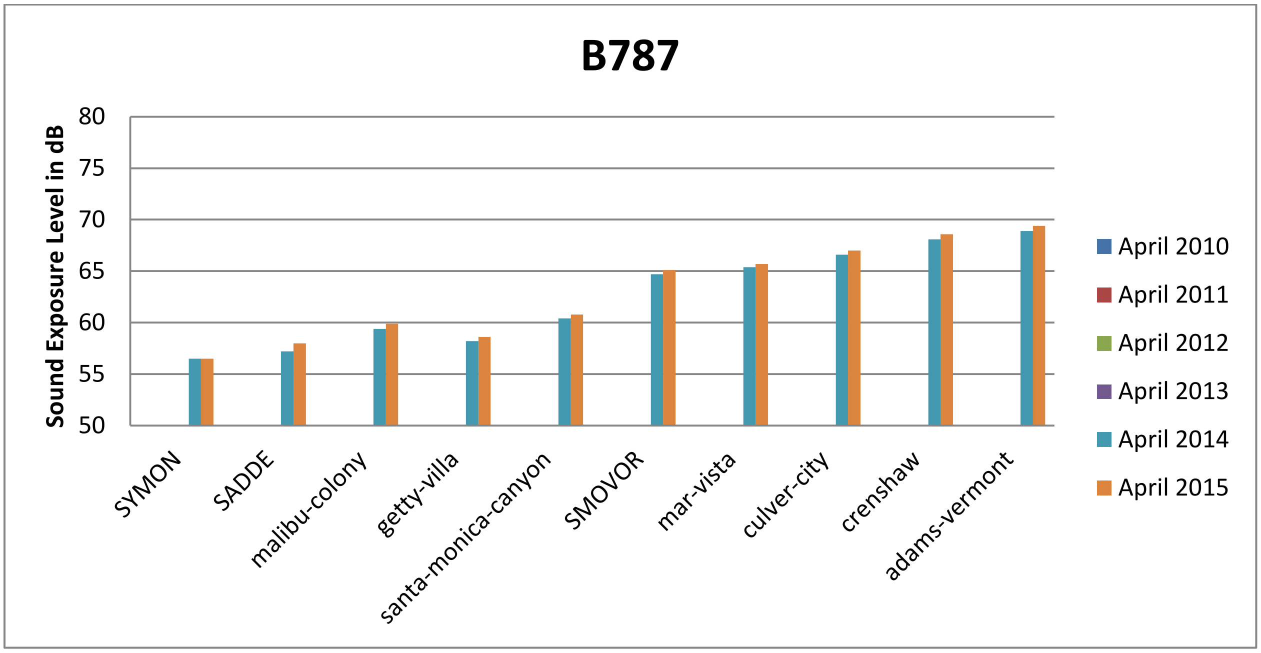
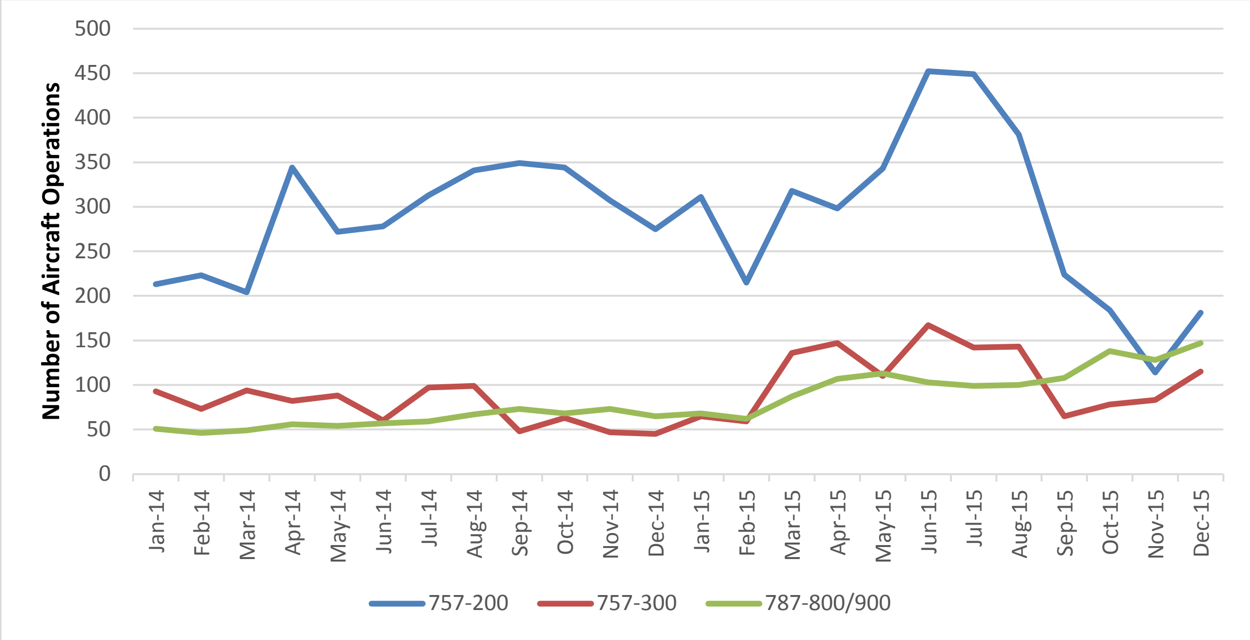


Figure 22. Monthly Activity Levels for Large Narrow-Body Aircraft
(Source: HMMH RealContours™ and LAWA ANOMS data 2010-2015)



New large aircraft type analysis:

Figure 23. Average Daily SEL Values (dB) for Airbus A380 Aircraft
(Source: HMMH RealContours™ and LAWA ANOMS data 2010-2015)

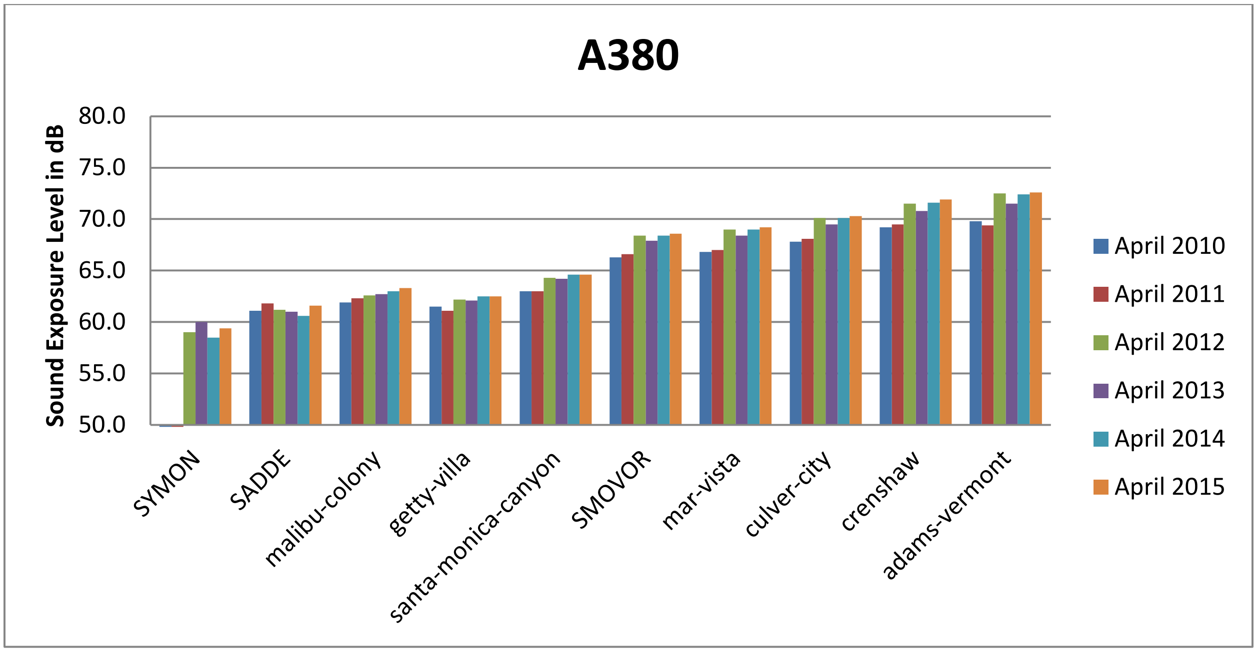
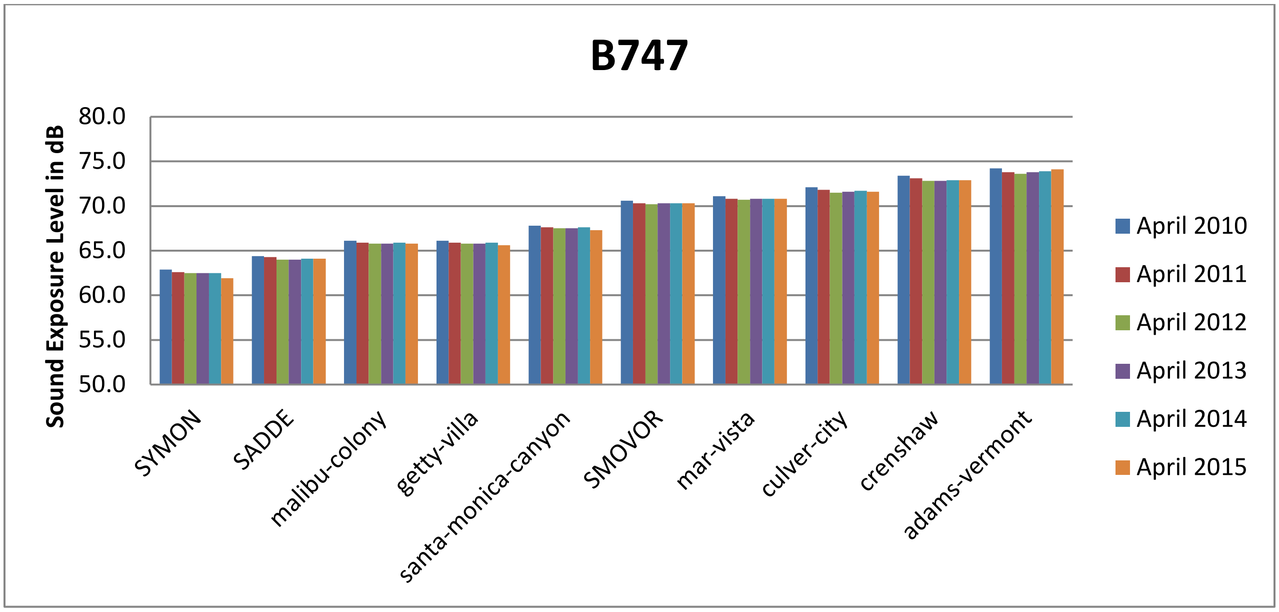


Figure 24. Average Daily SEL Values (dB) for Boeing 747 Aircraft
(Source: HMMH RealContours™ and LAWA ANOMS data 2010-2015)



As shown above, the Average Daily SEL values for the Boeing 747 aircraft type changed very little over the six-year period, while the Airbus A380 aircraft type increased in noise level by as much as 4 dB at some of the analysis gates. We did note that the A380 SEL values prior to 2012 were based on very few operations of this newer aircraft type. Therefore, as these aircraft increased operations, the higher

Average Daily SEL value may be more representative of how and where these aircraft fly in relation to the analysis locations.

7 Altitude Distribution and Flight Track Dispersion

The following section describes the methodology for analyzing altitude and flight track distribution and the results for use in this study.

7.1 Gate Creation

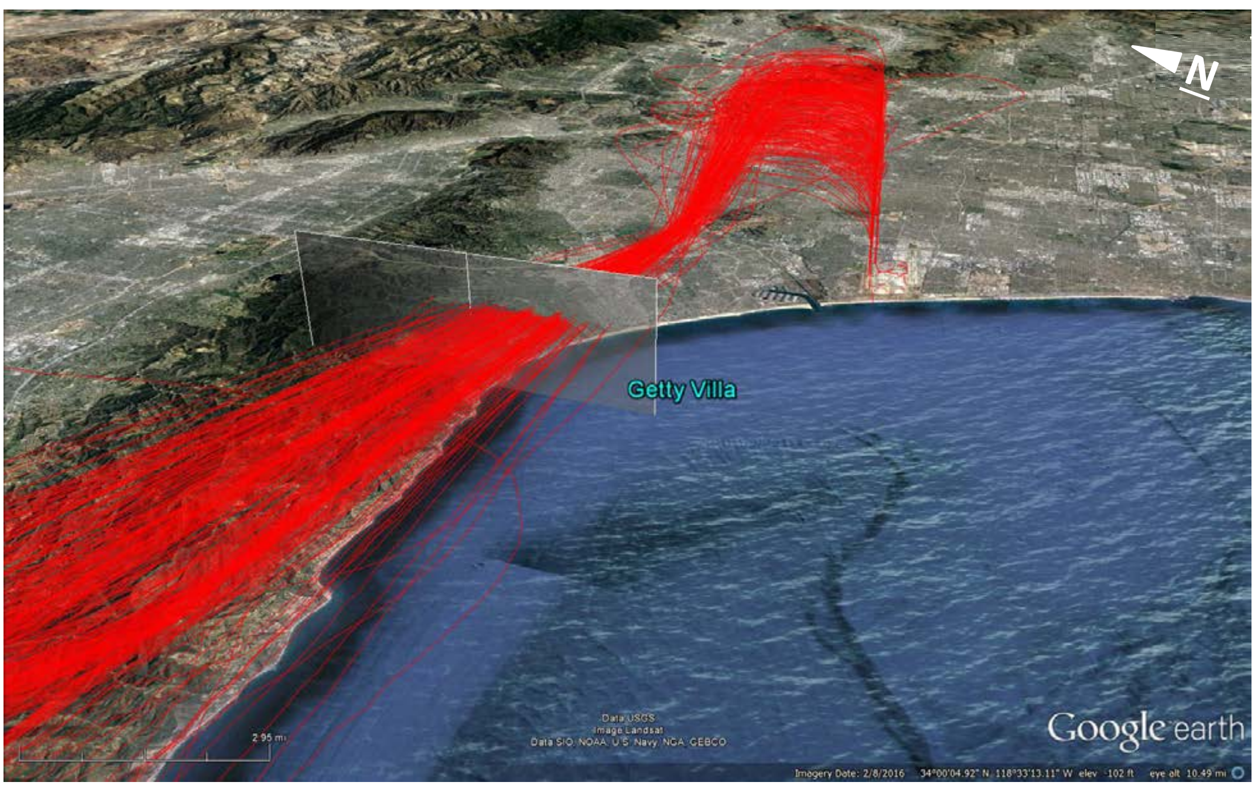
7.1.1 Gate Definition and Orientation

In order to investigate altitude distributions over analysis locations, a vertical gate in space was constructed and centered (anchored) over each analysis location, as described in Section 3. Each gate was defined by its anchor point, an orientation vector (in X and Y along the ground), a left width, a right width and an altitude (ceiling).

The orientation vector is a compass heading (true north) which a flight track is expected to progress to and penetrate through a given gate. As a pilot would be approaching this gate along this heading, there is a “left side” and “right side” to the gate, relative to the pilot seated in the cockpit. The left width is from the center of the gate to the left side. The right width is from the center to the right side.

The figure below represents the gate at Getty Villa with a number of northerly arrival tracks penetrating the gate at points called gate intersections.

Figure 25. Gate Intersections at Getty Villa
(Source: LAWA, Google Earth 2016)



7.1.2 Gate Intersections

A gate intersection (or gate crossing) is the location in space and time where a flight track penetrates a vertical gate. Each gate intersection is identified by the specific flight track (operation), the time of penetration, the altitude (feet, MSL) at the penetration point, and the left/right deviation (+/- feet) of the penetration point from the center (anchor point) of the gate. The deviation is zero at the center of the gate. Deviations to the left side of the gate are represented by negative distance values, while deviations to the right side of the gate are represented by positive distance values.

Gate crossing data for each flight track at each analysis location was computed and stored in the database. These crossing data were used to calculate average altitude and average deviation for use in the subsequent analyses presented later in this section.

The raw crossing data is provided as part of the deliverable data sets. Table 4 below is a small sample of this data set and identifies the columns contained in the data. The “OPID” column is the operation ID number unique to each flight track generated by the Bruel & Kjaer noise monitoring system, and is used as an index to refer back to individual flight tracks.

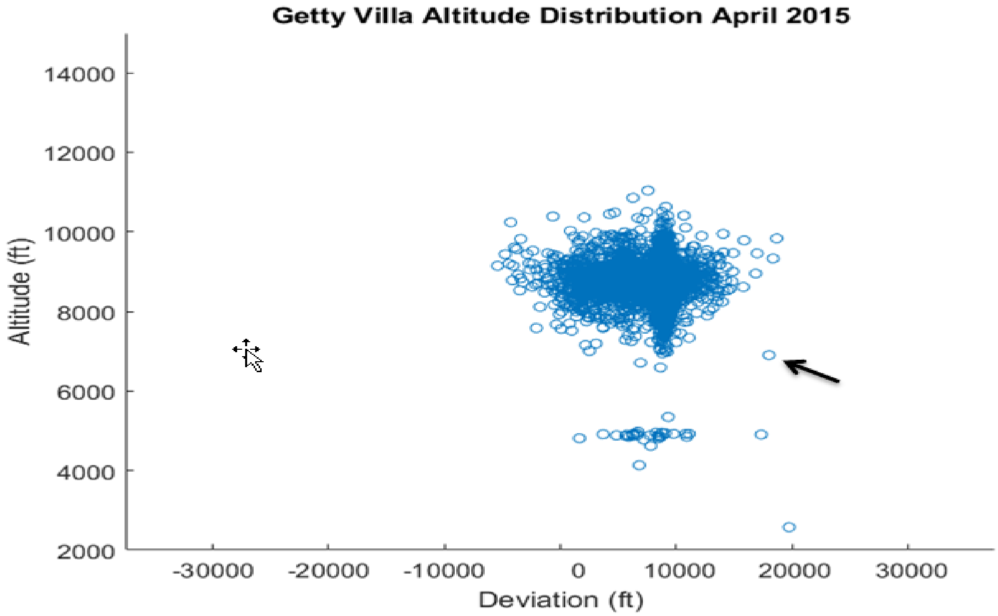
Table 4. Sample Gate Crossing Data
(Source: LAWA ANOMS Data 2010-2015)

OPID	GATENAME	AC TYPE	XTIME	ALT (ft)	DEV (ft)
39152183	G_SADDE	B77W	2015-01-01T06:26:01	9858	-839
39152183	G_malibu-colony	B77W	2015-01-01T06:26:49	9858	-646
39152183	G_getty-villa	B77W	2015-01-01T06:28:11	8454	8923
39152183	G_santa-monica-canyon	B77W	2015-01-01T06:28:45	7791	6512
39152183	G_SMOVOR	B77W	2015-01-01T06:29:22	7250	-164
39152183	G_mar-vista	B77W	2015-01-01T06:29:41	6916	1023
39152183	G_culver-city	B77W	2015-01-01T06:30:13	6374	-147
39152190	G_SADDE	A332	2015-01-01T06:30:43	9868	580
39152183	G_crenshaw	B77W	2015-01-01T06:30:57	5334	141
39152190	G_malibu-colony	A332	2015-01-01T06:31:32	9868	-42
39152183	G_adams-vermont	B77W	2015-01-01T06:31:36	4206	2463
39152195	G_SYMON	CRJ2	2015-01-01T06:32:25	11423	137
39152190	G_getty-villa	A332	2015-01-01T06:32:49	8070	9015
39152190	G_santa-monica-canyon	A332	2015-01-01T06:33:24	7696	6607
39152195	G_SADDE	CRJ2	2015-01-01T06:33:54	10374	-4350

Using data from the database such as the example presented in Table 4 above, a scatter plot of the gate crossings can be generated. Figure 26 below shows the altitude distribution scatter plot for the Getty Villa gate for April 2015, where each dot represents one gate penetration. For example, the single dot to which the arrow is pointing is a Compass Airlines Embraer 170.

Figure 26. Altitude Distribution at Getty Villa – April 2015

(Source: HMMH, LAWA ANOMS Data 2010 - 2015)



The x-y scatter plot seen in Figure 26 can be used to represent all of the gate crossings over a period of time – for example one day, one month, or one year. However, this visualization of gate crossing points is less helpful when analyzing a large number of crossings due to overlap.

As an x-y scatter plot is generated, each gate crossing produces one point on the graph. The scatter plot in Figure 26 is monochromatic in that there in that there is only one color used to represent crossing points on the background. As multiple crossing points may occur at the same position on the plot, areas become filled in with the same color producing areas of solid colors. There is nothing in the scatter plot that provides visual cues as to how many overlapping gate crossings there may be at a given x-y location on the plot.

To overcome issues with overlapping gate crossings and better visualize the "density" of crossings, the advanced visualization technique of developing density maps (or heat maps) for each gate was employed.

7.1.3 Altitude Distribution Density Map

A density map (or "heat" map) uses many colors to represent how many crossings have occurred and each location on the scatter plot. This analysis uses a rainbow spectrum map that depicts lower counts "cool" colors (e.g., blue) and higher counts as "warm" colors (e.g., red). Using this technique, the locations of the highest concentration of gate crossings are readily apparent.

In order to produce a density map of gate crossings, a 2-dimensional "grid", which represents altitudes (Y-axis) and deviations (X-axis) of gate crossing positions, was produced. For all gate crossing density maps developed for this study, a grid of 1,000 rows and 2,000 columns is used, regardless of the actual physical size of the gate itself. So these grids contain 2 million "cells". Each cell maps to a unique rectangle on the gate and each cell contains a counter of the number of crossings detected for that cell.

For each gate crossing over the time period of the plot being generated, the "cell" that this crossing belongs to is computed using the altitude and deviation of the gate crossing. The counter in that cell is incremented by 1 for each gate crossing intersecting that cell.

Once the grid of crossing "counts" are computed, the smallest and largest count values are determined. The largest value will be mapped to the "hottest" color in the rainbow color map, and the smallest count will be mapped to the "coolest" color of the rainbow map. Values between the smallest and largest values are mapped in a linear fashion so that values in the middle are mapped to the middle of the rainbow spectrum.

Each cell can then be changed from a value into a color and is then drawn on the density map graph in the color representing its count value.

Figure 27. Altitude Distribution Density at Getty Villa – April 2015
(Source: HMMH, LAWA ANOMS Data 2010 - 2015)

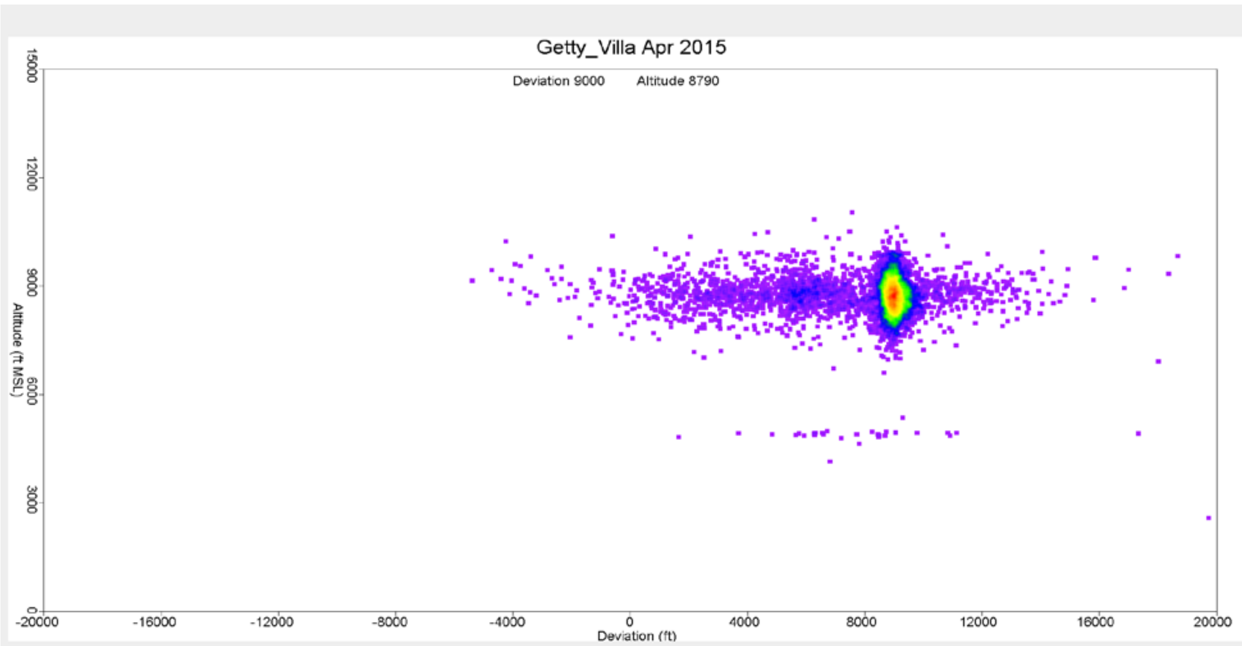


Figure 27 above shows the altitude distribution density map for the Getty Villa gate for April 2015, produced from the same gate crossing data as depicted in Figure 26: Altitude Distribution Scatter Plot for Getty Villa - April 2015. The scale and aspect ratio for the two figures are slightly different, but it is evident that there is much more information conveyed by the density map image. In Figure 27, it is clearly visible that flight tracks are most concentrated at a distance between approximately 8,000 feet and 10,000 feet laterally to the right of the analysis location defined as the center for the Getty-Villa gate, and between approximately 8,000 feet and 10,000 feet in altitude. In Figure 26, it is difficult to determine where flight tracks are the most concentrated, as track density appears the same between the analysis location defined as the center for the Getty-Villa gate and approximately 15,000 feet laterally to the right, and between approximately 7,000 feet and 11,000 feet in altitude.

7.2 Altitude Distribution Density Maps and Results

Altitude distribution density maps were prepared for all ten gates, for each month of the six-year analysis period. As a result, 720 altitude distribution graphs were prepared (i.e., 72 for each gate), which were examined for noticeable changes throughout the six-year period.

To perceive changes in altitude distribution visually over a year, or multiple years, a technique called "page flipping" is used to "flip" through the density map images in chronological order for a given gate at an analysis location. Page flipping allows patterns to emerge in the sequence that may be overlooked when viewing single graphs.

7.2.1 Altitude Distribution Density East of the SMO VOR/DME

A review of the density map images in chronological order throughout the six-year study period indicate that during the period from January 2010 to May 2014 the flight track dispersion of LAX northerly arrivals at each gate east of the SMO VOR/DME remained largely consistent on a month-to-month basis. The dispersion pattern of the gate crossings in each month studied shows a fairly circular pattern (see Figures 13-17in Appendix D for an example) implying rather uniform and even dispersion patterns in both altitude and deviation. This is indicative of aircraft flying several different headings on the arrival procedure that result in greater variation in dispersion when aircraft cross each gate.

By contrast, during the subsequent months, in the period extending from June 2014 to June 2015, data revealed that flight track dispersion east of the SMO VOR/DME through the gates of Mar Vista, Culver City, Crenshaw, and Adams Vermont became more concentrated. This dispersion of gate crossings shows a more elliptical pattern, reflecting a greater lateral concentration while the altitude dispersion remained relatively unchanged. This is indicative of a “narrowing” of the flight paths.

After June 2015, data for each month showed that tracks east of the SMO VOR/DME progressively increased in dispersion and returned to levels consistent with the density map images in the months prior to June 2014 and showed little change throughout the remainder of the study period. Thus, there appear to be three distinct phases or periods where a shift in data is noticeable: before June 2014, from June 2014 through June 2015, and after June 2015. The transitions from dispersed to concentrated flight paths, followed by a return to dispersed flight paths did not occur overnight, but rather gradually. While there was a lateral shift in flight tracks, the vertical component (i.e., altitude) of flight tracks remained fairly consistent throughout the study period

An example of the decrease in dispersion east of the SMO VOR/DME during the period from June 2014 to June 2015 when compared to other months during the study period is demonstrated in Figure 28 and Figure 29 below. Figure 28 shows the density map for the gate positioned at Culver City of LAX northerly arrivals during the month of April 2014, in which flight track density at the first gate located east of the SMO VOR/DME is consistent with the months before June 2014 and after June 2015. Figure 29 shows the density map for the gate positioned at Culver City of LAX northerly arrivals during the month of April 2015, in which flight track dispersion east of the SMO VOR/DME is consistent with the reduction of track dispersion that occurred during the period of June 2014 to June 2015.

Although only the density maps for the gates positioned at Culver City for April 2014 and April 2015 are presented in this section, density maps for each month from January 2014 through December 2015 are provided in Appendix D at the conclusion of this report and are consistent with the results of density maps for other gates east of the SMO VOR/DME. Density maps for all gates and additional months throughout the entire six-year study period not included in Appendix D can be found in the Supplemental Data Appendices.

Figure 28. Altitude Distribution Heat Map, Culver City, April 2014
(Source: HMMH, LAWA ANOMS Data 2010 – 2015)

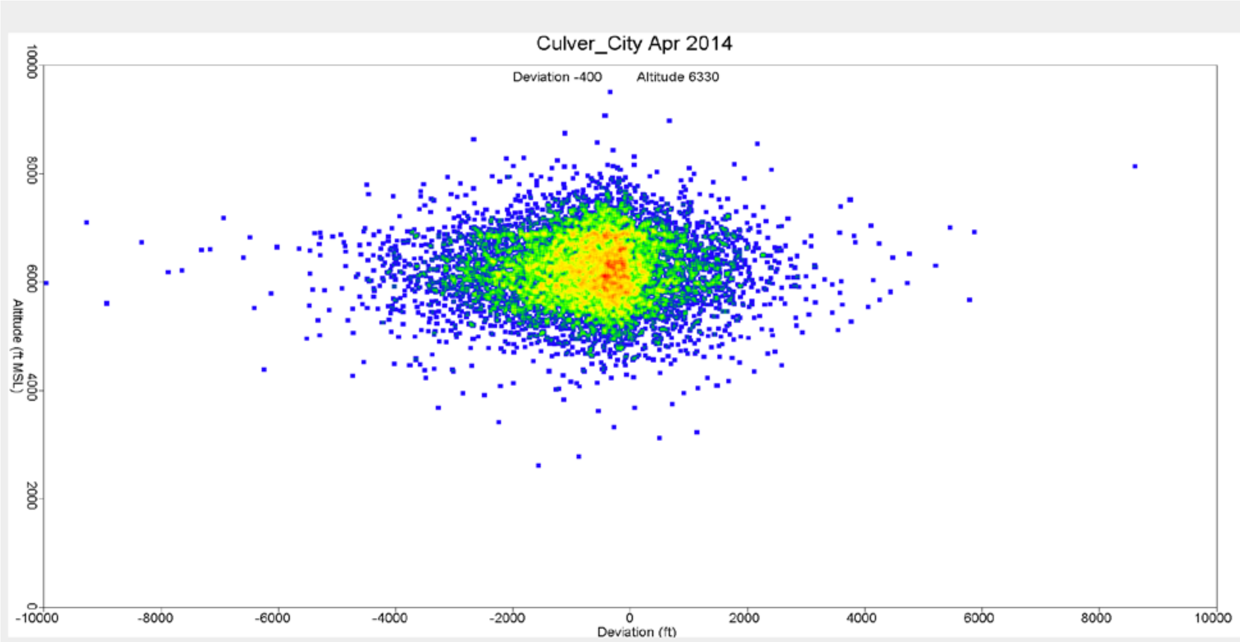
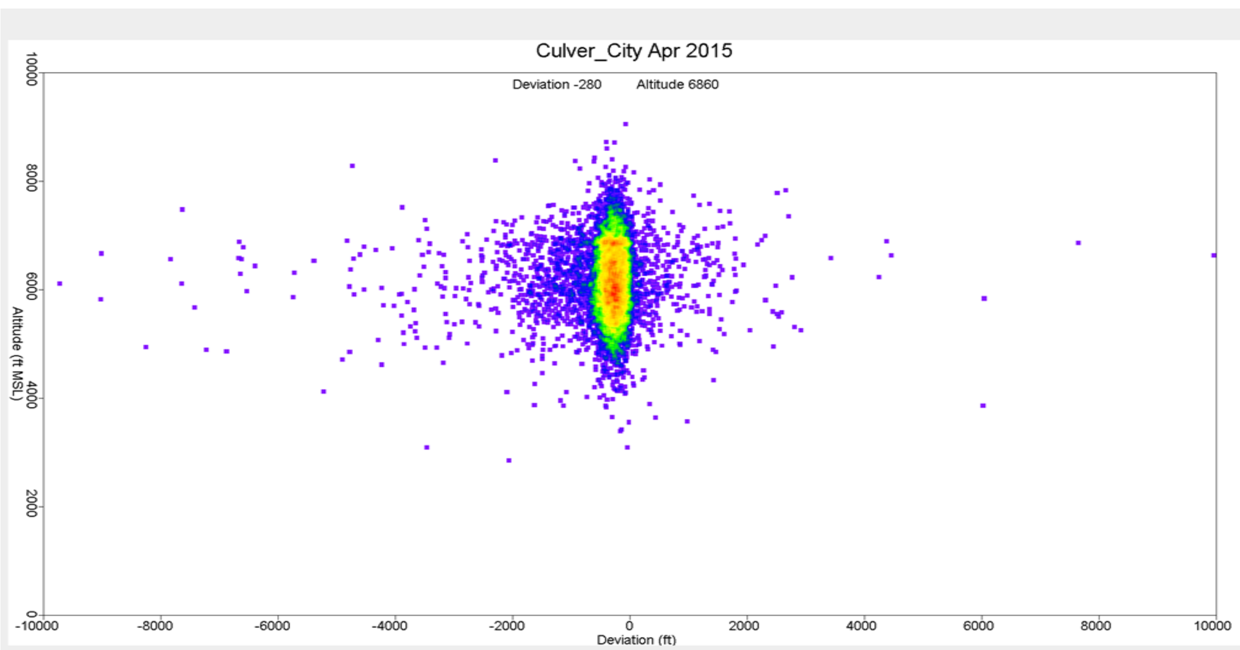


Figure 29. Altitude Distribution Heat Map, Culver City, April 2015
(Source: HMMH, LAWA ANOMS Data 2010 – 2015)



As demonstrated in Figure 28 and Figure 29 above, there was a noticeable decrease in lateral flight track dispersion, which had been the previous normal conditions going back to at least 2010, east of the SMO VOR/DME between June 2014 and June 2015 over the gate positioned at Culver City. This indicates aircraft during this period were flying with greater frequency over a narrower route, and likely contributed to the residents' perception of increased flights near the center of the traffic stream, while resident further away experienced a reduction in overflights. After June 2015 when flight tracks once again became more dispersed, the opposite happened and communities which had noticed fewer overflights were once again seeing them more often. This back and forth changing of flight tracks and overflights over certain communities may have contributed to more individuals becoming sensitized to aircraft noise.

7.2.2 Altitude Distribution Density West of the SMO VOR/DME

A review of the density map images in chronological order throughout the six-year study period indicate the flight track dispersion of LAX northerly arrivals at each gate west of the SMO VOR/DME remained consistent on a month to month basis. There were minimal changes in flight track dispersion, and gate locations west of the SMO VOR/DME did not exhibit the changes in flight track dispersion present at gate locations east of the SMO VOR/DME between June 2014 and June 2015 as described in Section 7.2.1 above. At gates west of the SMO VOR/DME the dispersion pattern of the gate crossings showed an elliptical pattern implying a concentrated pattern of lateral gate penetrations over the same dispersion in altitude. This is indicative of aircraft flying the same, or very similar, headings that result in smaller levels of variation in lateral dispersion when aircraft cross each gate.

An example of the consistent dispersion west of the SMO VOR/DME during the study period is demonstrated in Figure 30 and Figure 31 below. Figure 30 shows the Density Map for the gate positioned at Santa Monica Canyon of LAX northerly arrivals during the month of April 2014, which exhibits flight track dispersion west of the SMO VOR/DME consistent with the months before June 2014 and after June 2015 when flight track dispersion remained largely unchanged from month to month at gate locations east and west of the SMO VOR/DME. Figure 31 shows the density map for the gate positioned at Santa Monica Canyon of LAX northerly arrivals during the month of April 2015, which exhibits flight track dispersion during the period of June 2014 to June 2015 consistent with the reduction of track dispersion (i.e., narrowing of the arrival stream) that occurred at gate locations east of the SMO VOR/DME.

Although only the density maps for the gates positioned at Santa Monica Canyon for April 2014 and April 2015 are presented in this section, density maps for each month from January 2014 through December 2015 are provided in Appendix D at the conclusion of this report and are consistent with the results of Density Maps for other gates west of the SMO VOR/DME. Density maps for all gates and additional months throughout the entire six-year study period not included in Appendix D can be found in the Supplemental Data Appendices.

Figure 30. Altitude Distribution Heat Map, Santa Monica Canyon, April 2014
(Source: HMMH, LAWA ANOMS Data 2010 – 2015)

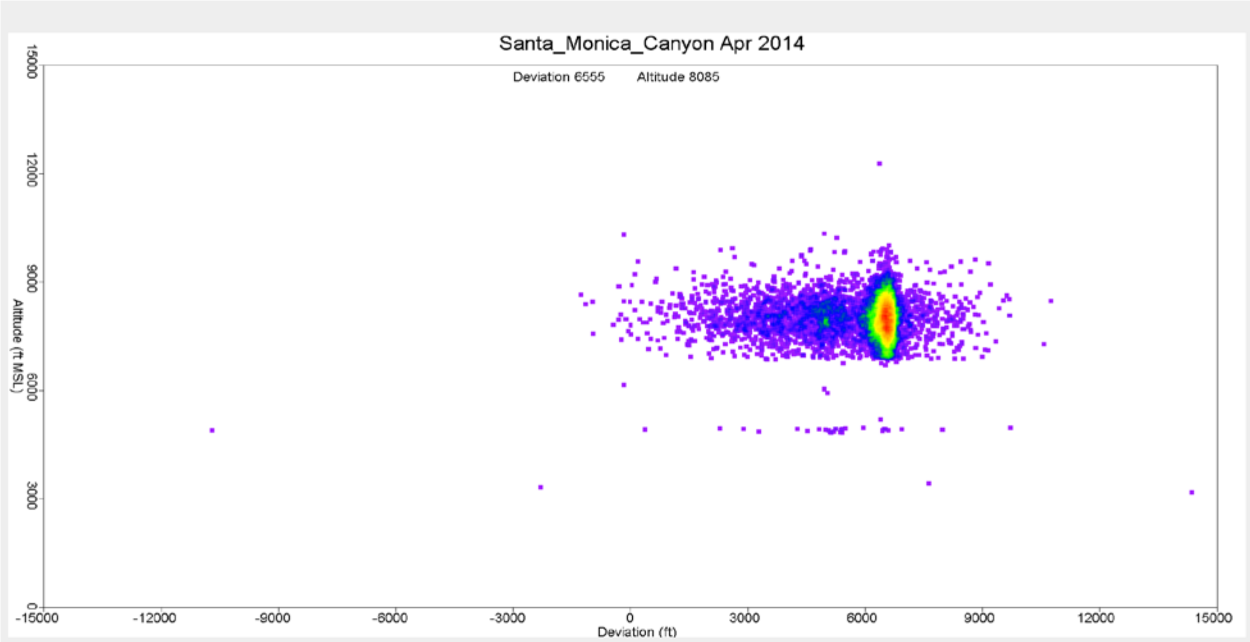
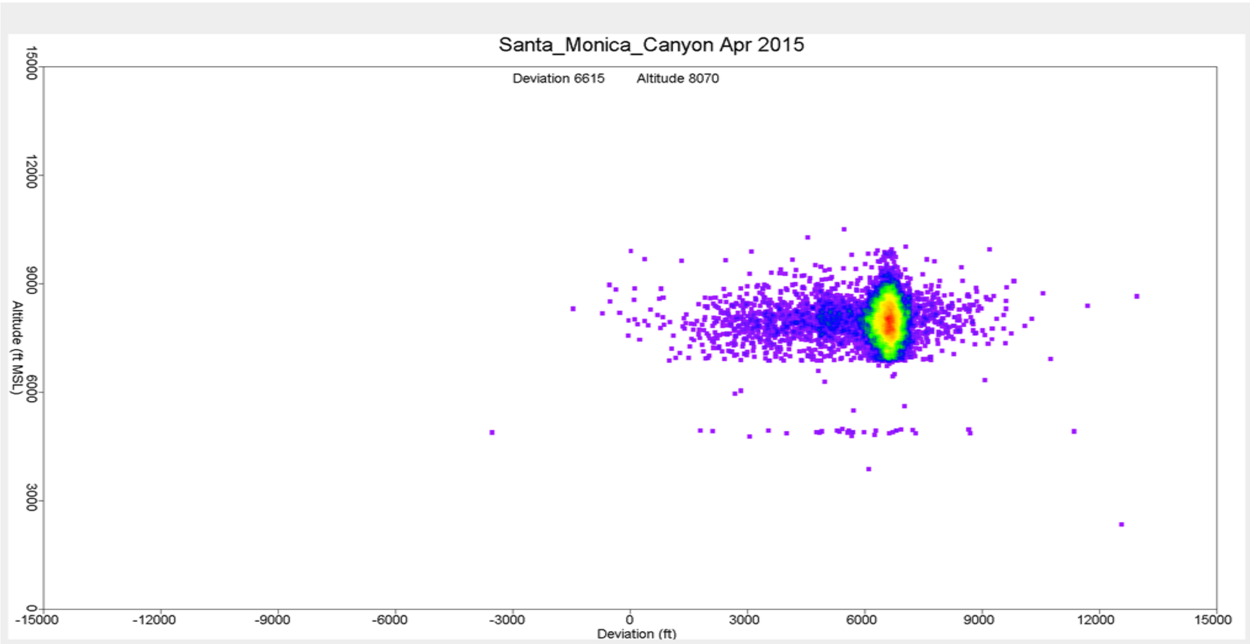


Figure 31. Altitude Distribution Heat Map, Santa Monica Canyon, April 2015
(Source: HMMH, LAWA ANOMS Data 2010 – 2015)

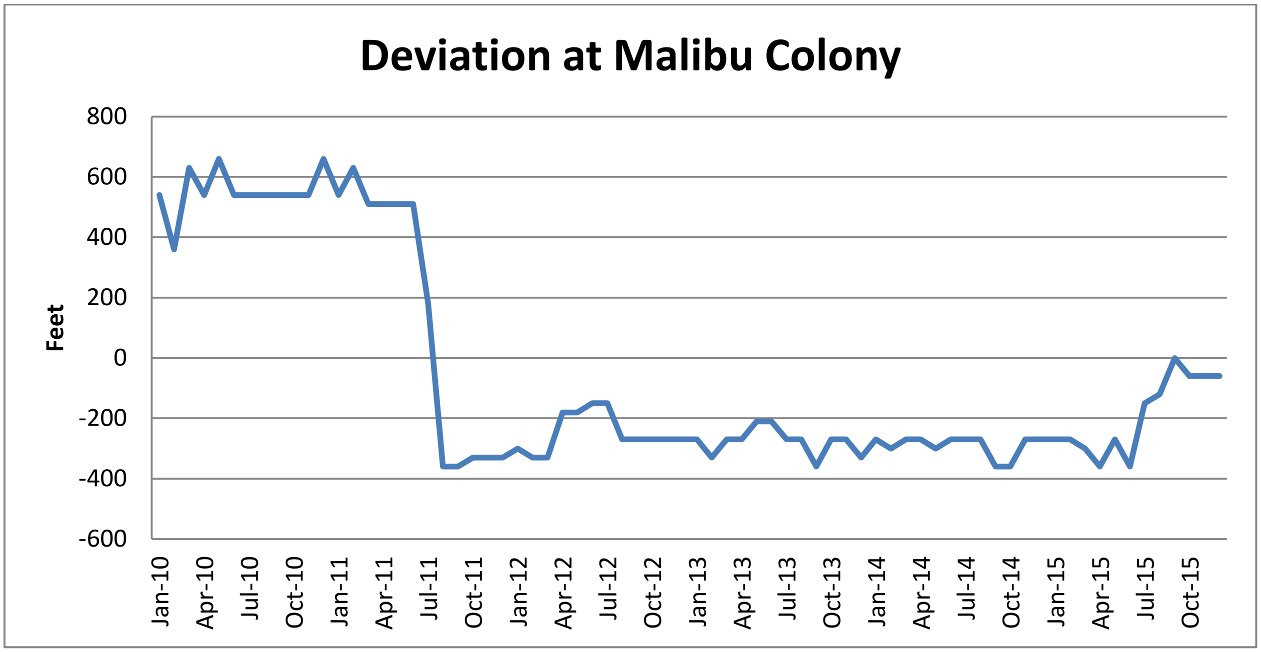


As demonstrated in Figure 30 and Figure 31 above, there was little change in altitude or lateral flight track dispersion west of the SMO VOR/DME during the period from June 2014 to June 2015 over the gate positioned at Santa Monica Canyon. This indicates aircraft throughout this period were flying with consistent frequency over the same general area.

7.2.3 Deviation Shifts at Malibu Colony

A closer review of flight track gate penetrations at the Malibu Colony gate showed a shift in the ground location of flight paths as demonstrated in Figure 32 below.

Figure 32. Ground Track Shift Measurement at Malibu Colony
(Source: LAWA ANOMS Data 2010 - 2015)



This graph shows that, relative to the ground position of the flight path over Malibu Colony at the start of the study time frame in January 2010, there was a shift to the north (negative values are left of gate center from a pilot's point of view on the north downwind arrival) of approximately 800 feet around July 2011. Then, around July 2015, there was a small shift of approximately 200 feet back to the south. This means that on the whole over the five-year period, flight tracks made a general shift toward the north closer to the community. This shift may have caused some residents in Malibu Colony to notice more overflights throughout the study period.

7.3 Average Altitudes by Time of Day

In order to analyze broader time periods, a time-of-day analysis was performed for the Culver City gate. This gate was chosen for analysis because it is east of the Santa Monica VOR/DME. a fixed navigational point where all aircraft arriving on the north arrival route are to be at or above 7,000 feet per FAA procedure as they descend heading eastbound, and is closest to the midpoint of the downwind leg of the north arrival procedure. Four time periods were plotted and analyzed: midnight to 6 AM, 6 AM to noon, noon to 6 PM, and 6 PM to midnight. The analysis focused on operations counts and average altitude during different months of 2010 and 2015. The first time period, midnight to 6 AM, showed extreme variation in average altitude throughout both 2010 and 2015. These random variations probably occur due to fewer operations occurring during this time period and ATC personnel may be handling these aircraft differently because the airspace is less crowded. The other three time periods, however, showed very little change in average altitude throughout both years. These figures can be found in the Supplemental Data Appendices. Given that the aircraft transponders are considered accurate within plus or minus 300 feet of an aircraft's assigned altitude, it would be reasonable to conclude that deviations in altitude within this range are consistent normal aircraft operations. Some deviation within the range of accuracy of an aircraft's transponder should be anticipated. The results of this analysis indicate that aircraft during the months analyzed are not flying at different altitudes during different times of the day; average hourly altitudes in the morning throughout 2010 were between 6,100 feet and 6,500 feet while average hourly altitudes in the morning in 2015 were between 6,100 feet and 6,400 feet.

The following graphs are representative of this analysis. These graphs detail the 6AM to noon time period in order to compare 2010 to 2015. The y-axis depicts average altitude in units of feet MSL.

Figure 33. Average Altitudes During Morning Hours in 2010
(Source: LAWA ANOMS Data 2010 - 2015)

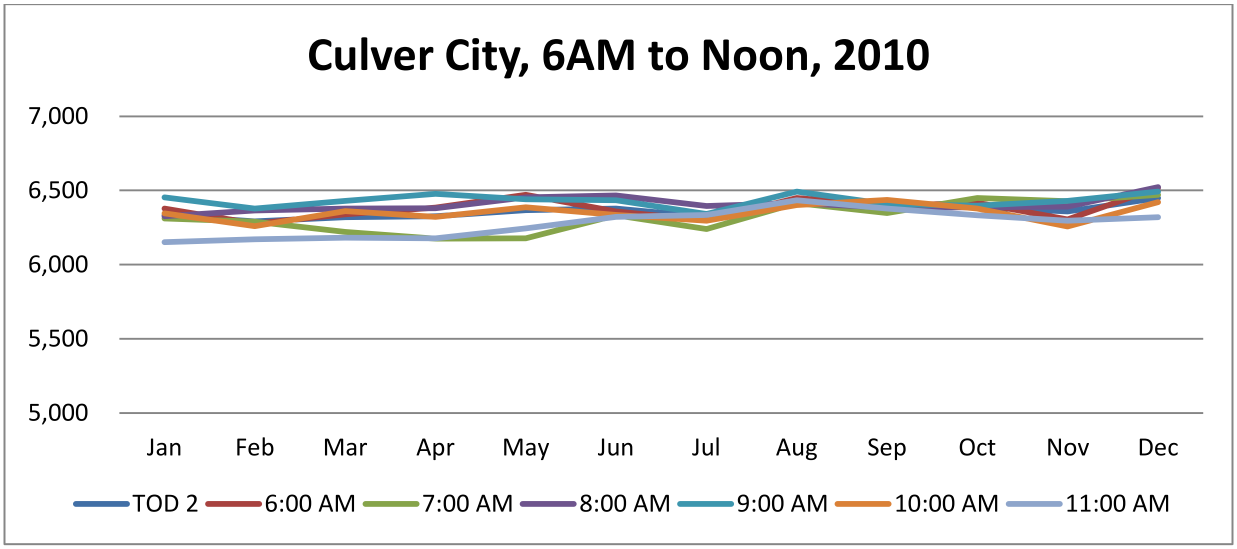
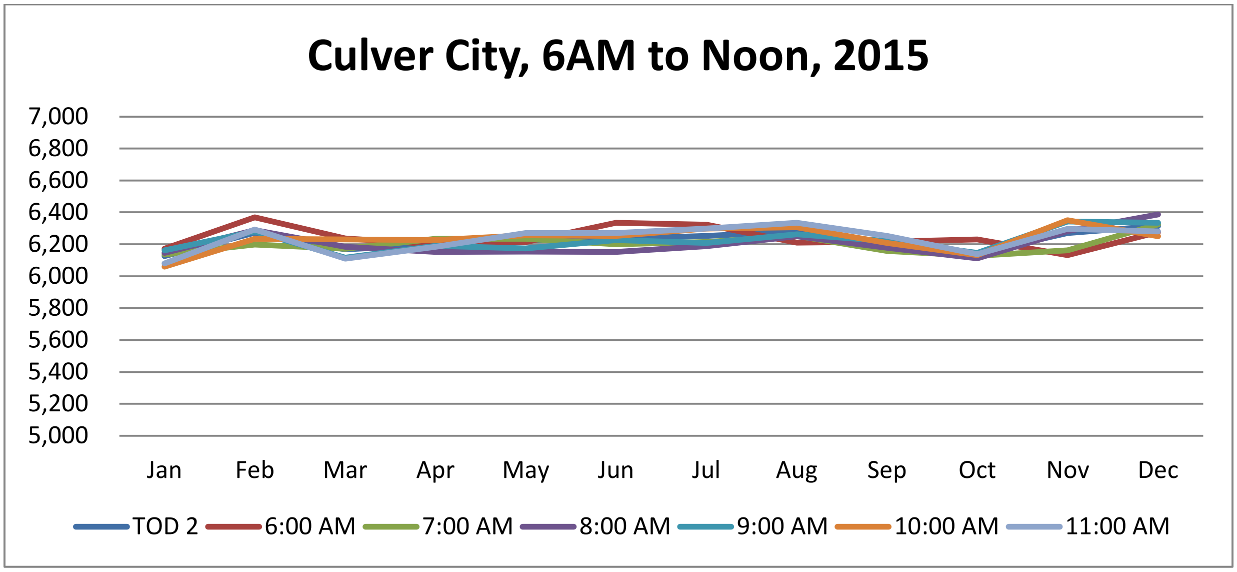


Figure 34. Average Altitudes During Morning Hours in 2015
(Source: LAWA ANOMS Data 2010 - 2015)

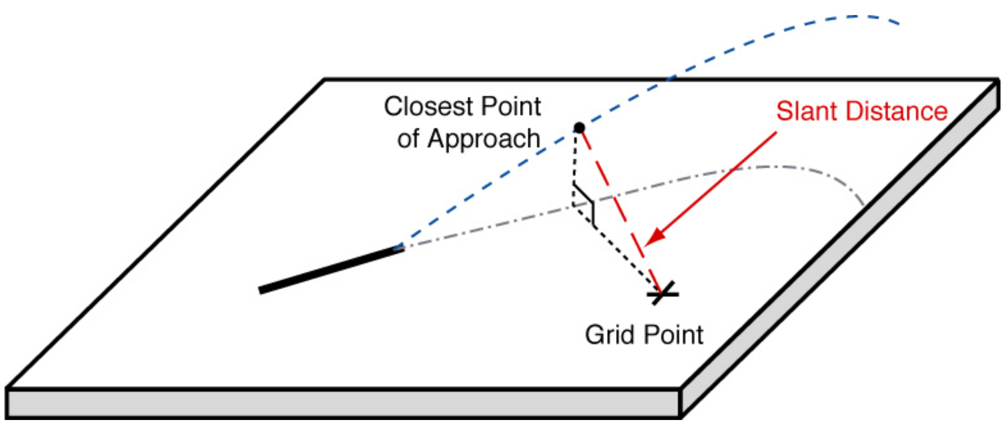


7.4 Average Altitude and Slant Distance by Category

In order to see whether certain aircraft type categories were flying differently than others, average altitudes and slant distances were calculated monthly for each analysis location for each year between 2010 and 2015. The distance between the point on the ground directly below the aircraft and the location of measurement is the aircraft's "slant distance". In this case, the measured location is at the center point of each gate. Slant distance is useful to show deviations in flight tracks as a change in the point directly below the aircraft will yield a slant distance change. Figure 35 below illustrates this visually. In this diagram, the black dot represents the aircraft's closest point of approach to the gate center while the black "X" represents the gate center point. The red dotted line is the slant distance between the gate center point and the aircraft at the aircraft's closest point of approach. The slant distance will always be greater than the aircraft's altitude when the aircraft is not directly overhead.

This analysis did not show any trends or obvious consistent outliers over the years. There was minor variation year to year and location to location for all categories, but on average all aircraft type categories were flying at the same general altitude. The one noticeable outlier is non-jet aircraft in 2015. After April 2015, non-jet aircraft began flying considerably lower than jet aircraft at each location; however, they also began decreasing in number. By June 2015, there were less than twenty non-jet aircraft arrivals per month, some of which were most likely small general aviation propeller planes. The average slant distance by category also did not reveal any major trends or consistent outliers between aircraft type categories over the study period. Even after the June 2014 narrowing of flight tracks east of the Santa Monica VOR/DME, average slant distances remained consistent with their values over the remainder of the study period.

Figure 35. Visual Example of Slant Distance
(Source: HMMH 2008)



7.5 Altitude Band Analysis

In order to visualize the distribution of aircraft altitudes over each analysis location, a coarse histogram of these altitudes was calculated with counts developed at 500 foot increments, starting at 500 feet and ending at 8,000 feet. These data are provided in CSV files, and a sample of two such altitude band histograms is shown below. The values above each point are the number of operations in each band. For example, the peak point in 2010 shows 1,306 operations between 4,000 and 4,500 feet. The next point for 2010 shows 1,035 operations between 4,500 and 5,000 feet, and so on.

Figure 36. Sample Altitude Band Histogram – Adams Vermont, January 2010 and 2015
(Source: LAWA ANOMS Data 2010-2015)

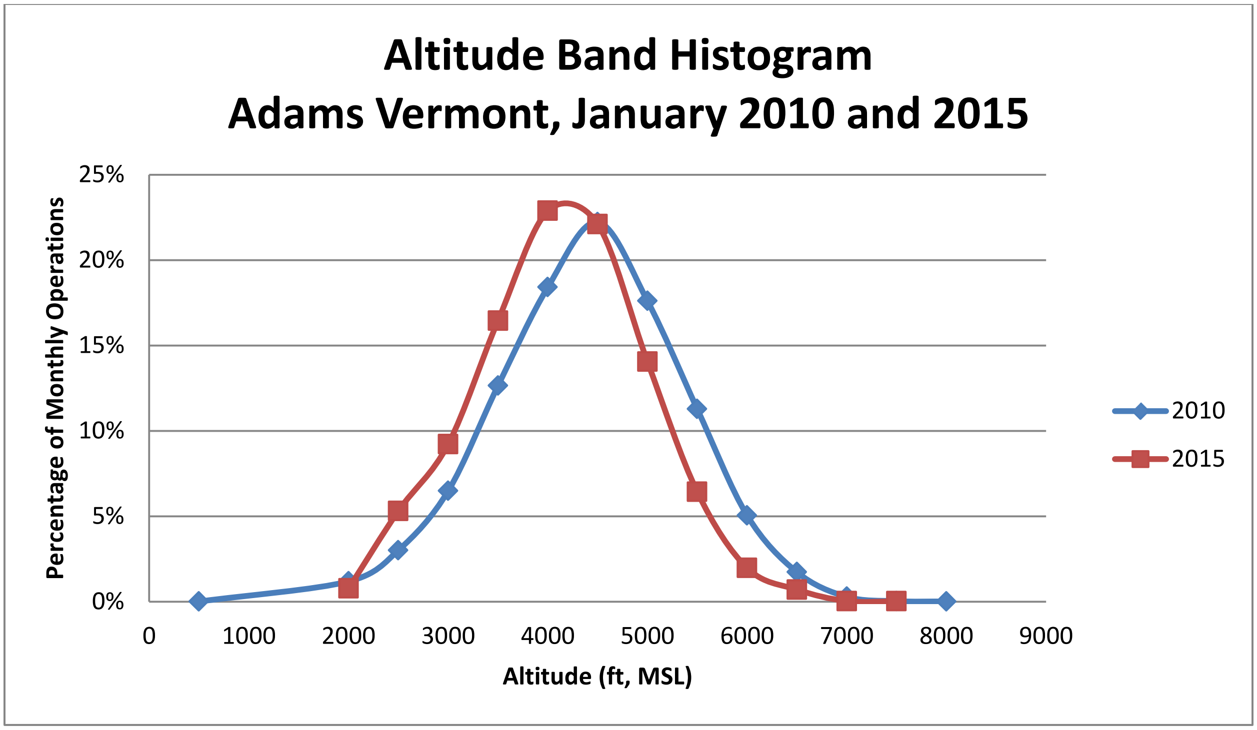
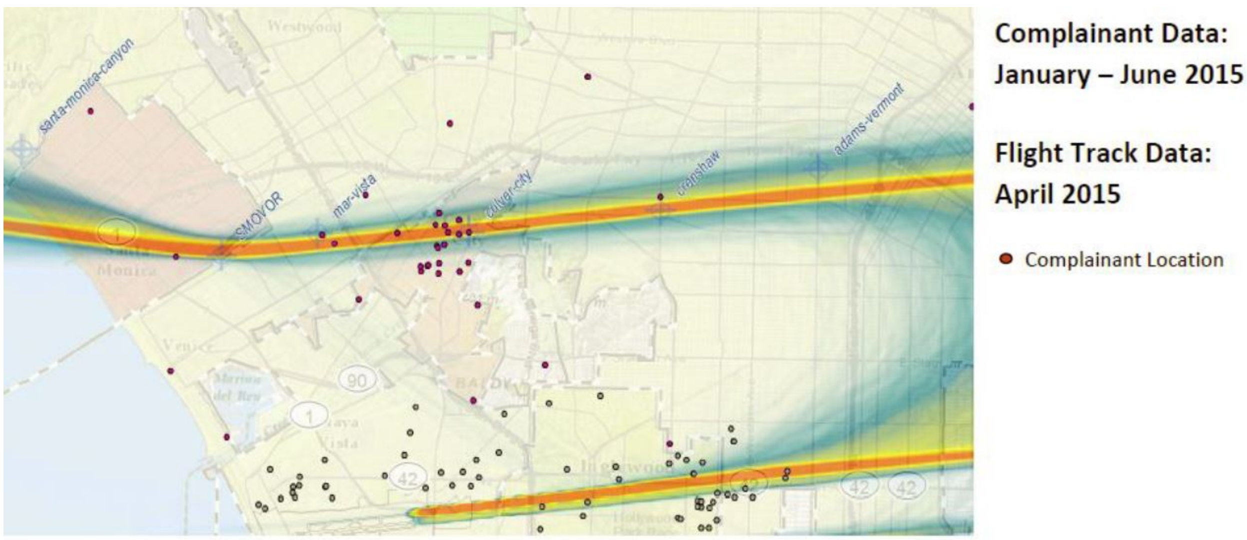


Figure 36 suggests that – on average – aircraft at the Adams-Vermont gate were somewhat lower in 2015 as compared with 2010. It is unclear whether this is a result of procedural changes, changes to fleet mix, increased traffic levels, or (likely) a combination of all of these factors. In any event, this supports residents' observations that aircraft are somewhat lower now. This change in average altitude alone is unlikely to result in noticeable changes in noise level (e.g., the decibel difference for a single aircraft at 4000 feet vs. 4500 feet is about 0.5 dB). However, the change in altitude, especially if aircraft are becoming larger at the same time, may result in perception of an even bigger increase in noise.

8 Complainant Distribution During 2014 and 2015

To determine whether community complaints directly correlated with changes in flight tracks, staff at LAWA overlaid complainant locations on flight track density maps for four six-month periods in 2014 and 2015 for areas west and east of the SMO VOR/DME. For locations both west and east of the SMO VOR/DME, the number of persons complaining markedly increased in 2015, especially from July to December. The area near Culver City saw the largest increase in number of persons complaining over the two-year period and complaints became more densely grouped along the narrowing of the flight tracks in 2015. West of the SMO VOR/DME, persons complaining were much more sparsely grouped and much fewer in number when compared to locations to the east of the SMO VOR/DME. However, there was still an increase in 2015 when compared to 2014, with the area near Santa Monica Canyon having the densest group of complainants. Figure 37 below depicts locations of persons complaining from January to June of 2015 for locations east of the SMO VOR/DME. As noted above, complainants are very densely grouped near Culver City and the narrowed flight path. Images for all time periods, both east and west of the SMO VOR/DME, can be found in Appendix E.

Figure 37. Complainants East of SMO VOR, January – June 2015



Source: LAWA, HMMH 2016

Overall, there were 148 complainants in 2015 compared to only 47 in 2014 and 43 in 2013.[9] With the timing of the large increase in complainants and their locations, one may conclude that they correlate with the changes in flight tracks over 2014 and 2015. However, other correlations may exist, so a 100% causal relationship between changes in flight tracks and an increase in the number of complainants cannot be assumed.

[9] Data provided by LAWA.

9 Observations

In summary, the analyses of operations, flight tracks, altitudes, and noise data from 2010 through 2015 indicate the following:

- Procedure Review: From 2010 to 2015 there were no published procedure changes utilizing the north downwind arrival that would have resulted in vertical (i.e., altitude) or lateral changes to aircraft flight paths. Although two new arrival procedures were published during this period, FAA designated the procedures as “Not Available”; indicating they were not to be flown by aircraft.
- Flight Track Density: There was a change in flight track density from June 2014 through June 2015 for locations east of the SMO VOR/DME. For that year-long time period, flight tracks became much more concentrated over the communities and neighborhoods of Culver City, Crenshaw, and Adams-Vermont which meant planes were flying through a much narrower corridor after passing the SMO VOR/DME on arrival to LAX. This results in aircraft overflying the same locations more frequently which could lead to an increase in perceived noise. Flight tracks east of the SMO VOR/DME became more dispersed again after June 2015, appearing as they did before the June 2014 change. As detailed in Section 2, it is likely that a difference in air traffic control instructions to arriving aircraft caused this change. Also, there was a small change in the center of the flight track density at the Malibu Colony gate in July of 2011, whereby flight tracks shifted slightly north toward the community.
- Activity Levels: There was an overall increase in north downwind arrivals from 2010 to 2015 of about 20%, which was greater than the overall 14% increase in operations at LAX over that same period, and is true for all aircraft groups except non-jet. This increase in operations makes it likely that aircraft are passing over the affected communities more often than in years prior, which is consistent with complainant comments regarding more frequent operations and can result in a perceived noise increase.
- Fleet Mix: There have been a number of changes to the fleet mix utilizing the north downwind arrival, specifically: (1) there were more regional jets in the fleet mix in 2015 than in 2010; (2) there was a ten-fold increase in New Large Aircraft (A380 and B748) between 2010 and 2015; (3) there is an increasing trend of large two-engine aircraft (B777 and B787) replacing large four-engine aircraft (B747); and (4) there are fewer non-jet aircraft operating at LAX.
- Noise Levels: Analysis of noise levels as measured by average SEL by aircraft group reflects the changing fleet mix within each category. Overall, SEL modeling did not reveal a perceivable change in aircraft noise levels on the whole, though it did highlight some changes in fleet mix that would be perceivable by the community. The most notable of these changes is the decrease in the use of non-jet aircraft in favor of regional jets and the increase in new large jets such as the Airbus A380 and the Boeing 747-800. Other fleet changes, such as the introduction of the newer (and somewhat larger) 757-300 result in increased noise levels; although newer aircraft generally are quieter overall, some (such as the 757-300) are louder on arrival.
- Altitudes: There seems to have been a general shift to lower altitudes at some locations, which may be a result of increased traffic, changes in procedures or air traffic controller instructions. The magnitude of the altitude change is not enough to result in significant changes in noise level, but may contribute to a perception that aircraft are both lower and louder, especially for new, large aircraft.

It would appear that several of these changes have combined to increase general perception of air traffic flow in the area, and usage of the north downwind arrival corridor. All of the items listed above, as well as other community-related items such as increased news coverage, have most likely contributed to the increase in the number of persons complaining in portions of the north downwind arrival corridor. Due to the increase in operations both on the north downwind arrival and at LAX as whole, planes are overflying communities more frequently than they have in the past. This can lead to greater perceived noise and a higher level of annoyance as aircraft pass overhead more often.

Aircraft arriving on the north downwind arrival have also become generally larger as fleet mix has changed since 2010. New large aircraft such as the Airbus A380 and Boeing 747-800 have become more prevalent at LAX than they were in 2010. Since these aircraft are so large, they may be perceived as being noisier or flying lower than they actually are. The shift away from non-jet aircraft to more regional jets at LAX is also occurring.

Perhaps most important is the change in the arrival pattern east of the SMO VOR/DME from June 2014 to June 2015, which is where the majority of complainants are located and provided the impetus for this study. This narrowing of the arrival corridor and then change back to a more dispersed set of flight tracks may have led to more perceived noise over communities, perhaps because the changes were more sudden (and therefore noticeable) than gradual increases in operations over time. Areas where flight tracks narrowed saw a year-long increase in overflights, while areas that used to have more frequent overflights did not receive as many. After June 2015 when flight tracks once again became more dispersed, the opposite happened and communities which had noticed fewer overflights were once again seeing them more often. This back and forth changing of flight tracks and overflights over certain communities may have contributed to more individuals becoming sensitized to aircraft noise.

Overall, the increase in complaints from communities under the north downwind arrival pattern appears to have resulted from the combination of the factors detailed above.