New York Community Aviation Roundtable

Meeting: Wednesday, October 23, 2024

7:00 – 9:00 PM
Online Zoom Meeting

Co-Chairs:
Barbara E. Brown
Maria R. Becce
Facilitator: Bill Huisman

Agenda

1) **Welcome/Announcements** 7:00

2) **Roll Call** 7:05

3) **Meeting Notes: Lei Zhao, Recording Secretary/LGA Committee** 7:15

4) **Port Authority Updates: Adeel Yousuf and Jacob Attwood** 7:20
   a. Total operations trends and runway utilization data
   b. Fly Quiet Program schedule for next year's annual report
   c. Updates to noise complaints webform and acknowledgements
   d. New mobile app

5) **Boston University/Oregon State University**
   a. Aircraft Noise Exposure and Body Mass Index 7:35
      - Presenters: Junenette L. Peters and Matthew Bozigar
        Objective: Aircraft noise exposure is linked to cardiovascular disease risk. One understudied candidate pathway is obesity.

6) **FAA: Office of Environment & Energy – Noise Division**
   a. Project 003: Cardiovascular Study
      - Presenter: Adam R. Scholten, Environmental Protection Specialist

7) **Thomas Lintner, President & CEO, The Aloft Group** 8:30
   a. **Aviation's Inconvenient Truth: We Forgot About The People**

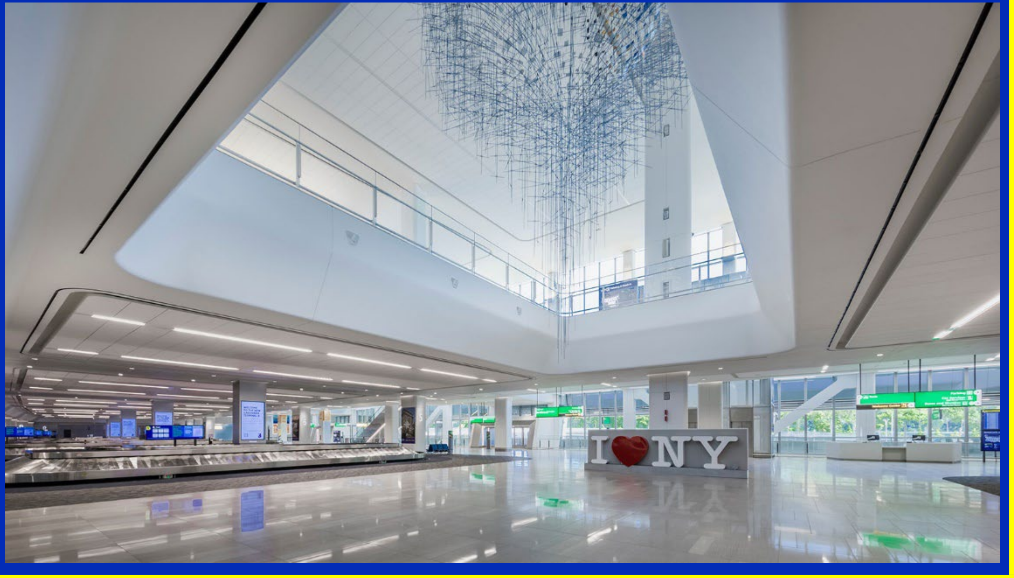
8) **Public Comment – Suggestions for AGENDA items** 8:50

9) **Adjournment**

PORT
AUTHORITY
NY NJ

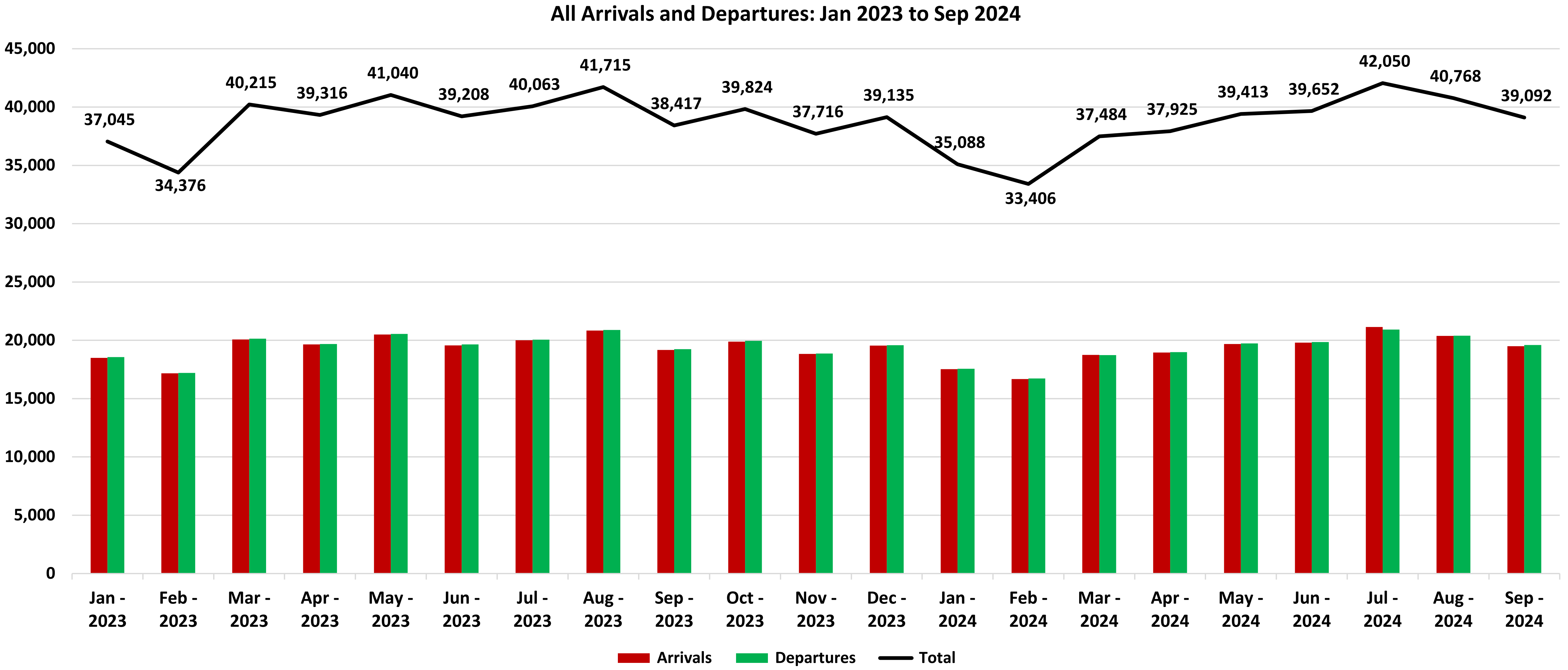
New York Community Aviation Roundtable Operations

October 23, 2024



AIR LAND RAIL SEA

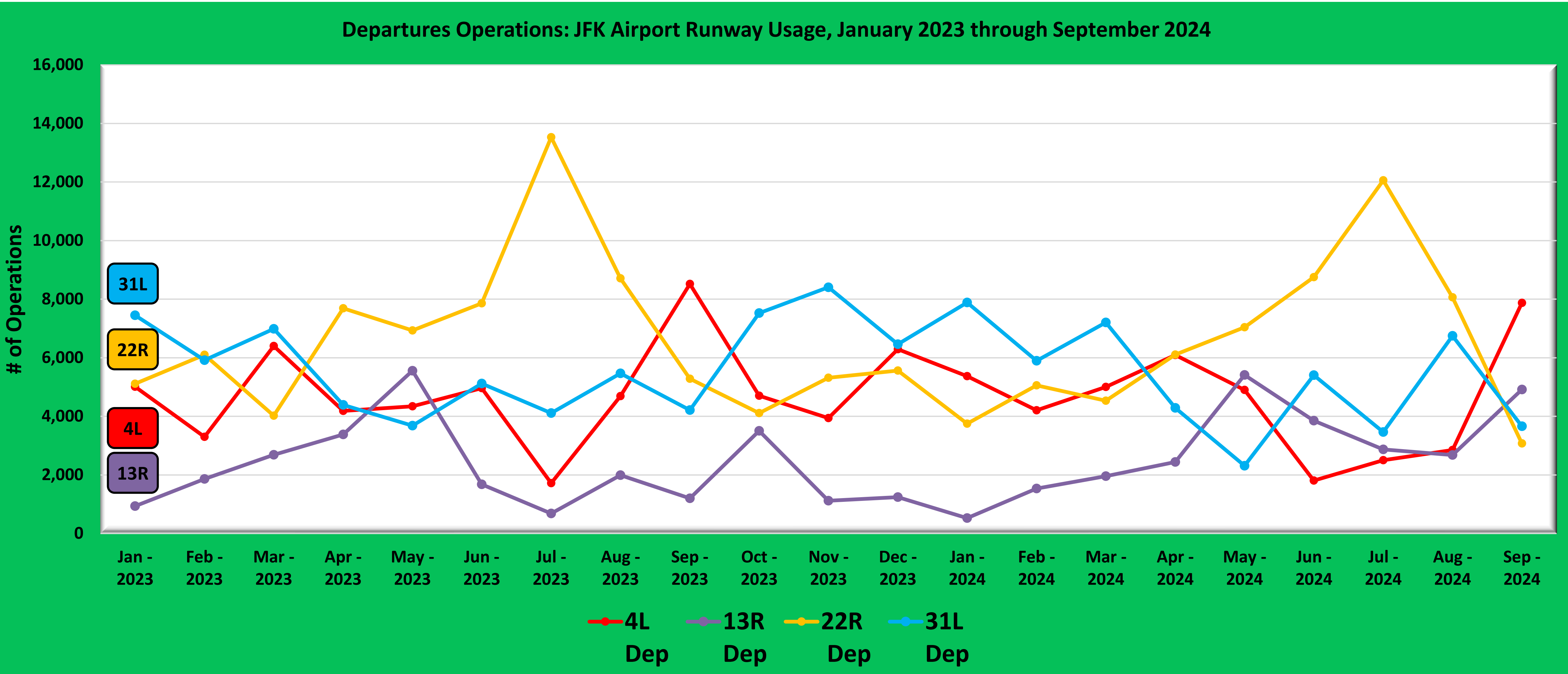
JFK 2023 to 2024 Operations Overview



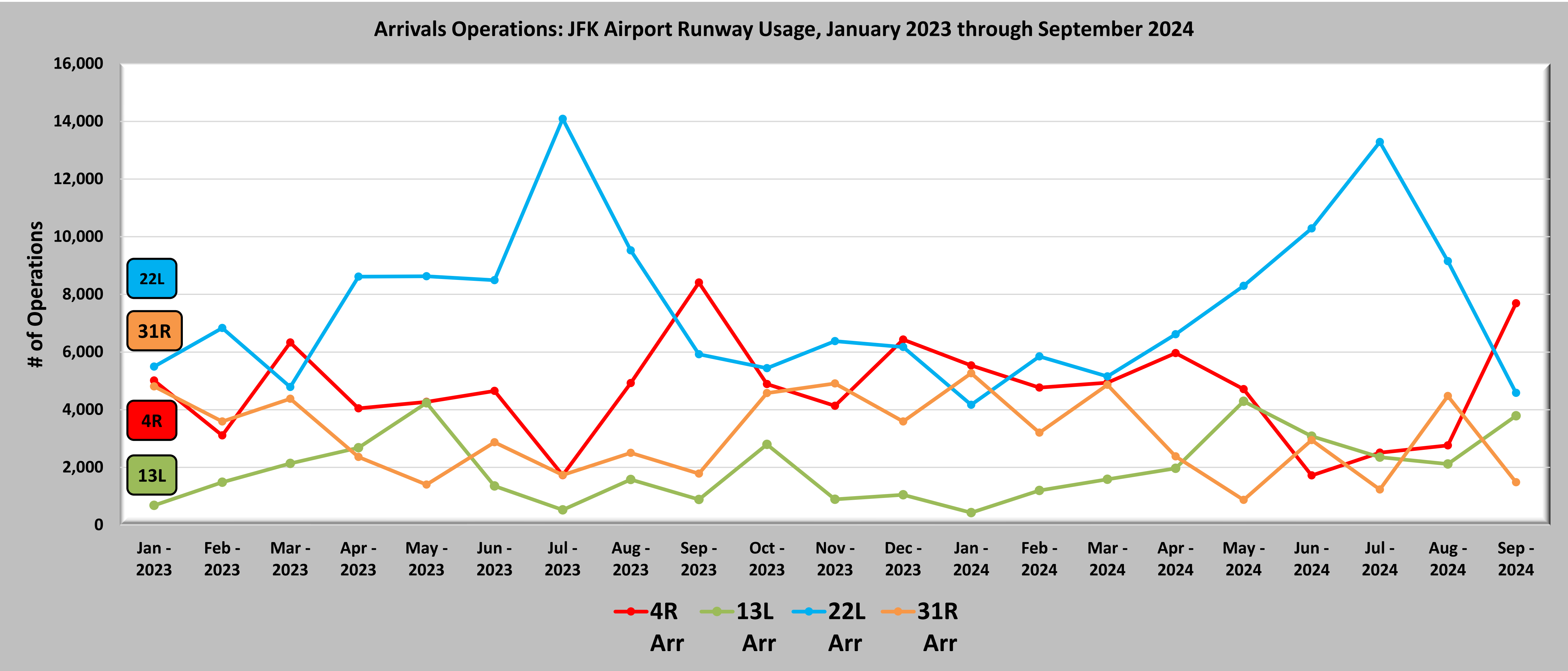
JFK Operations By Runway for Past 13 Months

Month	Total Operations	4L Arr	4L Dep	4R Arr	4R Dep	13L Arr	13L Dep	13R Arr	13R Dep	22L Arr	22L Dep	22R Arr	22R Dep	31L Arr	31L Dep	31R Arr	31R Dep	Unk Arr	Unk Dep
Sep - 2023	38,417	1,201	8,519	8,408	0	886	1	3	1,201	5,925	0	417	5,281	554	4,212	1,779	12	4	14
Oct - 2023	39,824	627	4,707	4,891	1	2,795	12	22	3,507	5,439	1	434	4,114	1,097	7,523	4,576	65	5	14
Nov - 2023	37,716	520	3,937	4,133	0	895	31	1	1,117	6,377	0	661	5,314	1,338	8,408	4,911	55	3	8
Dec - 2023	39,135	869	6,292	6,432	0	1,047	3	3	1,243	6,176	1	577	5,561	854	6,461	3,590	14	3	9
Jan - 2024	35,088	551	5,374	5,535	3	428	2	1	525	4,170	1	319	3,748	1,256	7,884	5,264	20	2	5
Feb - 2024	33,406	472	4,204	4,765	11	1,198	3	2	1,532	5,845	1	435	5,061	748	5,893	3,204	15	6	11
Mar - 2024	37,484	538	5,003	4,934	1	1,584	6	3	1,956	5,153	0	318	4,536	1,348	7,208	4,862	13	6	15
Apr - 2024	37,925	746	6,094	5,963	1	1,966	7	3	2,442	6,614	1	602	6,110	660	4,286	2,381	12	8	29
May - 2024	39,413	586	4,898	4,715	1	4,291	13	12	5,415	8,297	2	661	7,044	247	2,314	870	5	3	39
Jun - 2024	39,652	183	1,810	1,718	0	3,078	5	17	3,853	10,285	0	852	8,755	717	5,403	2,947	11	3	15
Jul - 2024	42,050	281	2,504	2,513	0	2,350	1	9	2,871	13,286	2	1,211	12,057	251	3,464	1,230	3	3	14
Aug - 2024	40,768	308	2,848	2,760	0	2,115	1	5	2,682	9,154	13	657	8,065	899	6,747	4,471	15	6	22
Sep - 2024	39,092	1,167	7,870	7,687	0	3,785	8	17	4,913	4,582	30	393	3,076	371	3,659	1,486	10	5	33

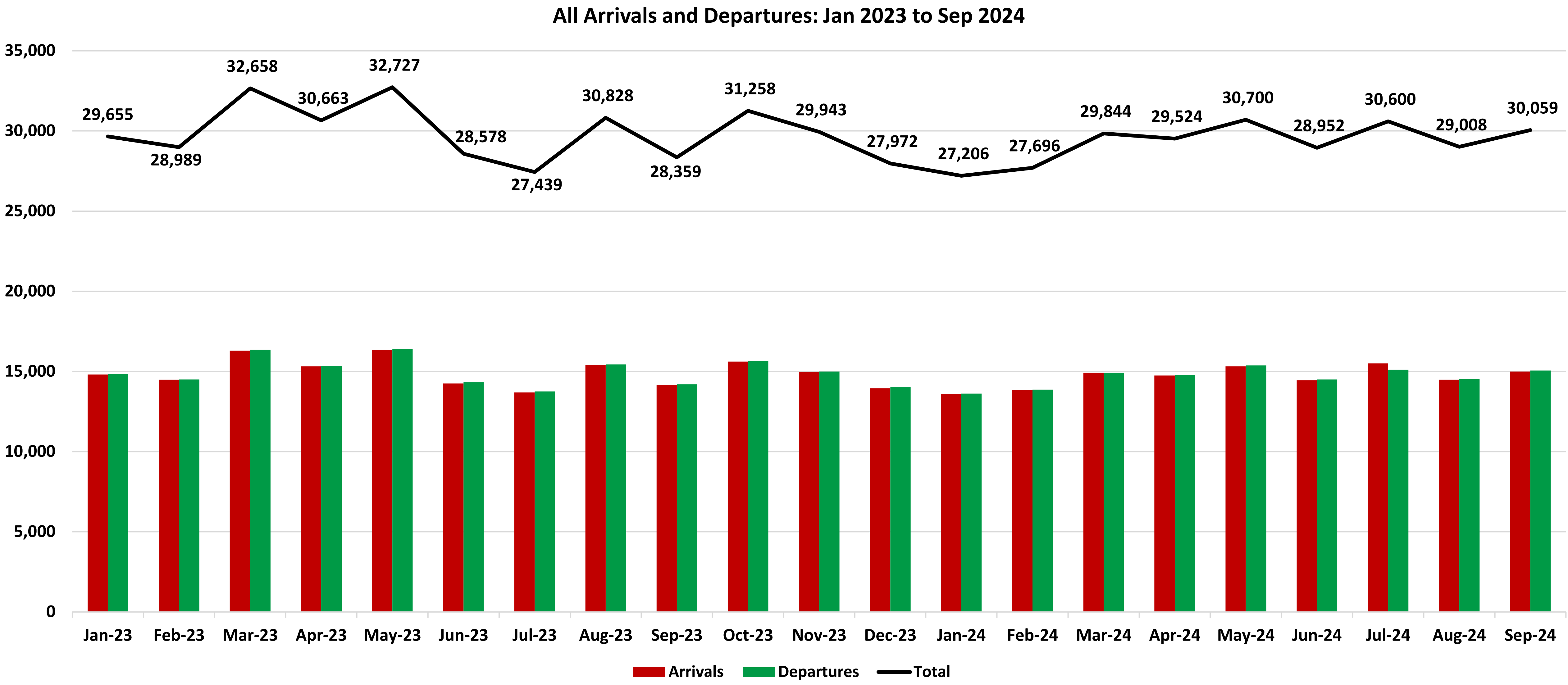
Departures Overview Jan 2023 to Sep 2024



Arrivals Overview Jan 2023 to Sep 2024

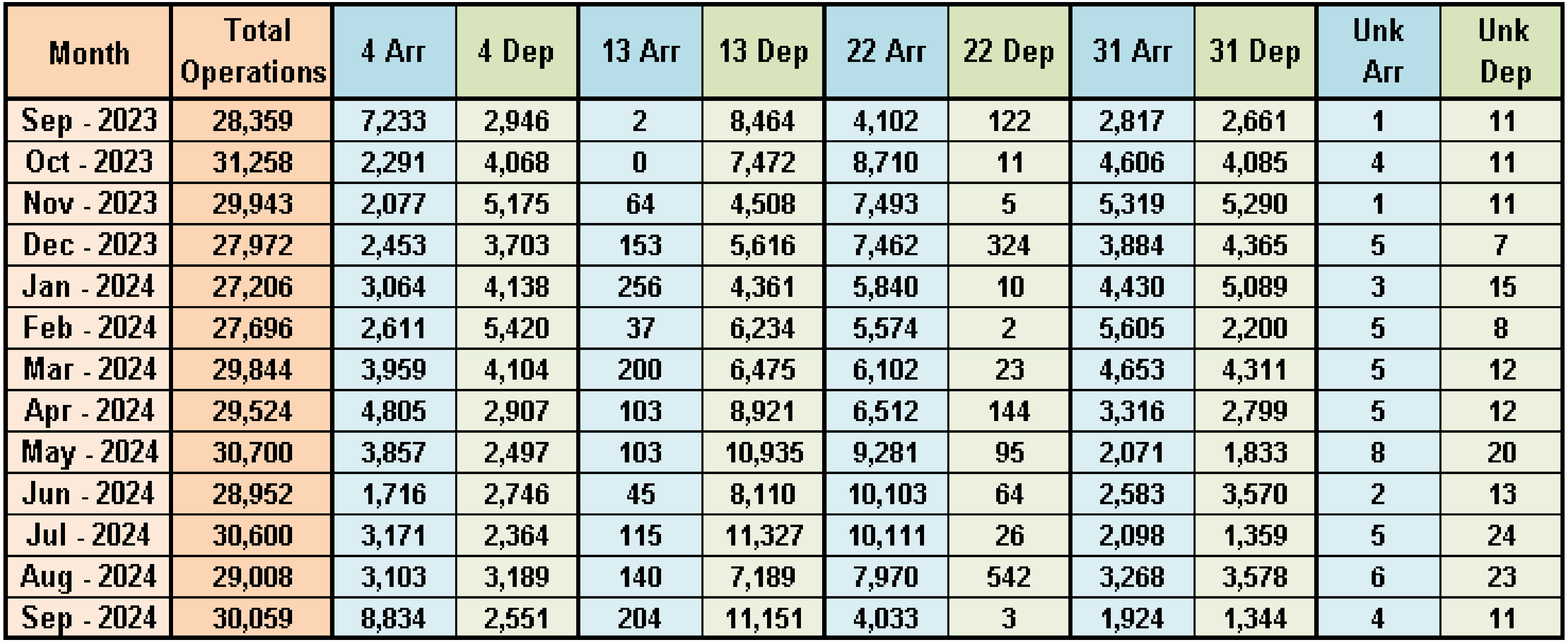


LGA 2023 to 2024 Operations Overview



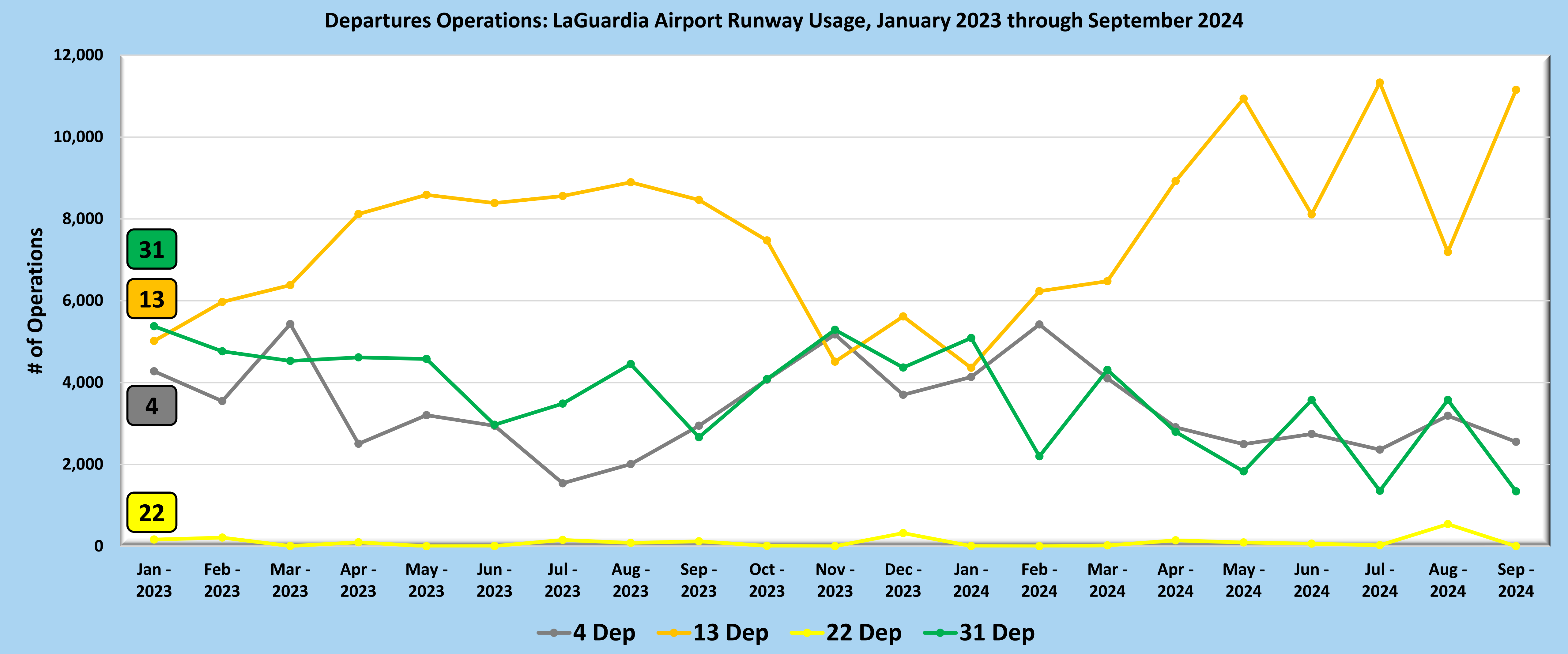
PORT AUTHORITY NY NJ
AIR LAND RAIL SEA

LGA Operations By Runway for Past 13 Months



Month	Total Operations	4 Arr	4 Dep	13 Arr	13 Dep	22 Arr	22 Dep	31 Arr	31 Dep	Unk Arr	Unk Dep
Sep - 2023	28,359	7,233	2,946	2	8,464	4,102	122	2,817	2,661	1	11
Oct - 2023	31,258	2,291	4,068	0	7,472	8,710	11	4,606	4,085	4	11
Nov - 2023	29,943	2,077	5,175	64	4,508	7,493	5	5,319	5,290	1	11
Dec - 2023	27,972	2,453	3,703	153	5,616	7,462	324	3,884	4,365	5	7
Jan - 2024	27,206	3,064	4,138	256	4,361	5,840	10	4,430	5,089	3	15
Feb - 2024	27,696	2,611	5,420	37	6,234	5,574	2	5,605	2,200	5	8
Mar - 2024	29,844	3,959	4,104	200	6,475	6,102	23	4,653	4,311	5	12
Apr - 2024	29,524	4,805	2,907	103	8,921	6,512	144	3,316	2,799	5	12
May - 2024	30,700	3,857	2,497	103	10,935	9,281	95	2,071	1,833	8	20
Jun - 2024	28,952	1,716	2,746	45	8,110	10,103	64	2,583	3,570	2	13
Jul - 2024	30,600	3,171	2,364	115	11,327	10,111	26	2,098	1,359	5	24
Aug - 2024	29,008	3,103	3,189	140	7,189	7,970	542	3,268	3,578	6	23
Sep - 2024	30,059	8,834	2,551	204	11,151	4,033	3	1,924	1,344	4	11

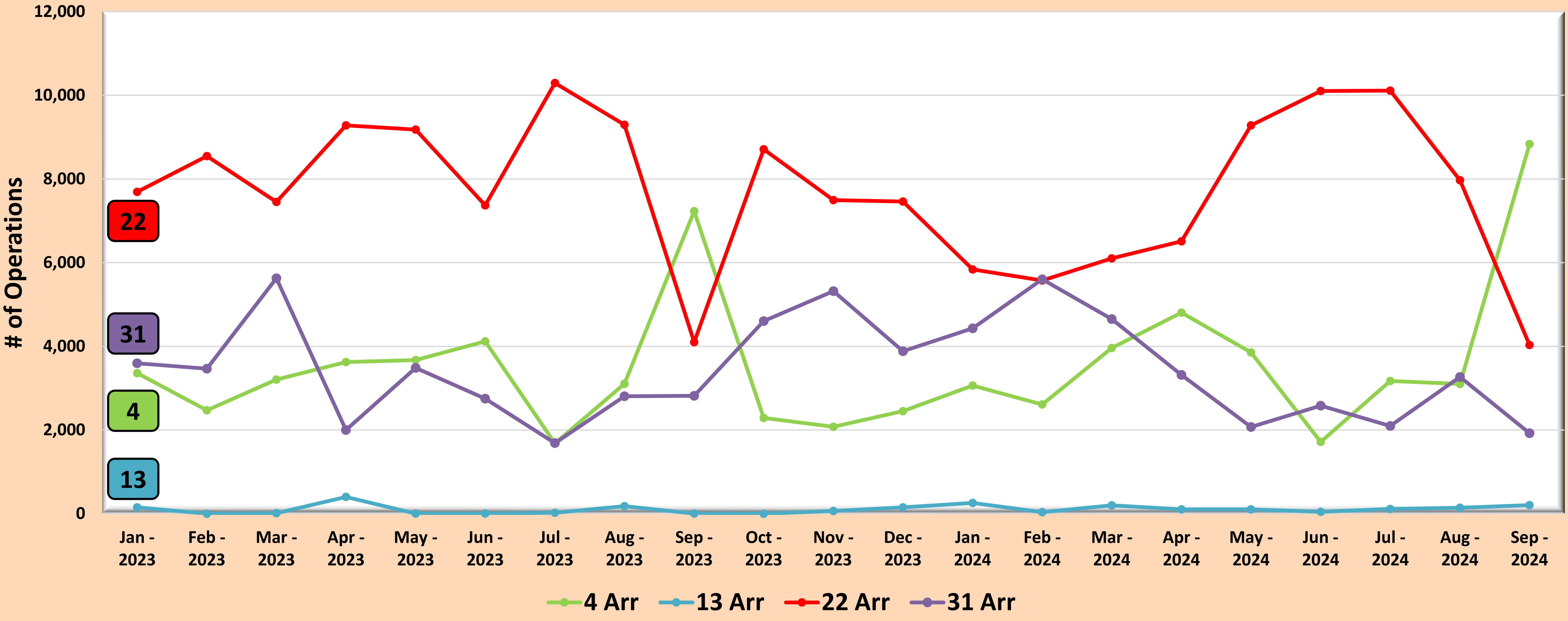
Departures Overview Jan 2023 to Sep 2024



PORT AUTHORITY NY NJ
AIR LAND RAIL SEA

LGA Arrivals Overview – Jan 2023 to Sept 2024

Arrivals Operations: LaGuardia Airport Runway Usage, January 2024 through September 2024



Factors in Runway Selection

Runway Selection is determined by FAA based on the following criteria (in order of decreasing priority):

- Runway availability
- Prevailing wind and weather patterns
- Operational efficiency
- Community noise concerns

Flying into the wind provides the greatest margin of safety when landing or departing at any airport

FlyQuiet Program Update

- Technical Manual posted on noise office website under the Fly Quiet Program (https://aircraftnoise.panynj.gov/fly-quiet-program/)

- A resource guide providing detailed technical information on score calculations and other program metrics

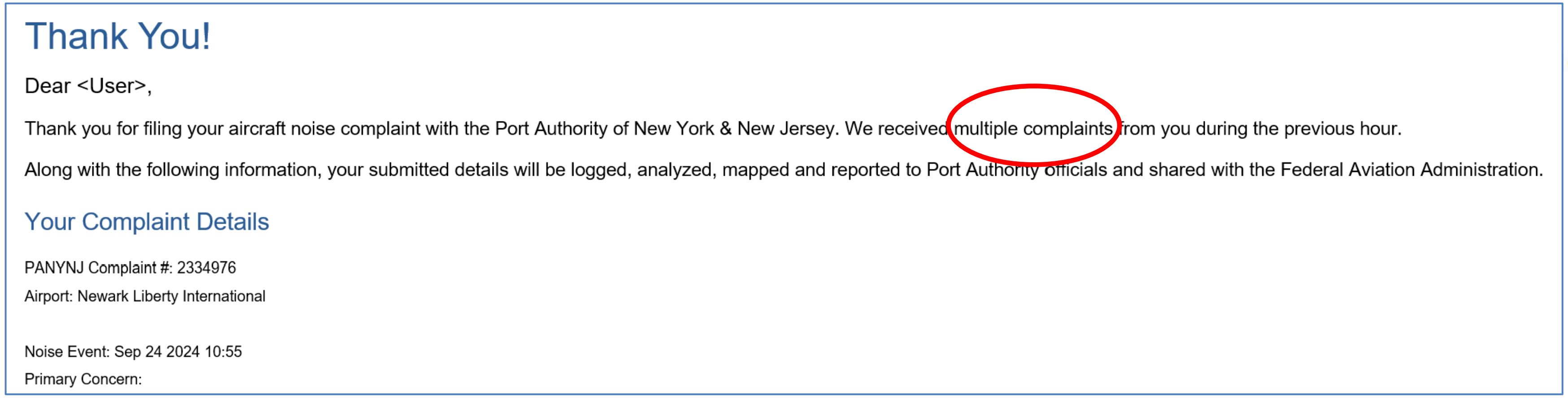
- Written for a technical audience (airlines, FAA, etc.) to provide:
  - FQP scoring methodology
  - Fleet noise calculations
  - Engagement points calculations
  - Runway and flight procedure use
  - Airline rankings and awards

- Next FQP annual report (2024 data) expected to be released in April 2025

Complaint Webform Updates

- Webform Security was updated
  - Manual entry of the security code was eliminated
  - Security is checked behind the scenes on the user's browser
  - Speeds up the complaint filing process by removing the manual entry

- Email Receipts
  - Acknowledgement emails are no longer being sent for each individual complaint
  - Acknowledgement emails are now being sent once per hour to inform user of the multiple complaints submitted



Thank You!

Dear <User>,

Thank you for filing your aircraft noise complaint with the Port Authority of New York & New Jersey. We received multiple complaints from you during the previous hour.

Along with the following information, your submitted details will be logged, analyzed, mapped and reported to Port Authority officials and shared with the Federal Aviation Administration.

Your Complaint Details

PANYNJ Complaint #: 2334976

Airport: Newark Liberty International

Noise Event: Sep 24 2024 10:55

Primary Concern:

Removed

Mobile App

Noise Complaint Form

Your Information * Required field

First Name: *
Last Name: *
Phone: * ( ) -
Email: *
Enter an Address: * Enter a location
P.O. Box not allowed

Complaint Information * Required field

Noise Event - Date: * Today
Noise Event - Time: * -- : -- -- Now
Airport: * Select Airport

Primary Type of Complaint:
☐ Too Loud & Low
☐ Too Low
☐ Hovering
☐ Too Early or Late
☐ Military
☐ Too Loud
☐ Too Frequent
☐ Excessive Vibration
☐ Change in Flight Pattern
☐ General Complaint/Other (Provide Details in Comments)

Operation Type: Select Operation Type
Comments:

Submit Complaint

Filing Your Complaint

Welcome to the Port Authority of New York & New Jersey's airport noise complaint management system, powered by PlaneNoise®.

There are two ways to file an aircraft noise complaint:

1. Complete and submit the form on this page, or
2. Leave a voicemail on our airport noise complaint hotline 1-800-225-1071.

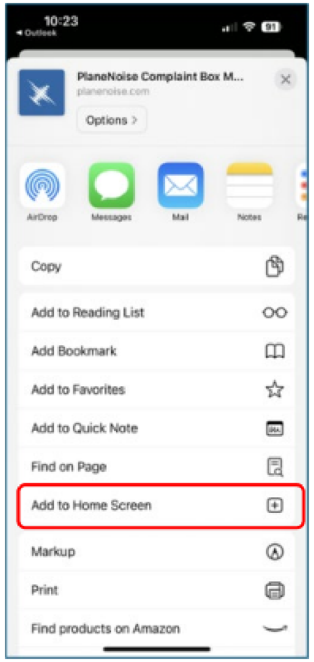
Either way, we ask that you kindly provide as much information as possible. Details will help the Port Authority review and process your complaint.

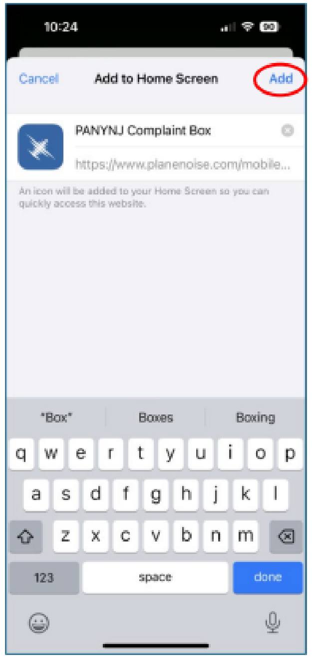
Thank you for filing your complaint with the Port Authority of New York & New Jersey.

To make a reasonable modification request with respect to this form, click here.

Try our mobile app! Simply scan the QR code with your smartphone:

https://www.panynj.gov/content/dam/port-authority/aircraft-noise/mobile-app-download-instructions.pdf





1. Scan the QR Code on your mobile device.

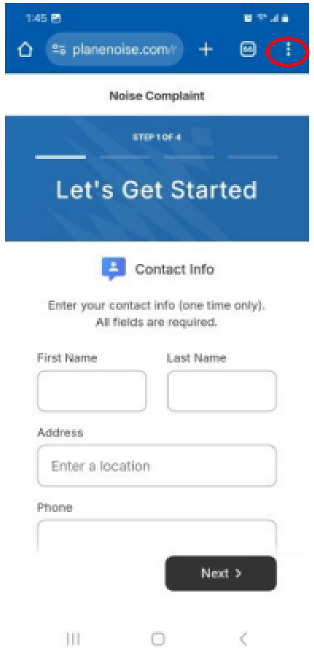
2. At the bottom of the screen click the icon in the middle with arrow pointing upwards.

3. Click the "Add to Home Screen" option.

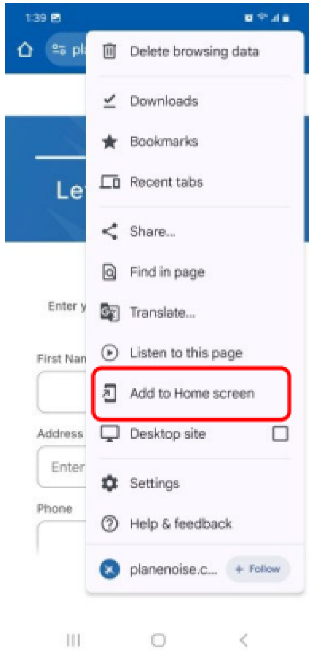
4. On the next page click "Add" in the top right corner.

Mobile App

https://www.panynj.gov/content/dam/port-authority/aircraft-noise/mobile-app-download-instructions.pdf



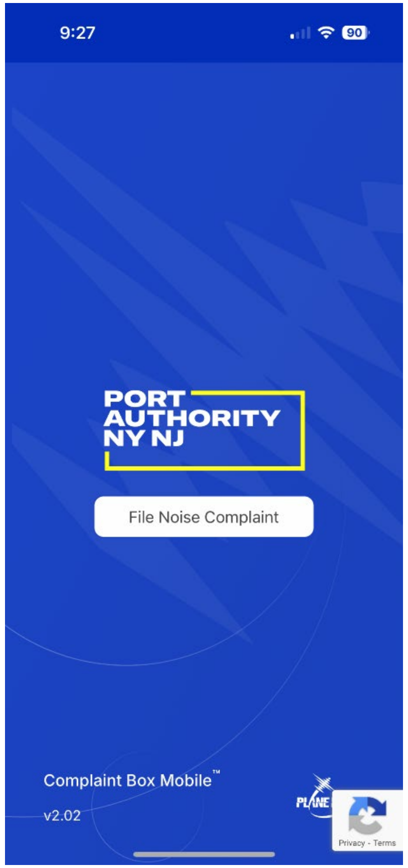
Enter your contact info (one time only). All fields are required.



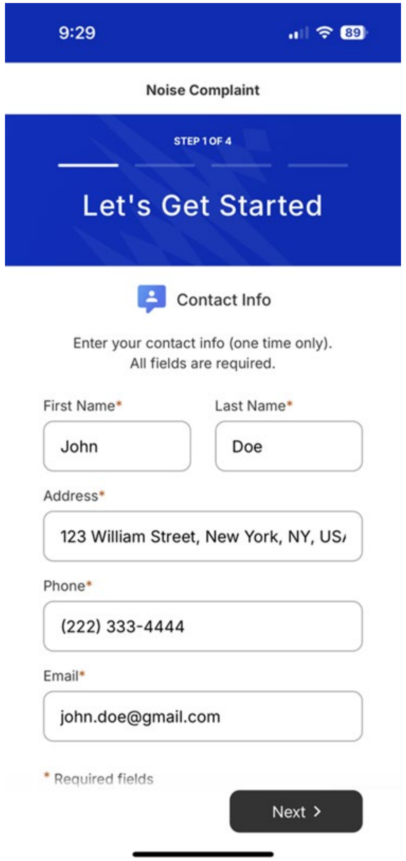
1. Scan the QR Code on your mobile device.
2. At the top right corner click the three vertical dots to open a dropdown menu.
3. In the dropdown menu click "Add to Home screen". *Please note that the "Add to Home screen" might be near the bottom of the dropdown list and may require you to scroll down to see it).*

New Noise Complaint App

New Noise Complaint App to make filing complaints more convenient



Submit a noise complaint in 4 easy steps



Enter your contact info (one time only). All fields are required.

First Name* John

Last Name* Doe

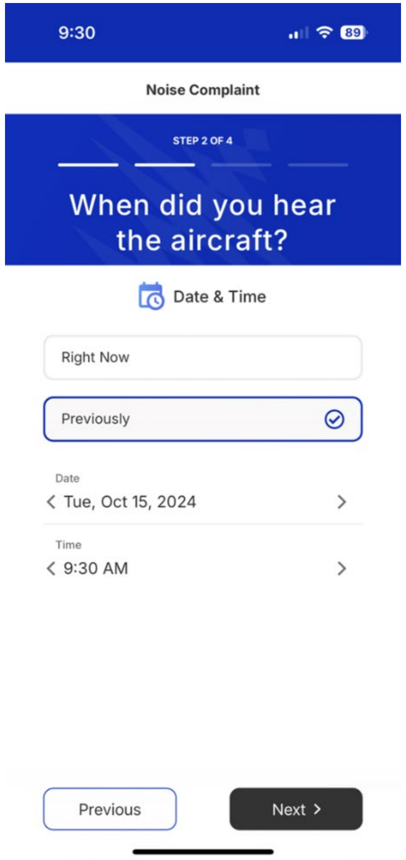
Address* 123 William Street, New York, NY, US/

Phone* (222) 333-4444

Email* john.doe@gmail.com

* Required fields

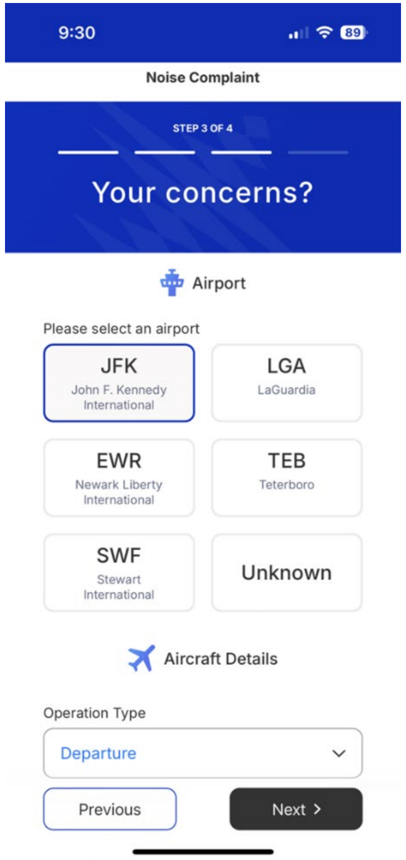
Enter your usual complaint and complaint location information



Date: Tue, Oct 15, 2024

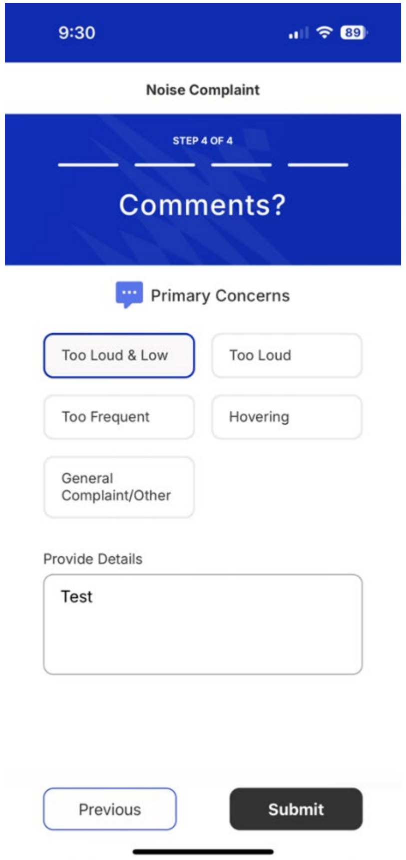
Time: 9:30 AM

Complaint location information is saved for more convenient future filings



Operation Type: Departure

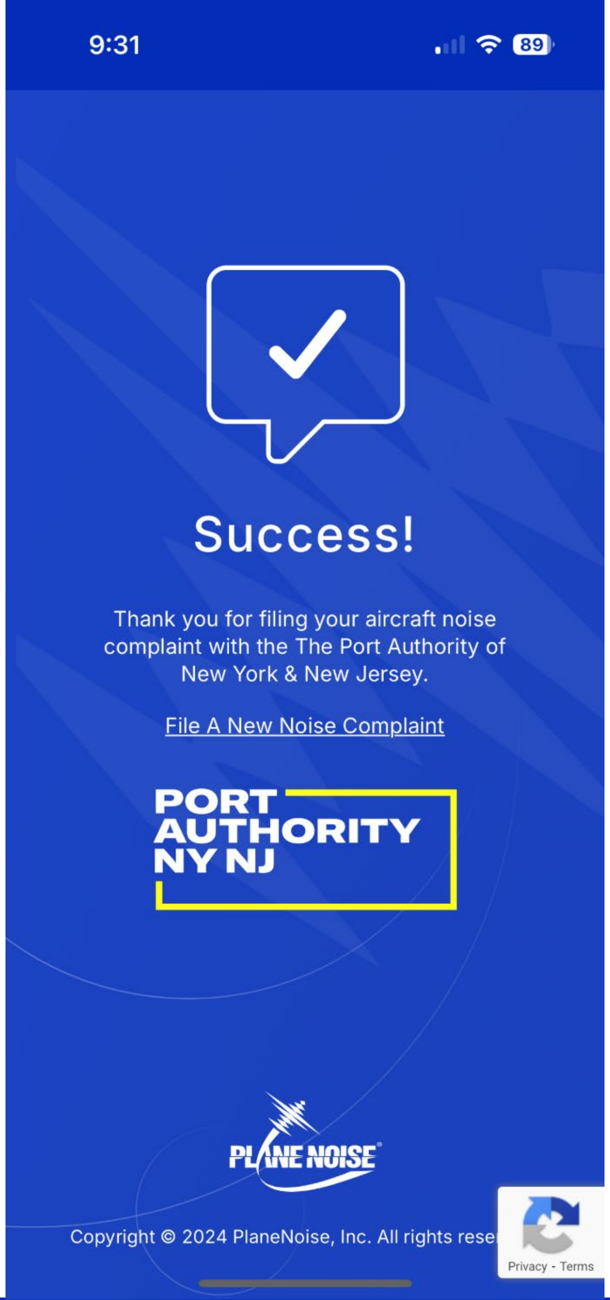
Hit Submit…



Provide Details: Test

New Noise Complaint App

Your complaint will be submitted to our system (same as if you filed through the web form)



Success!

Thank you for filing your aircraft noise complaint with the The Port Authority of New York & New Jersey.

File A New Noise Complaint

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Helpful Links

- PA Aircraft Noise webpage https://aircraftnoise.panynj.gov/
- Webtrak https://webtrak.emsbk.com/panynj4
- Submit a noise complaint https://aircraftnoise.panynj.gov/submit-a-noise-complaint/
- Monthly Reports https://aircraftnoise.panynj.gov/reports/
- Noise information and FAQs https://aircraftnoise.panynj.gov/faqs/

Thank You

Questions?

Summary of Ongoing FAA Sleep Research

Presented to:	New York Community Aviation Roundtable (NYCAR)
By:	Adam Scholten – Noise Division, Office of Environment and Energy
Date:	October 23, 2024

Federal Aviation Administration

FAA Noise Research Program Key Areas

As detailed in a January 2021 Federal Register Notice, FAA's primary areas of noise research fall into three broad categories:

- **Effects of Aircraft Noise on Individuals and Communities**
  - Including research on the heath and economic impacts from aviation noise
- **Noise Modeling, Noise Metrics and Environmental Data Visualization**
- **Reduction, Abatement and Mitigation of Aviation Noise**

https://www.federalregister.gov/documents/2021/01/13/2021-00564/overview-of-faa-aircraft-noise-policy-and-research-efforts-request-for-input-on-research-activities

FAA Aircraft Noise Heath and Economic Impacts Research Overview

Cardiovascular Disease

Objective: Evaluate associations between aircraft noise and cardiovascular outcome

Methods: Use existing health cohorts to evaluate link between health outcomes and noise exposure while accounting for wide range of factors

National longitudinal health cohorts:

- Medicare database
- Women's Health Initiative
- Nurses' Health Study / Health Professional Follow-up Study

Team: Research being conducted by Boston University School of Public Health through ASCENT Project 3

Economic Impacts of Noise

Objective: Conduct an empirical assessment of the economic impacts of aircraft noise on businesses and on residential property values

Methods: Identify airport communities with a change in noise, then conduct economic assessments for each community. Examine how results vary among communities and economic sectors

Team: Research being conducted by Massachusetts Institute of Technology through ASCENT Project 3 and Project 72

National Sleep Study

Objective: Quantify the impact of aircraft noise exposure on sleep disturbance through a dose-response relationship

Methods: National study of individuals in communities around 77 U.S. Airports wherein sleep disturbance data is collected from individuals exposed to varied noise levels; 2-year data collection effort began in 2021

Team: Research being conducted by University of Pennsylvania School of Medicine through ASCENT Project 17 and the FAA Technical Center

Reauthorization Connection: HR 302 § 189 – Study on Potential Health and Economic Impacts of Overflight Noise

ASCENT 03: https://ascent.aero/project/noise-impact-health-research/
ASCENT 72: https://ascent.aero/project/aircraft-noise-exposure-and-market-outcomes-in-the-us/
ASCENT 17: https://ascent.aero/project/noise-exposure-response-sleep-disturbance/

Sleep Disturbance Research Efforts Overview

Objective: To generate a dose-response relationships between aircraft noise exposure and sleep disturbance

Research Plan: Develop and use a scientifically sound, yet inexpensive, study methodology to obtain objective measures of sleep disturbance

Timeline:

Pilot Studies:

- 2016 - 1st airport: establish feasibility of unattended acquisition of acoustic and physiological field data, unattended sleep measurements
- 2017 - 2nd airport: determine field study recruitment methodology that maximizes response rate and minimizes cost; no staff; all equipment is mailed

National Sleep Study:

- 2021 - National field study sampling around 77 U.S. Airports: acquire current objective sleep disturbance data relative to varying degrees of exposure at many airports; data collection completed in October 2023

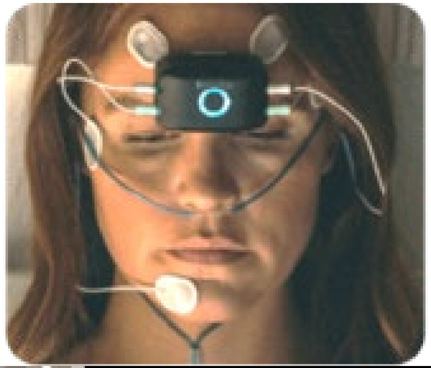
Research team led by University of Pennsylvania School of Medicine with technical support from HMMH and Westat -- FAA sponsorship under ASCENT Project 17 and the FAA Technical Center

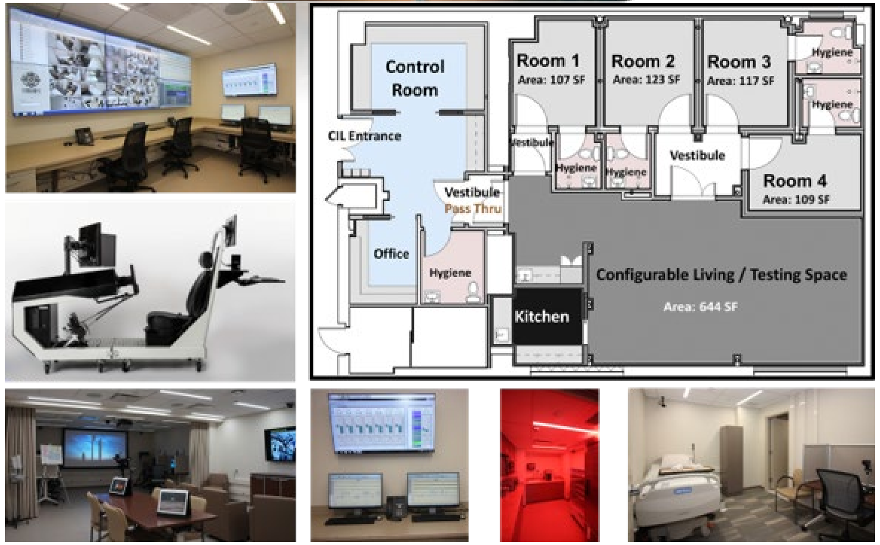
National Sleep Study (NSS) Overview

- A national field study to acquire current U.S. data on sleep disturbance relative to varying degrees of aircraft noise exposure to inform future policy considerations.
- Relies on an inexpensive methodology of using actigraphy and electrocardiography (ECG) that was tested through ASCENT pilot studies and found to provide a sensitive measure of awakenings.
  - Participants living near 77 U.S. airports are being selected using **stratified random population sampling**, so that the sample will be generalizable to populations most affected by aircraft noise
  - Sampling regions are classified into 40<45 dB, 45<50 dB, 50<55 dB and ≥55 dB based on L_{night}.
- A total of **400 participants** were recruited over a period of 2 consecutive years.
- The NSS will develop an exposure-response function describing the relationship between selected noise metric of an aircraft -- as measured inside the bedroom -- and the probability of awakening based on physiological measurements

ASCENT 86 Sleep Research

- Research at University of Pennsylvania under ASCENT Project 86 to examine how broadband noise could mitigate sleep disturbance due to aircraft noise
- Study leverages sleep research being done by University of Pennsylvania and ongoing efforts to improve our understanding of UAS/AAM as well as long-standing knowledge of subsonic aircraft and helicopters
- Laboratory study
  - 24 Volunteers
  - Four acoustically isolated bedrooms
  - Broadband noise played back over ceiling speakers
  - One adaptation night, followed by six conditions: aircraft noise night has 90+ noise events





ASCENT 86: https://ascent.aero/project/study-on-the-use-of-broadband-sounds-to-mitigate-sleep-disruption-due-to-aircraft-noise/

Questions

Environment International 187 (2024) 108660

Contents lists available at ScienceDirect

Environment International

journal homepage: www.elsevier.com/locate/envint

Full length article

Aircraft noise exposure and body mass index among female participants in two Nurses' Health Study prospective cohorts living around 90 airports in the United States

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[g] Department of Epidemiology, Gillings School of Global Public Health, University of North Carolina, Chapel Hill, NC 27599, USA
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ARTICLE INFO

Handling Editor: Adrian Covaci

Keywords:
Transportation noise
Aircraft noise
Obesity
Body mass index
Cohort study
Body weight

ABSTRACT

Objective: Aircraft noise exposure is linked to cardiovascular disease risk. One understudied candidate pathway is obesity. This study investigates the association between aircraft noise and obesity among female participants in two prospective Nurses' Health Study (NHS and NHSII) cohorts.

Methods: Aircraft day-night average sound levels (DNL) were estimated at participant residential addresses from modeled 1 dB (dB) noise contours above 44 dB for 90 United States (U.S.) airports in 5-year intervals 1995–2010. Biennial surveys (1994–2017) provided information on body mass index (BMI; dichotomized, categorical) and other individual characteristics. Change in BMI from age 18 (BMI18; tertiles) was also calculated. Aircraft noise exposures were dichotomized (45, 55 dB), categorized (<45, 45–54, ≥55 dB) or continuous for exposure ≥45 dB. Multivariable multinomial logistic regression using generalized estimating equations were adjusted for individual characteristics and neighborhood socioeconomic status, greenness, population density, and environmental noise. Effect modification was assessed by U.S. Census region, climate boundary, airline hub type, hearing loss, and smoking status.

Results: At baseline, the 74,848 female participants averaged 50.1 years old, with 83.0%, 14.8%, and 2.2% exposed to <45, 45–54, and ≥55 dB of aircraft noise, respectively. In fully adjusted models, exposure ≥55 dB was associated with 11% higher odds (95% confidence interval [95%CI]: −1%, 24%) of BMIs ≥30.0, and 15% higher odds (95%CI: 3%, 29%) of membership in the highest tertile of BMI18 (ΔBMI 6.7 to 71.6). Less-pronounced associations were observed for the 2nd tertile of BMI18 (ΔBMI 2.9 to 6.6) and BMI 25.0–29.9 as well as exposures ≥45 versus <45 dB. There was evidence of DNL-BMI trends ($p_{trends} \le 0.02$). Stronger associations were observed among participants living in the West, arid climate areas, and among former smokers.

Discussion: In two nationwide cohorts of female nurses, higher aircraft noise exposure was associated with higher BMI, adding evidence to an aircraft noise-obesity-disease pathway.

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1. Introduction

Aircraft are a source of transportation noise. Though it has only been partially quantified globally (He et al., 2014), millions of people are exposed to some level of aircraft noise (International Civil Aviation Organization (ICAO), 2023). Aircraft noise has been found to cause higher annoyance than other sources of transportation noise (road, rail) at any noise level (Miedema and Oudshoorn, 2001). Exposure to aircraft noise has been associated with annoyance (Baudin et al., 2020) and many health outcomes (van Kempen et al., 2018), including poor sleep (Bozigar et al., 2023; Nassur et al., 2019b, 2019a), hypertension (Baudin et al., 2020; Kim et al., 2021; Yang et al., 2015), stroke (Weihofen et al., 2019), poor psychological health (Baudin et al., 2018; Hegewald et al., 2020; Seidler et al., 2017), cancer (Hegewald et al., 2017), coronary heart disease, cardiovascular disease, and related mortality (Correia et al., 2013; Evrard et al., 2015; Hansell et al., 2013; Héritier et al., 2017; Roca-Barceló et al., 2021). However, there have also been no associations found with some cardiovascular and mental health outcomes (Grady et al., 2023; Nguyen et al., 2023; Wicki et al., 2023).

Environmental noise has been linked to stress responses, which subsequently influence physiological, metabolic, and immunological functioning (An et al., 2018; Babisch, 2003; Sivakumaran et al., 2022; van Kempen et al., 2018). Dysregulation of the autonomic nervous system and hypothalamic–pituitary–adrenal axis due to sustained stress responses (Pasquali, 2012) has been shown to increase obesity risk (Björntorp and Rosmond, 2000; Bose et al., 2009). Chronic stress is associated with changes in behaviors, such as overeating, physical inactivity, and curtailed sleep, factors that also increase the risk for obesity (Razzoli et al., 2017; Tomiyama, 2019; Torres and Nowson, 2007). In women, aircraft noise has been linked with increases in salivary cortisol (Selander et al., 2009), which is a stress-response biomarker, as well as with poorer sleep (Bozigar et al., 2023; Smith et al., 2022). Additionally, individuals chronically exposed to psychological stress may have elevated stress responses to subsequent perceived stressors (Aschbacher et al., 2013).

Body mass index (BMI) is commonly used as a proxy for obesity, with higher levels shown to be associated with numerous chronic diseases (Larsson and Burgess, 2021; World Cancer Research Fund International, 2022; World Health Organization, 2000). In addition, changes in body weight across the life course have been investigated as an important disease risk factor (Song et al., 2015), particularly the rapid weight gain from young adulthood to the middle and late adulthood periods (Chen et al., 2019). Environmental noise has been associated with markers of general obesity (e.g., BMI) and central obesity (e.g., waist circumference, waist-hip ratio) (An et al., 2018; Christensen et al., 2016, 2015; Cramer et al., 2019; Foraster et al., 2018; Oftedal et al., 2015; Pyko et al., 2017, 2015). Positive associations have been found between aircraft noise exposure and central obesity (Eriksson et al., 2014; Pyko et al., 2017); however, some studies found no associations (Foraster et al., 2018). Other studies have found positive associations between aircraft noise and diabetes (SØrensen et al., 2013), which, like obesity, is impacted by impairment in insulin action (Verma and Hussain, 2017). However, recent systematic reviews have found minimal evidence of associations between noise and measures of adiposity (Sivakumaran et al., 2022; van Kempen et al., 2018), and as far as we know, no study of aircraft noise and obesity involving United States (U.S.) populations have been published, to date.

Therefore, our objective was to estimate the associations between aircraft noise exposure, BMI, and changes in BMI from young adulthood among participants in two U.S.-based prospective cohorts of female nurses living near 90 major U.S. airports. We hypothesized that exposure to aircraft noise would be associated with higher BMI in the NHS cohorts.

2. Materials and methods

2.1. Study population and period

The study population is comprised of participants from two nationwide prospective cohorts, the Nurses' Health Study (NHS) and the Nurses' Health Study II (NHSII), which have been described in detail elsewhere (Bao et al., 2016a; Morabia, 2016). In brief, at inception in 1976, NHS recruited 121,700 female registered nurses ages 30–55 from 11 large states with state death registries (Belanger et al., 1978). Started in 1989, NHSII recruited 116,429 female registered nurses ages 25–42 from 14 states with large numbers of registered nurses. Cohort participants now live in all 50 states. The study participants were followed biennially by mailed questionnaires, with NHS participants responding to surveys in even years and NHSII participants responding in odd years, with response rates of $\geq$90% (Bao et al., 2016b; Morabia, 2016). The study period for NHS was 1994–2016 and for NHSII was 1995–2017, in which outcome metrics of BMI and aircraft noise exposure estimates were available. The protocol for this study was approved by the Institutional Review Board of Brigham and Women's Hospital, Boston, Massachusetts, and consent was implied through the return of the questionnaire.

2.2. Assessment of obesity outcomes

As an indicator of body fat, BMI was calculated from self-reported anthropometrics. Height was collected on the baseline questionnaire for all participants, and weight was self-reported on each biennial questionnaire. BMI is defined as the ratio of a person's weight (kg) to height-squared (m^2) (Keys et al., 1972). Self-reported BMI was found to be a reliable metric of obesity in this study sample (Rimm et al., 1990). Consistent with World Health Organization definitions, we employed categories in which a BMI of <18.5 was "underweight", 18.5–24.9 was "normal", 25.0–29.9 was "overweight", and $\geq$30.0 was "obese" (World Health Organization, 2000). Furthermore, to analyze differences in BMI from early adulthood to middle and late adulthood, we used a validated approach (Troy et al., 1995) in which we subtracted BMI calculated at the current follow-up from BMI calculated at age 18 (BMI18) from participant-recalled height and weight and grouped into tertiles. Age 18 represents the age of emerging adulthood and a critical period of weight gain (Lanoye et al., 2017); weight change since age 18 has been shown to be a risk factor for mortality in the NHS (Baer et al., 2011). BMI and BMI18 were calculated at each 2-year survey cycle (NHS: even years 1994–2016; NHSII: odd years 1995–2017).

2.3. Assessment of aircraft noise exposures

Day-night average sound level (DNL) is a metric intended to capture cumulative exposure to noise from aircraft over a 24-hour period (U.S. FAA (Federal Aviation Administration), 2022a). Annualized aircraft operations were used to quantify aircraft noise for an average day of the year. DNL is calculated in A-weighted decibels (dB), which selectively weights sound in the range of frequencies heard by humans and includes a 10 dB penalty for aircraft noise occurring between 22:00 and 07:00 (i.e., at night), a daily interval in which background noise levels from non-aircraft sources are generally low. DNL is similar to Lden, the metric commonly used for health decision-making in Europe and other parts of the world, except that Lden has different penalties for aircraft noise during the evening and at night (Brink et al., 2018; World Health Organization Regional Office for Europe, 2018). For this study, the U.S. Federal Aviation Administration's (FAA) Aviation Environmental Design Tool (AEDT) (U.S. FAA (Federal Aviation Administration), 2015) was used by the U.S. Department of Transportation's John A. Volpe National Transportation Systems Center (Volpe) to generate noise contours for 90 U.S. airports for every five years from 1995 to 2010 in 1 dB increments above 44 dB using aircraft operations data from the Official

Aviation Guide (OAG) for 1995 and from Enhanced Traffic Management System for 2000, 2005, and 2010. Further details of this method have been previously described elsewhere (Kim et al., 2021; Simon et al., 2022). The 90 airports included in this study were diverse in their characteristics – five (5.6%) were classified as airline primary hubs, 26 (28.9%) as secondary hubs, 16 (17.8%) as focus cities, and 43 (47.8%) as non-hubs/non-focus cities and together represented 87% of U.S. passenger enplanements (Nguyen et al., 2023; Simon et al., 2022). An airline hub is a central airport that airlines use to transfer passengers between flights as part of the "hub-and-spoke" system; primary hubs are the main centers with the most connections, while secondary hubs have fewer flights. Focus cities are key airports for airlines' point-to-point routes offering direct services rather than connections. In contrast, non-hub/non-focus airports are smaller, with limited flights, primarily serving direct, rather than connecting, passenger traffic.

Briefly, spatial estimation of exposures involved point-in-polygon linkage of geocoded residential address coordinates to temporally contemporaneous, airport-specific aircraft noise contours in 1 dB increments within a geographic information system (ArcGIS version 10.8.1, ESRI). Participants were assigned the DNL value corresponding to the contour in which their residence was located. Coordinates located outside aircraft noise contours but within 22.2 mi (35.7 km) of one of the 90 airports were assigned a value of 44 dB, i.e., 1 dB less than the lowest modeled noise contour of 45 dB. A buffer radius of 22.2 mi (35.7 km) represented the maximum empirical distance from an airport for which we had modeled aircraft noise above DNL of 44 A-weighted decibels (dB).

Every two-year survey cycle, each address was matched to the most recent of the aircraft noise contours provided at five-year intervals (1995, 2000, 2005, 2010) occurring in the past when the survey cycle did not coincide with the year for which there was an aircraft noise contour. For example, NHSII participants in 1999 were temporally matched to the year 1995 aircraft noise contours, while participants in 2001 were temporally matched to the year 2000 aircraft noise contours. Patterns in aircraft noise exposures at the 90 study airports over time are described elsewhere (Nguyen et al., 2023). For participants exposed to noise from multiple airports, noise levels were combined (Kim et al., 2021).

Because the FAA often uses DNL thresholds in decision-making in the U.S. (U.S. FAA (Federal Aviation Administration), 2022b), we dichotomized DNL at two cut points: <45 versus ≥ 45 and <55 versus ≥ 55 dB. Furthermore, we assessed the aircraft noise-BMI association by categorizing DNL at <45 dB (reference), 45–54 dB, and ≥ 55 dB. Last, we assessed associations with continuous aircraft noise per 10 dB among the subset of the population exposed to DNL ≥ 45 dB.

2.4. Covariates and potential confounders

Covariates and potential confounders were identified from the literature or hypothesized based on *a priori* knowledge and outlined in a theoretical directed acyclic graph (DAG; Supplemental Fig. 1) using the web-based tool, Daggity (Textor et al., 2016). Information on covariates was collected in the biennial survey and included: survey year indicators, cohort indicator (NHS/NHSII), age (continuous), age^2 (continuous), race (White, Black, American Indian, Asian, Hawaiian), individual SES metrics of living alone (yes, no) and spouse's education (<high school, high school, >high school), U.S. Census region (Northeast, Midwest, South, West), parity (nulliparous, 1–2 children, ≥ 3 children), postmenopausal status (yes, no, missing), hormone therapy (never, current, former, missing), smoking status (never, former, current, missing), alcohol use (none, >0–4, 5–9, 10–14, 15–29, ≥ 30 g/day, missing), Alternative Healthy Eating Index (AHEI) diet quality score (quintiles and a missing category) (McCullough and Willett, 2006), and physical activity quantified in reported metabolic equivalent of task (MET) (<3, 3–8, 9–17, 18–26, ≥ 27 h of total energy expenditure per week, missing) (Ainsworth et al., 1993). When metrics were not assessed during a survey cycle (e.g., diet quality), the values of the most recent cycle's assessed metrics were carried forward.

Potential environmental confounders included quintiles of air pollution (concentration of particulate matter of diameter 2.5 μm or smaller, $PM_{2.5}$), greenness, population density, neighborhood socioeconomic status (nSES), and environmental noise. Air pollution levels were estimated annually at the home address using a spatio-temporal prediction model with high predictive accuracy (Yanosky et al., 2014). Greenness was estimated from thenormalized difference vegetation index (NDVI) at 30 m resolution from annual Landsat satellite imagery in Google Earth Engine by matching each participant's current home address to a corresponding aggregated 270 m grid cell for 2000 to 2017. Population density was estimated in people/km^2 at the census tract level using decennial U.S. Census years 2000 and 2010, linearly interpolating between census years if necessary. At the census tract level, nSES was estimated as a summed z-score from many components of socioeconomic status from the U.S. Census (e.g., area-level race, education, income, home value, nativity, unemployment) (Deville et al., 2022). We used a time-invariant metric of environmental noise at 270 m resolution from the National Park Service model estimating combined noise from topographic, climate, hydrologic, and anthropogenic features including roads and military flight operations (Mennitt et al., 2014). Missing values were generally modeled as a missing category.

2.5. Inclusion and exclusion criteria

Participants with at least one successfully geocoded residential address at baseline that was linkable to environmental metrics (e.g., aircraft noise estimates) during our study period were included. Residential addresses were updated every biennial survey to capture participant moves. Participants were excluded at baseline or had their person-time excluded during follow-up if they did not reside within 22.2 mi (35.7 km) of one of 90 study airports. Participants living in areas outside the 22.2 mi (35.7 km) buffers could have lived closer to airports not included in the study, as well as in areas different from those of the population most likely to be exposed to aircraft noise from one of the 90 study airports. Participants were also excluded if they ever developed diabetes or cancer and at any time-period. Participant-years were also excluded if participants died, were currently pregnant, were missing outcome measures, had missing aircraft noise exposure estimates, or were missing other potential spatial confounders (e.g., neighborhood socioeconomic status, nSES, U.S. Census region, greenness, environmental noise, or population density). Finally, the <2% of the participant-years during which participants were classified as "underweight" (BMI <18.5) (World Health Organization, 2000) were excluded as there were too few participants in this category to facilitate statistical modeling. Supplementary Table 1 shows the counts and percentages of participants excluded by criteria at baseline and throughout the study period.

2.6. Statistical analyses

We used repeated participant measures of BMI and BMI18 linked to exposure data also updated over time. For all statistical analyses, generalized estimating equations (GEE) in SAS 9.4 (SAS Institute) were used to estimate associations among repeated measures as mixed models did not fully converge. We used an independent covariance matrix, the default for the GEE procedure to facilitate convergence, as well. Categories of BMI and BMI18 were modeled using multinomial logistic regression, in which odds ratios were interpreted as odds of membership in a category of BMI ≥ 25.0 (either 25.0–29.9 or ≥ 30.0) and BMI18 tertile (second or third) compared to respective reference groups (BMI: 18.5–24.9; BMI18: first tertile) for those exposed to aircraft noise. For continuous DNL, we estimated odds ratios and interpreted them as odds of BMI 25.0–29.9 or ≥ 30.0 and BMI18 second or third tertile from exposure to a 10 dB increase. In a sensitivity analysis, we modeled continuous BMI as a linear outcome. Linear regression assumptions using a log-standardized version of continuous BMI [ln(BMI)] were empirically assessed while fitting linear regression models. Potential trends between aircraft noise and BMI were estimated by using DNL 10 dB categories as continuous values and assessing the resulting coefficient for this version of DNL.

Our model building strategy consisted of first adjusting for the linear and quadratic effects of age, survey period, and cohort (Model 0). Then, we additionally adjusted for individual factors region of residence, race, living alone, spouse's education, parity, post-menopausal status, hormone therapy, smoking status, alcohol use, diet quality, and physical activity (Model 1). Finally, we added to Model 1 potential environmental confounders when they changed the association between DNL and BMI (Model 2).

Hypothesized effect measure modification by U.S. Census region of residence (Northeast, Midwest, South, West), U.S. climate boundary (humid, arid), airline hub type (non-hub/non-focus city, focus city, hub), self-reported hearing loss (none, any), and smoking status (never, former, current) was assessed. Addresses east of the 100th meridian (west of the prime meridian) were considered humid, while those west

Table 1

Characteristics of female participants in the Nurses' Health Study (NHS) and NHSII at baseline (NHS: 1994; NHSII: 1995) overall and by aircraft day-night average sound level (DNL) exposure group.

	Overall	**Day-night average sound level (DNL) group**					
		Nurses' Health Study			**Nurses' Health Study II**		
		<45 dB	**45–54 dB**	**≥ 55 dB**	**<45 dB**	**45–54 dB**	**≥ 55 dB**
	N = 74,848	N = 30,794	N = 5,193	N = 775	N = 31,352	N = 5,849	N = 885
Demographics							
Age, yr (SD)	50.1 (11.2)	59.7 (7.1)	60.0 (7.1)	60.2 (6.9)	40.8 (4.5)	40.7 (4.5)	40.6 (4.5)
Region of residence							
Northeast, %	43.1	49.5	57.9	59.8	34.7	37.5	49.5
Midwest, %	21.5	15.0	14.7	8.6	28.0	29.9	16.1
South, %	18.6	18.2	16.9	16.8	18.7	21.4	20.7
West, %	16.8	17.3	10.6	14.7	18.6	11.2	13.7
Race							
White, %	95.0	96.4	92.5	89.4	94.8	92.7	87.3
Black, %	2.8	2.2	5.7	9.3	2.3	4.2	6.8
American Indian, %	0.3	0.2	0.3	0.1	0.3	0.3	0.6
Asian, %	1.9	1.2	1.5	1.1	2.4	2.7	5.1
Hawaiian, %	0.1	0.0	0.0	0.0	0.1	0.2	0.1
Currently live alone, %	10.1	9.5	10.5	10.9	10.2	12.7	11.8
Spouse's education							
<High school, %	2.0	3.5	3.9	3.7	0.4	0.7	0.4
High school, %	18.0	24.9	26.1	31.1	11.0	10.9	14.1
>High school, %	55.3	43.2	39.2	32.2	68.3	65.2	63.4
Not married or missing, %	24.7	28.4	30.8	33.0	20.3	23.2	22.1
Parity							
Nulliparous, %	15.9	5.5	5.5	5.3	25.5	28.2	29.2
1–2 children, %	43.4	35.0	35.0	38.5	51.8	49.5	48.6
3 + children, %	39.8	57.6	57.7	54.0	22.7	22.3	22.2
Missing, %	0.9	1.8	1.8	2.3	0.0	0.0	0.0
Post-menopausal							
No, %	51.6	10.8	10.3	12.2	91.1	90.8	92.9
Yes, %	47.2	89.0	89.5	87.8	6.9	6.8	5.5
Missing, %	1.2	0.2	0.2	0.0	2.1	2.4	1.6
HT							
Never, %	60.5	26.1	29.9	31.6	93.1	93.2	94.5
Former, %	22.2	40.3	35.6	31.6	5.5	5.6	4.0
Current, %	8.8	16.6	16.1	17.1	1.3	1.2	1.5
Missing, %	8.5	17.0	18.5	19.7	0.1	0.0	0.0
Smoking status							
Never, %	53.1	42.9	40.7	41.6	63.6	62.1	60.9
Former, %	34.2	43.4	43.9	43.5	25.3	25.4	25.6
Current, %	12.5	13.6	15.1	14.5	11.0	12.3	13.5
Missing, %	0.2	0.2	0.4	0.3	0.1	0.2	0.0
AHEI indicator, %	81.9	83.3	81.3	78.8	81.2	79.9	77.1
Index (SD)	51.3 (10.8)	52.9 (10.6)	52.4 (10.6)	52.7 (10.8)	49.9 (10.7)	49.6 (10.9)	50.3 (10.8)
Alcohol g/day (SD)	4.6 (8.1)	5.5 (9.2)	5.1 (9.1)	4.1 (7.5)	3.9 (6.8)	3.9 (7.3)	3.8 (6.5)
PA indicator, %	94.7	89.6	87.8	86.0	100.0	100.0	100.0
MET hr/week (SD)	20.4 (26.1)	19.9 (24.4)	18.5 (23.0)	17.7 (22.0)	21.0 (27.6)	21.2 (28.4)	21.9 (31.6)
PM2.5, μg/m3 (SD)	14.6 (2.9)	14.5 (2.9)	15.4 (2.9)	15.4 (2.7)	14.4 (3.0)	15.0 (2.8)	14.9 (2.6)
NDVI (SD)	0.33 (0.10)	0.36 (0.10)	0.32 (0.11)	0.28 (0.11)	0.36 (0.10)	0.33 (0.11)	0.29 (0.11)
Pop density, pp/km^2 (SD)	2,250 (4,827)	1,757 (3,296)	3,447 (5,916)	4,452 (6,174)	2,169 (5,215)	3,622 (6,978)	4,221 (5,650)
nSES indicator, %	100.0	100.0	100.0	100.0	100.0	99.9	99.7
Sum z-score (SD)	−0.2 (3.3)	−0.4 (3.3)	−0.5 (3.0)	−0.8 (3.0)	0.0 (3.4)	−0.3 (3.4)	−0.3 (3.1)
EN, dB (SD)	48.5 (2.8)	48.0 (2.7)	49.9 (2.4)	50.7 (2.4)	48.3 (2.9)	50.1 (2.5)	50.5 (2.3)
BMI, kg/m^2 (SD)	26.1 (5.5)	26.3 (5.0)	26.6 (5.2)	26.9 (5.3)	25.8 (5.8)	26.1 (5.9)	26.4 (6.1)
BMI change from age 18, kg/m^2 (SD)	4.8 (4.7)	5.0 (4.5)	5.3 (4.8)	5.4 (4.8)	4.6 (4.7)	4.7 (4.8)	5.0 (4.8)

Values are means (SD) for continuous variables and percentages for categorical variables. Study sample metrics are standardized to the age distribution of the NHS and NHSII cohorts. Values of categorical variables may not sum to 100% due to rounding. dB: decibel, SD: standard deviation, HT: hormone therapy; AHEI: Alternative Healthy Eating Index; PA: physical activity; MET: metabolic equivalent of task; PM$_{2.5}$: concentration of particulate matter 2.5 μm or smaller, NDVI: normalized difference vegetation index; pop: population; nSES: neighborhood socioeconomic status; EN: environmental noise (median daytime); BMI: body mass index.

of the 100th meridian were considered arid (Seager et al., 2018). The few participants living near airports in Hawaii and Alaska were placed in the humid climate category. The two airline hub types of secondary hubs and largest primary hubs were collapsed into a single "hubs" category due to a small count of participants living around the largest primary hubs (Nguyen et al., 2023). In NHS, hearing loss was self-reported in 2006, 2008, 2012, and 2016; in NHSII, hearing loss was self-reported in 2009, 2013, and 2017. Analyses of effect modification by hearing loss were for the period 2006–2017, and values within this period were carried forward if missing. Categories of mild, moderate, or severe hearing loss were grouped and dichotomized as "any" (versus "none"). Interactions between potential effect modifiers and dichotomized aircraft noise exposures were estimated from multinomial models by including respective multiplicative interaction terms and assessed for statistical significance using Type III Wald tests. Additionally, multinomial models of BMI were stratified by the levels of each potential effect modifier to assess the stratum-specific associations between DNL and BMI.

3. Results

3.1. Descriptive results

The 74,848 participants contributed 538,229 observations, averaging 7 observations (median: 8; range: 1–12) per participant throughout the study period. At study baseline, their average age was 50.1 years (standard deviation, SD 11.2), and 83.0%, 14.8%, and 2.2% of the participants were exposed to <45, 45–54, and ≥ 55 dB of aircraft noise, respectively (Table 1). Participants primarily lived in the Northeast U.S. (43.1%) (Fig. 1). The study sample of female nurses lacked sociodemographic diversity, with 95.0% identifying as White, 10.1% reporting living alone, and 20.0% having a spouse with a high school education or less.

Key differences were seen across exposure categories among participants by self-identified race, in which a greater proportion of Black participants and correspondingly lower proportions of White participants were exposed to higher levels of aircraft noise. There were large differences across exposure groups for participants' area population density and environmental noise. Increasing average BMI and BMI18 were evident with increasing categories of aircraft noise exposure.

Characteristics were similar across the cohorts, though some differences were noted. NHS participants were older and lived more in the Northeast than NHSII participants. There were differences related to parity, post-menopausal status, HRT use, smoking status, and alcohol use across the cohorts. Counts of participants excluded by criterion are found in Supplementary Table 1. Three by three cell counts of participants and person-years for DNL and BMI categories overall and within strata of potential effect modifiers are included for reference in Supplementary Tables 2-7.

3.2. Regression results

Environmental factors that altered associations with DNL in multivariable regression models of BMI included greenness, population density, neighborhood socioeconomic status, and environmental noise, and these were included in the fully-adjusted model, Model 2. Of note, air

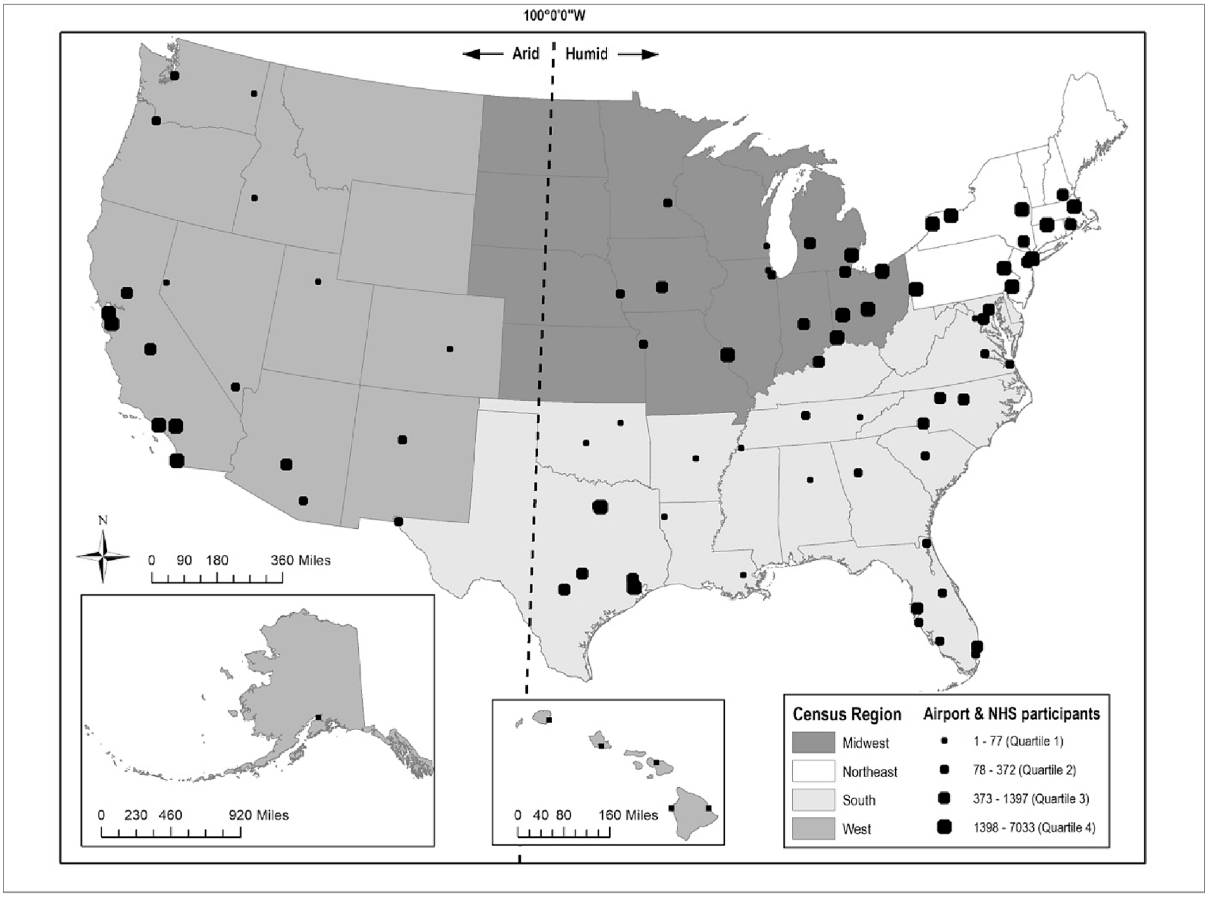

Fig. 1. Locations of 90 study airports in the United States symbolized by quartiles of participants pooled from the Nurses' Health Study (NHS) and NHSII living around each airport. Increasing point sizes are proportional to the increasing quartiles of study participants from the pooled sample of NHS and NHSII living within 22.2 miles (35.7 km) of each study airport at baseline. States are outlined and colors indicate each of four U.S. Census regions. The 100th meridian west of the Prime Meridian denotes the boundary between arid and humid areas.

pollution was not included in Model 2 as it did not empirically affect the noise-BMI association. Results from Model 2 of categorical BMI indicated 5% higher odds (95%CI: 1%, 9%) of being in the BMI 25.0–29.9 category and 5% higher odds (95%CI: 1%, 10%) of being in the BMI ≥30.0 category versus being in the BMI 18.5–24.9 category among participants exposed to DNL ≥45 dB (Table 2). At the 55 dB cut point, the estimates increased in magnitude to 13% higher odds (95%CI: 3%, 23%) of being in the BMI 25.0–29.9 category and 11% higher odds (95% CI: −1%, 24%) of being in the BMI ≥30.0 category versus being in the BMI 18.5–24.9 category in the fully adjusted model.

For changes in BMI since age 18, associations were modest for the middle tertile (ΔBMI 2.9 to 6.6) relative to the first (ΔBMI −52.3 to 2.8) at either the DNL 45 or 55 dB cut point (Table 2). The estimated associations for the third tertile (ΔBMI 6.7 to 71.6) versus the first tertile were similar in magnitude to the BMI results for the BMI ≥30.0 category versus the BMI 18.5–24.9 category.

We observed 5% higher odds of being in either the BMI 25.0–29.9 category (95%CI: 2%, 8%) or the ≥30.0 category (95%CI: 1%, 9%) from a 10 dB increase in DNL for DNL ≥45 dB (Table 3). Similarly, we saw elevated odds of being in either the 2nd (point estimate: 2%; 95%CI: −1%, 6%) or 3rd (point estimate: 5%; 95%CI: 1%, 9%) tertiles of BMI18 from a 10 dB increase in DNL.

Fig. 2 and Supplementary Table 8 indicate an exposure–response association with a statistically significant trend ($p_{trends} \leq 0.02$) of higher odds of being in either the BMI 25.0–29.9 category or the BMI ≥30.0 category versus being in the BMI 18.5–24.9 category for increasing exposures to aircraft noise of 45–54 and ≥55 dB versus <45 dB. Adjusting for demographics, lifestyle, and environmental factors attenuated the associations but the exposure–response trends remained.

There were differences in the association between aircraft noise and BMI category by Census region (p = 0.05) (Table 4). For participants living in the West, exposure to DNL ≥45 dB was associated with 14% (95%CI: 3%, 27%) and 26% (95%CI: 10%, 44%) higher odds for participants being in the BMI 25.0–29.9 category or the BMI ≥30.0 category versus being in the BMI 18.5–24.9 category, respectively. Estimated odds ratios nearly doubled when moving the cut point from 45 to 55 dB

Table 3
Results from multinomial logistic regression models of categorical body mass index (BMI) and tertiles of change in BMI from age 18 using a continuous version of day-night average sound level (DNL) exposure for DNL ≥45 dB (dB) by level of adjustment for potential confounding factors in the pooled sample from the Nurses' Health Study (NHS) and NHSII cohorts 1994–2017.

	Odds ratio (95% confidence interval) for DNL 10 dB increase		
	Body mass index categories		
Model	**18.5–24.9**	**25.0–29.9**	**≥30.0**
$N_{observations}$	**251,628**	**166,916**	**119,690**
$N_{participants}$	**46,202**	**39,778**	**24,771**
0: Age	Reference	1.09 (1.05, 1.12)	1.14 (1.10, 1.18)
1: 0 + demographics & lifestyle	Reference	1.05 (1.02, 1.08)	1.06 (1.02, 1.10)
2: 1 + environmental	Reference	1.05 (1.02, 1.08)	1.05 (1.01, 1.09)
	Body mass index (kg/m^2) change from age 18		
	Tertile 1	**Tertile 2**	**Tertile 3**
	ΔBMI	**ΔBMI**	**ΔBMI**
	−52.3–2.8	**2.9–6.6**	**6.7–71.6**
$N_{observations}$	**167,523**	**168,421**	**167,701**
$N_{participants}$	**35,220**	**41,066**	**33,444**
0: Age	Reference	1.04 (1.01, 1.07)	1.11 (1.07, 1.15)
1: 0 + demographics & lifestyle	Reference	1.02 (0.99, 1.05)	1.04 (1.00, 1.08)
2: 1 + environmental	Reference	1.02 (0.99, 1.06)	1.05 (1.01, 1.09)

Model 0 adjusted for age, age^2, survey period, and cohort. Model 1 adjusted for the covariates in Model 0 as well as region, race, living alone, spouse's education, parity, post-menopausal status, hormone therapy, smoking status, alcohol use, diet quality, and physical activity. Model 2 adjusted for the covariates from Model 1 in addition to greenness, population density, neighborhood socioeconomic status, and environmental noise.

Table 2
Estimated odds ratios (OR) and 95% confidence intervals (CI) for the association between aircraft day-night average sound level (DNL) at thresholds of 45 and 55 dB and categorical body mass index (BMI) and tertiles of change in BMI from age 18 by level of adjustment for potential confounders in the pooled Nurses' Health Study (NHS) and NHSII cohorts 1994–2017.

	Odds ratios (95% confidence interval)					
	Body mass index (kg/m^2) categories					
	DNL ≥45 vs <45 dB			**DNL ≥55 vs <55 dB**		
Model	**18.5–24.9**	**25.0–29.9**	**≥30.0**	**18.5–24.9**	**25.0–29.9**	**≥30.0**
$N_{observations}$	**251,628**	**166,916**	**119,690**	**251,628**	**166,916**	**119,690**
$N_{participants}$	**46,202**	**39,778**	**24,771**	**46,202**	**39,778**	**24,771**
0: Age	Reference	1.09 (1.06, 1.13)	1.16 (1.11, 1.21)	Reference	1.20 (1.09, 1.31)	1.27 (1.14, 1.42)
1: 0 + demographics & lifestyle	Reference	1.05 (1.01, 1.09)	1.07 (1.02, 1.12)	Reference	1.14 (1.04, 1.24)	1.14 (1.02, 1.28)
2: 1 + environmental	Reference	1.05 (1.01, 1.09)	1.05 (1.01, 1.10)	Reference	1.13 (1.03, 1.23)	1.11 (0.99, 1.24)
	Body mass index (kg/m^2) change from age 18					
	Tertile 1	**Tertile 2**	**Tertile 3**	**Tertile 1**	**Tertile 2**	**Tertile 3**
	ΔBMI	**ΔBMI**	**ΔBMI**	**ΔBMI**	**ΔBMI**	**ΔBMI**
	−52.3 – 2.8	**2.9 – 6.6**	**6.7 – 71.6**	**−52.3 – 2.8**	**2.9 – 6.6**	**6.7 – 71.6**
$N_{observations}$	**167,523**	**168,421**	**167,701**	**167,523**	**168,421**	**167,701**
$N_{participants}$	**35,220**	**41,066**	**33,444**	**35,220**	**41,066**	**33,444**
0: Age	Reference	1.04 (1.00, 1.08)	1.12 (1.07, 1.17)	Reference	1.09 (0.99, 1.20)	1.26 (1.13, 1.41)
1: 0 + demographics & lifestyle	Reference	1.02 (0.98, 1.06)	1.04 (0.99, 1.09)	Reference	1.07 (0.97, 1.18)	1.15 (1.03, 1.29)
2: 1 + environmental	Reference	1.02 (0.98, 1.06)	1.05 (1.00, 1.10)	Reference	1.07 (0.97, 1.19)	1.15 (1.03, 1.29)

Model 0 adjusted for age, age^2, survey period, and cohort. Model 1 adjusted for the covariates in Model 0 as well as region, race, living alone, spouse's education, parity, post-menopausal status, hormone therapy, smoking status, alcohol use, diet quality, and physical activity. Model 2 adjusted for the covariates from Model 1 in addition to greenness, population density, neighborhood socioeconomic status, and environmental noise.

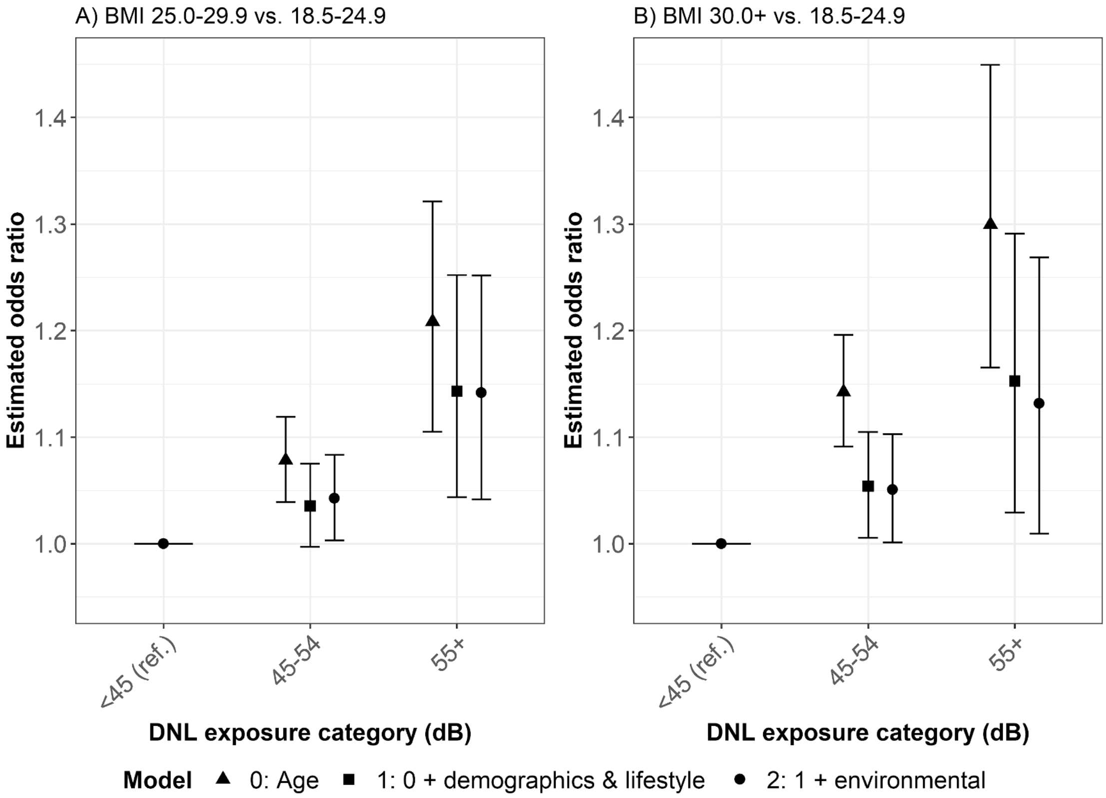

Fig. 2. Estimated odds ratios (OR) and 95% confidence intervals (CI) for the potential exposure–response association between categorical aircraft day-night average sound levels (DNL) in decibels (dB) and categorical body mass index (BMI) by level of adjustment for potential confounding factors in the pooled sample from the Nurses' Health Study (NHS) and NHSII cohorts 1994–2017. * For BMI 25.0–29.9, p_{trend} values were <0.01 for Models 0, 1, and 2. For BMI ≥30.0, p_{trend} values were <0.01 for Models 0 and 1, and $p = 0.02$ for Model 2. Model 0 adjusted for age, age^2, survey period, and cohort. Model 1 adjusted for the covariates in Model 0 as well as region, race, living alone, spouse's education, parity, post-menopausal status, hormone therapy, smoking status, alcohol use, diet quality, and physical activity. Model 2 adjusted for the covariates from Model 1 in addition to greenness, population density, neighborhood socioeconomic status, and environmental noise.

among participants living in the West region. The largest odds ratios were for participants living in arid climate areas, where differences were found at both the 45 ($p = 0.01$) and 55 dB ($p = 0.05$) cut points. For example, the odds of being in the BMI ≥30.0 category versus being in the BMI 18.5–24.9 category for participants living near an airport in an arid region were 52% higher (95%CI: 13%, 104%) for those exposed to DNL ≥55 dB, versus 6% (95%CI: −6%, 19%) for those in a humid region. There was little evidence that the aircraft noise-BMI group association differed by airline hub type, though there was a possible indication of odds ratio decreases from non-hub/non-focus cities to focus cities to hubs for participants exposed to DNL ≥55 dB. Few differences were found by hearing loss status ($p = 0.84$ at 45 dB; $p = 0.27$ at 55 dB) or smoking status at the 45 dB cut point ($p = 0.99$). However, when exposed to DNL ≥55 dB ($p = 0.06$), participants who were former smokers had 32% higher odds (95%CI: 14%, 53%) of being in the BMI 25.0–29.9 category versus being in the BMI 18.5–24.9 category, although the association attenuated for the BMI ≥30.0 category.

4. Discussion

In this cohort study of females living throughout the U.S., we investigated the association between aircraft noise exposure and an indicator of general obesity, BMI. We had access to data with wide geographic coverage, as exposures were estimated around 90 airports spanning different sizes and covering most of the passenger enplanements across all four Census regions and two main climate types in the U.S. Both BMI outcomes and aircraft noise exposures were available over several decades. We found that aircraft noise exposure at DNL levels ≥45 dB was associated with higher BMI among participants, with the largest associations for exposures ≥55 dB, indicative of an exposure–response relationship. Moreover, exposures to DNL ≥45 dB were also associated with higher BMI of participants since they were 18 years of age.

Evidence of the relationship between exposure to transportation noise and greater obesity to date has been dependent on the study type and objectives, population, and obesity metrics used. All studies of transportation noise and obesity found in the literature to date were conducted in select European populations – Denmark, Switzerland, Oslo, and Stockholm (Christensen et al., 2016, 2015; Cramer et al., 2019; Eriksson et al., 2014; Foraster et al., 2018; Oftedal et al., 2015; Pyko et al., 2017). In a meta-analysis of these seven studies, chronic exposure to transportation noise was associated with higher waist circumference but was not associated with BMI (An et al., 2018).

We found only four studies to date that investigated the associations between aircraft noise and obesity and a fifth that considered aircraft noise as a confounder because there was insufficient statistical power to examine it as a main exposure (Christensen et al., 2016). Three of the studies were located in the greater Stockholm area of Sweden (Eriksson et al., 2014; Pyko et al., 2017, 2015), while the other was located in Switzerland (Foraster et al., 2018). These studies did not find associations between aircraft noise exposure and BMI. As such, these results differed from our central findings of associations between aircraft noise, BMI, and BMI changes since age 18. Why we found associations, but the previous research did not, is poorly understood; however, natural, cultural, physical, and societal differences exist across the U.S. and select European countries previously studied that are hypothesized to play a role. We found no previous studies in the literature that were able to assess changes in obesity from early adulthood to later periods of

Table 4

Estimated odds ratios (OR) and 95% confidence intervals (CI) for potential effect measure modifiers of the association between aircraft day-night average sound level (DNL) and categorical body mass index (BMI) from fully-adjusted models (Model 2) in the pooled Nurses' Health Study (NHS) and NHSII cohorts 1994–2017.

			Odds ratio (95% confidence interval)							
			DNL ≥45 vs <45 dB				DNL ≥55 vs <55 dB			
	$N_{observations}$	$N_{participants}$	BMI 18.5–24.9	BMI 25.0–29.9	BMI ≥30.0	p	BMI 18.5–24.9	BMI 25.0–29.9	BMI ≥30.0	p
Census region	**538,234**	**74,848**				**0.05**				**0.20**
Northeast	226,954	32,652	Reference	1.05 (0.99, 1.12)	1.03 (0.96, 1.11)		Reference	1.09 (0.96, 1.25)	1.05 (0.89, 1.24)	
Midwest	117,909	16,526	Reference	0.98 (0.91, 1.06)	0.96 (0.87, 1.06)		Reference	1.12 (0.91, 1.40)	0.87 (0.66, 1.15)	
South	101,409	15,714	Reference	1.08 (1.00, 1.18)	1.11 (1.00, 1.23)		Reference	1.14 (0.94, 1.38)	1.24 (0.98, 1.57)	
West	91,961	13,374	Reference	1.14 (1.03, 1.27)	1.26 (1.10, 1.44)		Reference	1.23 (0.96, 1.58)	1.46 (1.07, 1.98)	
Climate boundary	**538,234**	**74,848**				**0.01**				**0.05**
Humid	444,764	62,506	Reference	1.04 (1.00, 1.08)	1.04 (0.98, 1.09)		Reference	1.10 (1.00, 1.22)	1.06 (0.94, 1.19)	
Arid	93,470	13,618	Reference	1.14 (1.03, 1.27)	1.26 (1.10, 1.44)		Reference	1.28 (1.00, 1.62)	1.52 (1.13, 2.04)	
Airline hub type	**538,234**	**74,848**				**0.82**				**0.38**
Non-hub/non-focus city	180,061	26,094	Reference	1.07 (1.00, 1.15)	1.03 (0.94, 1.13)		Reference	1.24 (1.02, 1.51)	1.37 (1.07, 1.75)	
Focus city	134,522	19,834	Reference	1.07 (1.00, 1.16)	1.09 (0.99, 1.19)		Reference	1.17 (0.96, 1.41)	1.11 (0.87, 1.41)	
Hubs	223,651	33,531	Reference	1.03 (0.98, 1.09)	1.04 (0.97, 1.12)		Reference	1.09 (0.96, 1.23)	1.04 (0.89, 1.21)	
Hearing loss*	**153,306**	**43,892**				**0.84**				**0.27**
None	104,759	33,149	Reference	1.08 (1.00, 1.17)	1.05 (0.96, 1.15)		Reference	1.37 (1.12, 1.68)	1.11 (0.87, 1.43)	
Any	48,547	17,992	Reference	1.09 (0.98, 1.21)	1.15 (1.01, 1.31)		Reference	1.21 (0.99, 1.64)	1.41 (0.99, 2.03)	
Smoking status	**537,442**	**74,740**				**0.99**				**0.06**
Never	295,576	39,766	Reference	1.05 (1.00, 1.11)	1.07 (1.00, 1.14)		Reference	1.03 (0.90, 1.17)	1.07 (0.92, 1.25)	
Former	197,678	30,845	Reference	1.07 (1.01, 1.14)	1.05 (0.97, 1.13)		Reference	1.32 (1.14, 1.53)	1.18 (0.98, 1.42)	
Current	44,188	11,359	Reference	1.05 (0.95, 1.17)	1.05 (0.92, 1.21)		Reference	1.08 (0.85, 1.39)	1.10 (0.81, 1.50)	

Model 2 adjusted for age, age^2, survey period, cohort (Model 0), region, race, living alone, spouse's education, parity, post-menopausal status, hormone therapy, smoking status, alcohol use, diet quality, physical activity (Model 1), greenness, population density, neighborhood socioeconomic status, and environmental noise. * Analyses of hearing loss did not include all survey years, as it was only available in certain years. In NHS, hearing loss was ascertained in 2006, 2008, 2012, and 2016; in NHSII, hearing loss was ascertained in 2009, 2013, and 2017. "Any" includes mild, moderate, and severe self-reported hearing loss.

adulthood associated with aircraft noise exposure as in this study. More generally, systematic reviews of contemporary studies concluded that there is not enough research and subsequent findings on the subject of noise and BMI to establish a causative link with high certainty (Sivakumaran et al., 2022; van Kempen et al., 2018), indicating the importance of this study and continued research on the subject.

Regarding metrics of central obesity, higher waist circumferences were associated with exposure to aircraft noise over time (Eriksson et al., 2014; Pyko et al., 2017) and cross-sectionally (Pyko et al., 2015) in Stockholm-based studies. In a population-based cohort study in Switzerland, only sources of transportation noise other than aircraft were positively associated (Foraster et al., 2018). In a cohort study in Sweden, excess risk of central obesity was found at levels of aircraft noise below 50 dB, unlike road noise, which indicated significant associations above 50 dB (Pyko et al., 2017). The association with waist circumference was also stronger for aircraft than road noise. Pyko et al. (2017) also found that aircraft noise exposure was linked to weight gain. Our study was unable to assess associations between aircraft noise and indicators of central obesity because such self-reported metrics (e.g., waist circumference) had greater missingness compared to self-reported weight, and the missingness was related to the participant's category of BMI, suggesting the presence of selection bias. Moreover, indicators of central obesity were rarely assessed within the study period (NHS: 1996; NHSII: 1995, 2005).

Our findings in relation to general obesity can be considered alongside prior research in this cohort that indicated that aircraft noise exposure was associated with shorter sleep duration (Bozigar et al., 2023). BMI and sleep are closely intertwined (Larsen et al., 2020), but the directionality of whether higher BMI decreases sleep duration, lower sleep duration increases BMI, neither causes the other because both are downstream effects, or a complex causal interplay between the two is not known. There may be a stronger association between transportation noise and stress metrics for women. The Hypertension and Exposure to Noise near Airports (HYENA) study found that morning salivary cortisol concentrations were significantly higher for women exposed to noise at higher levels (60 dB vs. 50 dB), but greater cortisol concentrations were not observed among men at the same noise levels (Selander et al., 2009).

Though we did not observe large differences by adjusting for other environmental exposures in this study, failing to adjust for them can bias estimates of environmental effects on health (Chaix et al., 2010). One study showed that lower nSES was associated with higher BMI and waist circumference (Leal et al., 2011). Few studies of transportation noise have adjusted for similar area-level confounding factors comprising the built and social environments (Foraster et al., 2018). $PM_{2.5}$ was not observed to be a confounder of the association between aircraft noise and BMI in this study, but previous studies have linked air pollution with increases in BMI in children (Jerrett et al., 2014) and with metabolic syndrome in adults (Eze et al., 2015). Our results provided evidence of confounding of the aircraft noise-BMI association by area greenness, environmental noise, population density, and nSES in the study population given the independent associations each environmental factor had with BMI and correlations with aircraft noise exposure. As these environmental factors are further correlated or even driven by urbanization, which was unmeasured in our study, it is likely that urbanization similarly confounds the association. By excluding participants living greater than 22.2 mi (35.7 km) from a study airport, we helped limit the impact of confounding by urbanization further. Based on our theoretical DAG, the Daggity web tool (Textor et al., 2016) identified a minimally sufficient adjustment set, or the list of the fewest variables (i.e., actual confounders) to condition upon to sufficiently control for bias due to confounding of the association between the exposure and outcome given correct specification of the model, which was comprised of region, physical activity, nSES, environmental noise, and greenness. Main associations found by conditioning on only this set of confounders were qualitatively comparable and slightly larger in quantitative magnitude (possibly from reduced confounding) than those from Model 2 irrespective of the form of the outcome or exposure.

There has been somewhat limited evidence of effect modification of the association between transportation noise and obesity by individual and environmental characteristics. Several studies found no significant interactions (Christensen et al., 2016, 2015; Oftedal et al., 2015), while one study found an interaction between road traffic noise and age with waist circumference increase (Pyko et al., 2017), and another found that obesity was more likely to increase in people with high central obesity at study baseline (Christensen et al., 2015). One study found that the associations between road traffic noise and markers of obesity were stronger among noise-sensitive women (Oftedal et al., 2015). Results from previous research suggested that the association between aircraft noise and sleep was modified by level of hearing loss, with the strongest association in those reporting no hearing loss (Bozigar et al., 2023), though we found limited evidence of effect modification by level of hearing loss in the present study.

In contrast, we found that the association between aircraft noise exposure and BMI was modified by the Census region in which participants lived, the climate region, and to some extent airline hub type and smoking status of the participants. It is possible that aircraft noise is experienced differently in arid regions such as the West – perhaps the finding indicates differences in climate-related factors such as vegetation, temperature, and humidity (Zaporozhets, 2016) and related factors including window opening behaviors (Liu et al., 2021), housing construction and insulation, urbanization, heating/cooling type, time spent outdoors/indoors (Klepeis et al., 2001), etc. Additionally, there are complex, frequency-specific differences in noise levels due to the effects of temperature and humidity (Dreier and Vorländer, 2021) that may not be well-captured by AEDT modeling. Given the strong associations found for arid versus humid regions, further research on geographic and climatic differences on the impact of aircraft noise on obesity is needed. The DNL metric is a summary metric of 24 hr average of aircraft operations of different types (U.S. FAA (Federal Aviation Administration), 2022a), and suggestive evidence of changes in the association with BMI group by airline hub type may be reflective of differential types of aircraft and operations at each airport hub type, which could result in exposure differences not captured by the DNL metric used. Land use compatibility, policies, practices, and development around airport types may further be correlated with residential exposure to aircraft noise (U.S. FAA (Federal Aviation Administration), 2022c), which could manifest as differences in the association by airline hub types. There was evidence of effect modification by smoking status at higher levels of aircraft noise exposure. Smoking can cause endothelial dysfunction and other cardiometabolic issues that may encourage weight loss, and body mass usually increases upon quitting (Tian et al., 2015). However, why the impact of exposure to high levels of aircraft noise may be more strongly associated with BMI among former smokers is largely unknown.

This study was limited by several factors. BMI is a crude metric of general obesity and was self-reported, but self-reports have been shown to be valid in these cohorts (Rimm et al., 1990). Weight at age 18 was participant-recalled and is therefore prone to recall bias. NHS and NHSII assessed height at baseline (NHS: 1976; NHSII: 1989), which was used to calculate BMI along with self-reported weight collected over time (Eckel et al., 2018; Jun et al., 2012). Height changes with age, which could affect the interpretation of BMI (Onwudiwe et al., n.d.; Sorkin et al., 1999). We tightly controlled for linear and quadratic effects of age; however, genetic and lifestyle factors may also affect decline in height (Jelenkovic et al., 2020). Of note, a recent Framingham Heart Study publication demonstrated an advantage of calculating BMI using "young" height over age-related height in assessing chronic disease risk (Holt et al., 2023). The main exposure metric was a 5-year average at residential addresses and was therefore lacking finer spatiotemporal resolution. There may be exposure misclassification, for example, related to time spent at residences versus elsewhere. While there were many "exposed cases" at lower levels of aircraft noise exposure, there were fewer at the highest levels of aircraft noise exposure, such as ≥65 dB, which limited options for analyses of associations at high aircraft noise levels. We were unable to estimate noise at the most exposed façade as is common in recent studies of the health effects of road noise, but this approach is less relevant for studying the health effects of aircraft noise, which originates predominantly from above ground level. Other sources of transportation noise such as roads and railways were not included directly, but we did control for a measure of environmental noise and population density. We were unable to include markers of stress, which prevented investigation of the links between noise, stress, and obesity. In addition, we were unable to include estimates of noise sensitivity or annoyance. We could not include markers of job strain, which has been shown to modify the association between transportation noise and metabolic outcomes (Selander et al., 2013). Moreover, occupational noise exposures were not available for many of the questionnaire cycles. Nonetheless, many of the nurses who were not yet retired were likely exposed similarly due to similarities within the profession and related fields. Finally, there is some possibility of reverse causality, such as people with higher BMIs choosing or being forced into housing nearer airports for socioeconomic or other reasons (Lee, 2020). However, we adjusted for various socioeconomic indicators to mitigate some of these possibilities.

Despite the limitations, this study was strengthened by several factors. This was the first study of aircraft noise exposure and obesity to our knowledge that used a U.S.-based and nation-wide population. This study was able to use repeated measures of aircraft noise exposure, as well as characteristics at individual and neighborhood levels over multiple decades. Most of the main metrics (e.g., BMI, BMI18) used in this study had been previously validated in the NHS cohorts. We were able to investigate changes in BMI from early to late adulthood among the cohort participants. Availability of address-level exposure assignment at relatively low levels of aircraft noise exposure down to 45 dB for the large, national cohorts were additional strengths. The large sample size and repeated measures captured a wide range of participant exposure levels and further enabled us to examine several putative, but uncommonly examined effect measure modifiers at the individual and neighborhood levels.

5. Conclusion

In a population of women living around 90 large airports in the U.S., residential exposure to aircraft noise above 45 dB (DNL) was associated with higher self-reported BMI and recalled change in BMI since age 18 years independent of individual and neighborhood factors. There was a statistically significant trend providing evidence of an increasing aircraft noise exposure-BMI response for DNL ≥45 dB. Associations between aircraft noise exposure and BMI were stronger among participants living in the West, arid climate areas, and who formerly smoked. Aircraft noise and the potential roles of stress and obesity in risk of chronic disease morbidity and mortality deserve further scrutiny.

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CRediT authorship contribution statement

Matthew Bozigar: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis. **Francine Laden:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Jaime E. Hart:** Writing – review & editing, Supervision, Resources, Methodology, Conceptualization. **Susan Redline:** Writing – review & editing, Methodology, Conceptualization. **Tianyi Huang:** Writing – review & editing, Methodology. **Eric A. Whitsel:** Writing – review & editing. **Elizabeth J. Nelson:** Writing – review & editing, Resources, Conceptualization. **Stephanie T. Grady:** Writing – review & editing, Resources, Methodology. **Jonathan I. Levy:** Writing – review & editing, Methodology, Conceptualization. **Junenette L. Peters:** Writing – review & editing, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Susan Redline reports a relationship with Jazz Pharmaceuticals Inc that includes: consulting or advisory and funding grants. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The authors do not have permission to share data.

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Appendix A. Supplementary data

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Cardiovascular Disease and Aircraft Noise Exposure

Project 03

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ASCENT
AVIATION SUSTAINABILITY CENTER

ASCENT 03 – Overview of Research on Aircraft Noise and Health in U.S. Cohorts

Past/Current work

Noise and Cardiovascular Disease in Nurses Health Studies

- Use Nurses' Health Studies (NHS) to study
  - CVD / Mortality
  - Hypertension
  - Sleep

✚ New Cohorts

- Women's Health Initiative (WHI)
- Hispanic Community Health Study / Study of Latinos (HCHS/SOL)
- The National Longitudinal Study of Adolescent to Adult Health (Add Health)

✚ New Outcomes

- Intermediaries (e.g., adiposity and diabetes)
- Mental Health

✚ New Noise Data Sets

- Additional airports (28)
- Additional time periods (2019)

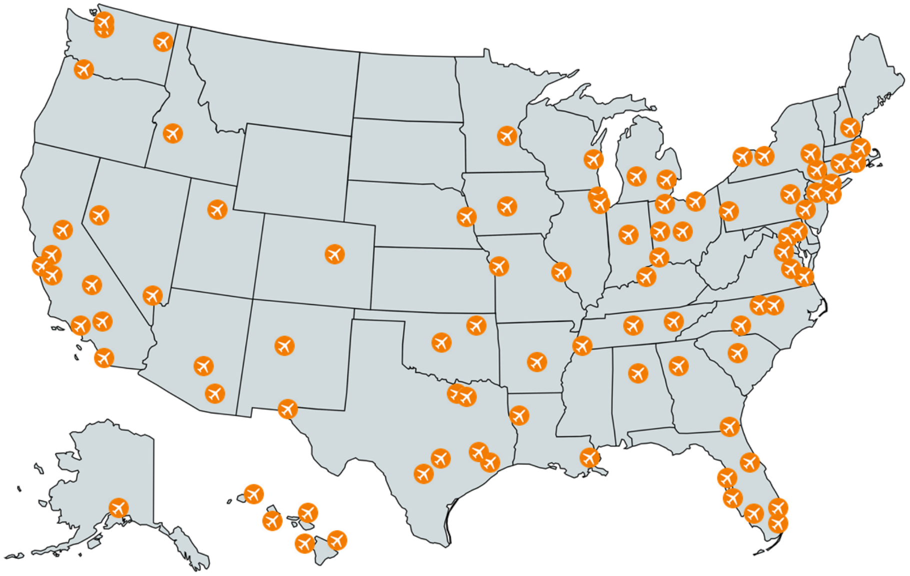
Objective: Evaluate relationships between aircraft noise exposure and human health in diverse populations

ASCENT 03 – Past/Current Work

- **Sociodemographic Patterns of Aircraft Noise**
  - Simon et al. 2022 *Environmental Health Perspectives (EHP)*
- **Trends in Aircraft Noise Exposure**
  - Nguyen et al. 2023 *Journal of Exposure Science & Environmental Epidemiology*
- **Noise and Hypertension**
  - DNL in NHS (Kim et al. 2022 *Environmental Research*)
  - DNL and Lnight/NL in WHI (Nguyen et al. 2023 *Environ Res*)
  - Lnight/NL in NHS (Peters et al. 2024 *Int J Hyg Environ Health*)
- **Noise and CVD, CVD Mortality, & All-Cause Mortality**
  - Grady et al. 2023 *Environmental Epidemiology*
- **Noise and Sleep Duration/Quality**
  - Bozigar et al. 2023 *EHP*
- **Noise and Adiposity**
  - Bozigar et al. 2024 *Environ Int*

***Legend** = Past work in **black** text, current work in **blue** text*

ASCENT 03 – Noise Exposure



Created with mapchart.net ©

- Noise contours surrounding 90 U.S. airports modeled using the Aviation Environmental Design Tool (AEDT)
- Estimates for Day-Night Average Sound Level (DNL) and Nighttime Average Sound Level (Lnight/NL) every 5 years from 1995 to 2015
- Range from 45-75 dB(A)

Socioeconomic Patterns of Noise Exposure

Purpose: Determining…

Who is exposed to aircraft noise?

How is exposure changing through time?

- Overlaid noise contours and Census tract data from U.S. Census Bureau (2010) and American Community Surveys for 2000-2015 and **estimated total and sub-population (race/ethnicity) exposure**
- **Estimated changes in noise exposure areas** at DNL 45, 55, 65, and Lnight 45
- **Identified groups at higher risk of exposure** - block groups with higher proportion Hispanic population and residents with ≤ high school education

Cohort Studies on Noise and Health

Purpose: Estimating the Health Effects of Noise where…

We have information on individual and area-level characteristics

We have information over time

- **Estimating the effect of noise exposure** at varying DNL and Lnight thresholds
- **Estimating the effect of noise on various outcomes**
  - Hypertension
  - Cardiovascular Disease
  - Sleep
  - Cardiometabolic outcomes (e.g., body mass index, diabetes)
  - Mental Health outcomes (e.g., depression and anxiety)

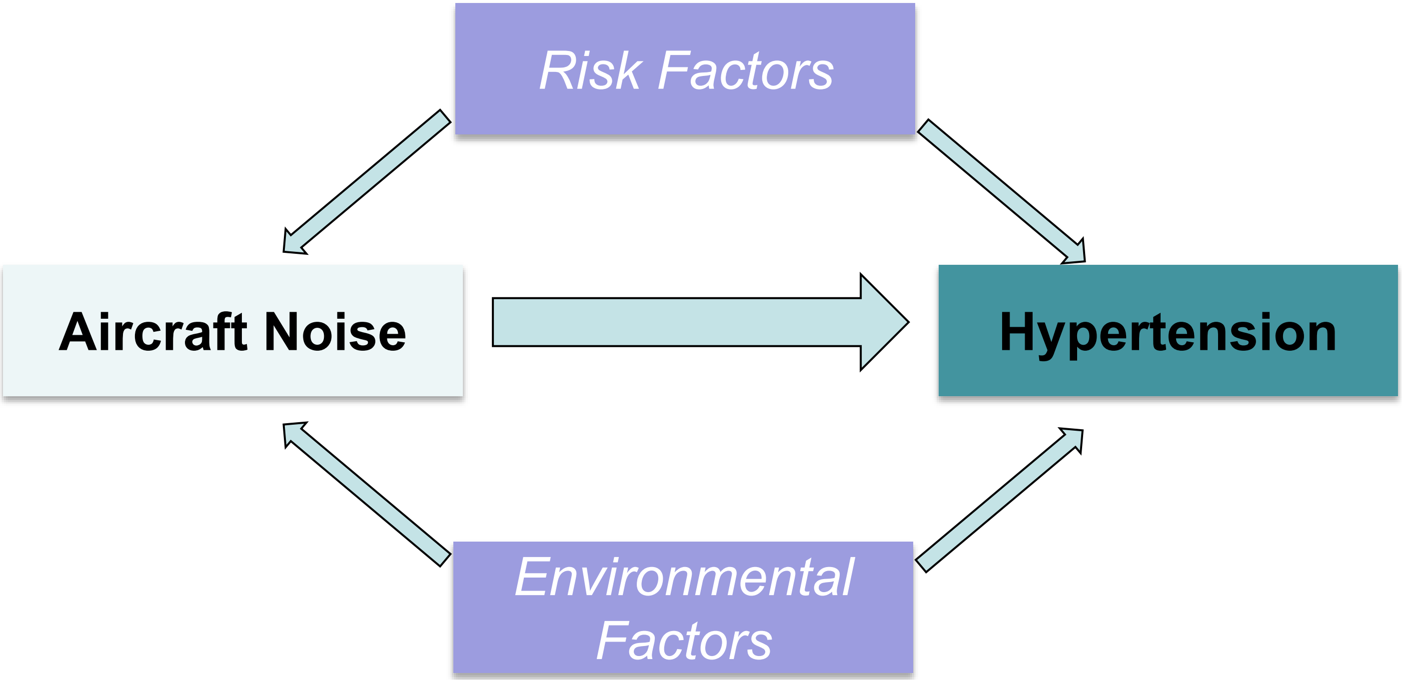
Cohorts

- Nurses Health Studies (NHS)
  - >237,000 pre- & post-menopausal female nurses across the US
- Women's Health Initiative (WHI)
  - >161,000 post-menopausal women recruited from centers across the US
- Hispanic Community Health Study / Study of Latinos (HCHS/SOL)
  - >16,000 Hispanic/Latino participants aged 18-64 across the U.S. (Chicago, Miami, San Diego, & Bronx area of New York City)
- The National Longitudinal Study of Adolescent to Adult Health (Add Health)
  - Nationally representative sample of >20,000 adolescents over 14 years old followed over 20 years

*Legend = _Current cohorts in **black** text, new cohorts in **blue** text_

Objectives (Hypertension Example)

- Evaluate the association between **aircraft noise exposure and incident hypertension**, adjusting for traditional hypertension risk factors and environmental factors



Methods – Nurses Health Studies

	Nurses' Health Study (NHS)	Nurses' Health Study II (NHS II)
Total Recruited	121,700	116,430
Initial Recruitment Date	1976	1989
Age at Recruitment	30-55	25-42
Study Period	1994-2014	1995-2015

Exposure of interest: dichotomized based on cut-points

- At the 45 and 55 dB(A) – e.g., comparison of exposed at ≥55 with <55

Outcome of interest: Self-reported hypertension categorized yes/no

- Validation study showed high accuracy[1]

Exclusion Criteria:

- Hypertension at the entrance into our study (1994 - NHS, 1995 - NHS II)
- Missing noise data

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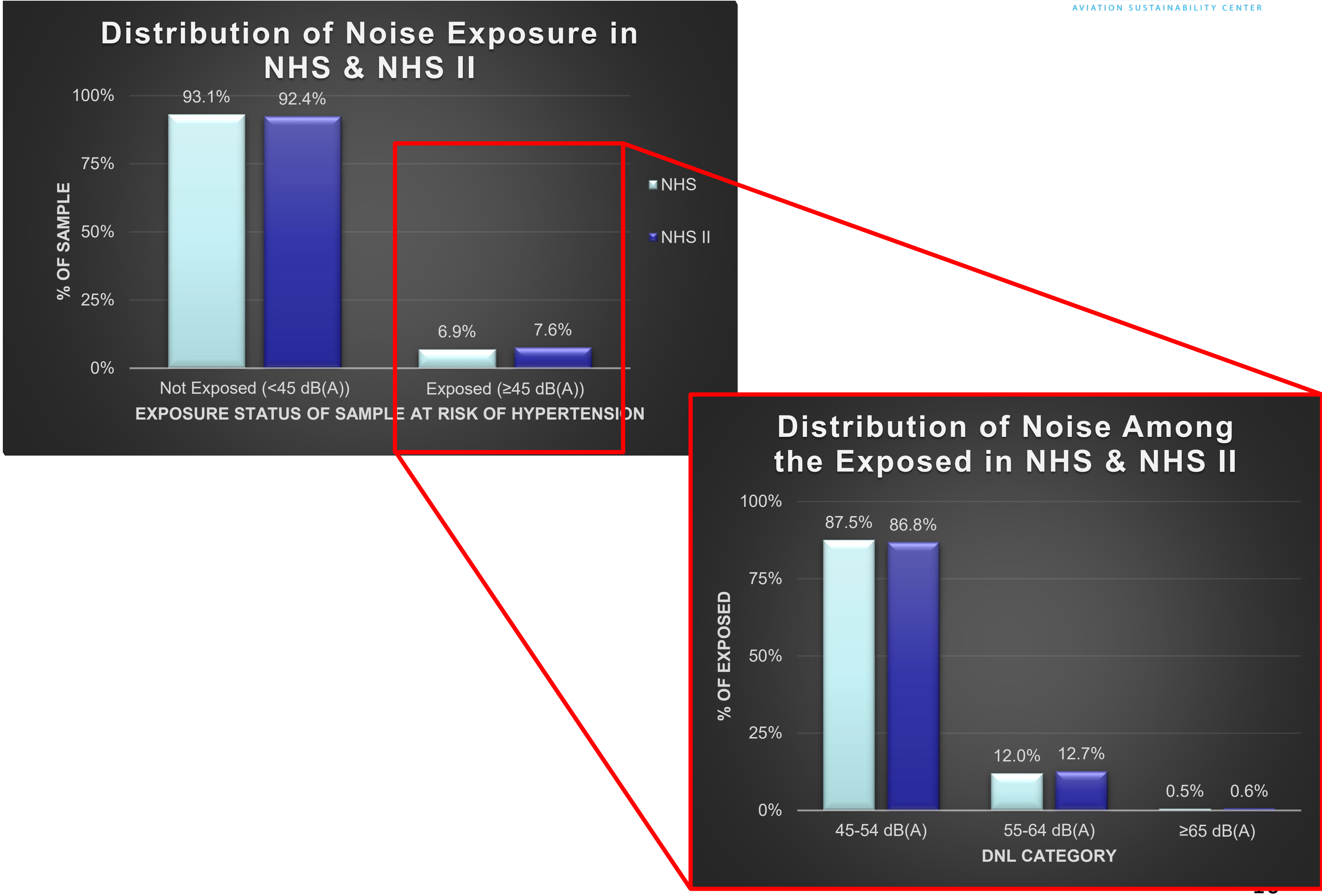

Hypertension and Noise Summary

Purpose: Investigating…

Whether aircraft noise exposure in day-night average noise level (DNL) and nighttime noise (Lnight/NL) is related to the risk of hypertension?

Highlights:

- **Found suggestive associations between increased levels of noise and incident hypertension**
- Adjusting for key sociodemographic and lifestyle factors, participants exposed to ≥55 dB had 10% increased risk of hypertension compared to participants exposed <55 dB, with 95% confidence interval (CI) of 1% to 19%.
- Although fewer participants are exposed to NL compared to DNL (~1% of the sample), results suggest the associations between NL and incident hypertension may be slightly stronger than those with DNL

Sleep and Noise Summary

Purpose: Investigating…

Whether there is an association between Lnight/NL and insufficient sleep quantity and poor sleep quality?

Highlights:

- **Found an association between noise and insufficient sleep (sleep <7 hours) but not with sleep quality.**
- In multivariable-adjusted models, those exposed to higher levels of Lnight/NL ≥45 dB were associated with a 23% increased odds of self-reported short sleep duration
- No evidence of association with sleep quality
- Relationship pronounced in participants living in the west, near cargo airports, and near water-adjacent airports.

Adiposity and Noise Summary

Purpose: Investigating…

Whether aircraft noise exposure is related to adiposity?

Highlights:

- **Found associations between higher levels of DNL and higher categories of body mass index (BMI)**

- DNL ≥55 dB was associated with:
  - 11% higher odds (95% CI: – 1%, 24%) of BMIs ≥30.0
  - 15% higher odds (95% CI: 3%, 29%) of membership in the highest tertile of BMI change since age 18 (ΔBMI 6.7 to 71.6)

- Found similar results when examining DNL continuously

- Stronger associations observed among participants living in the West, arid climate areas, and among former smokers

Summary

In US cohort studies, we found…

- Neighborhoods with more Hispanic population and more residents with low education were more likely to experience higher levels of aircraft noise;
  - There was substantial variation across airports
- Average aircraft noise was possibly linked with risk of developing hypertension
  - Evidence was stronger for nighttime aircraft noise
- Aircraft noise was linked to risk of insufficient sleep but not low-quality sleep
- Higher average aircraft noise was linked to higher obesity

Summary – Limitations/Future Direction

- **Previous findings have shown mixed results, with limitations in:**
    - The demographics of the cohort
    - Timing of aircraft noise exposure
    - Low levels of aircraft noise exposure (few above ≥45 dB)

- **New cohorts, airports, time periods, and outcomes have the potential to provide insight on:**
    - Health effects among various demographic groups
    - Critical time windows of exposure (e.g., earlier life exposure)
    - Understudied yet biologically-plausible outcomes
    - Exposure around additional airports

Publications (recent)

1. Peters JL, Grady ST, Laden F, Nelson E, Bozigar M, Hart JE, Manson JE, Huang T, Redline S, Kaufman JD, Forman JP, Rexrode KM, Levy JI. Long-term nighttime aircraft noise exposure and risk of hypertension in a prospective cohort of female nurses. *International Journal of Hygiene and Environmental Health.* 2024 Sep 12; 263:114457. doi: 10.1016/j.ijheh.2024.114457. PMID: 39270405.
2. Bozigar M, Laden F, Hart JE, Redline S, Huang T, Whitsel EA, Nelson EJ, Grady ST, Levy JI, Peters JL. Aircraft noise exposure and general obesity among female participants in two Nurses' Health Study prospective cohorts living around 90 airports in the United States. *Environment International.* 2024 Apr 15; 187:108660. doi: 10.1016/j.envint.2024.108660. PMID: 38677085.
3. Grady ST, Hart JE, Laden F, Roscoe C, Nguyen DD, Nelson EJ, Bozigar M, VoPham T, Manson JE, Weuve J, Adar SD, Forman JP, Rexrode K, Levy JI, Peters JL. Associations between long-term aircraft noise exposure, cardiovascular disease, and mortality in US cohorts of female nurses. Environmental Epidemiology 2023, 7(4): e259. doi: 10.1097/EE9.0000000000000259.
4. Bozigar M, Huang T, Redline S, Hart JE, Grady ST, Nguyen DD, James P, Nicholas B, Levy JI, Laden F, Peters JL. Associations between Aircraft Noise Exposure and Self-Reported Sleep Duration and Quality in the United States-Based Prospective Nurses' Health Study Cohort. Environmental Health Perspectives 2023; 131(4):47010. doi: 10.1289/EHP10959.
5. Nguyen DD, Whitsel EA, Wellenius GA, Levy JI, Leibler JH, Grady ST, Stewart JD, Fox MP, Collins JM, Eliot MN, Malwitz A, Manson JE, Peters JL. Long-term aircraft noise exposure and risk of hypertension in postmenopausal women. Environ Res. 2022 Dec 9;218:115037. doi: 10.1016/j.envres.2022.115037.
6. Simon MC, Hart JE, Levy JI, VoPham T, Malwitz A, Nguyen DD, Bozigar M, Cupples LA, James P, Laden F, Peters JL. Sociodemographic Patterns of Exposure to Civil Aircraft Noise in the United States. Environmental Health Perspectives 2022; 130(2) https://doi.org/10.1289/EHP9307.
7. Kim CS, Grady ST, Hart JE, Laden F, VoPham T, Nguyen DD, Manson JE, James P, Forman JP, Rexrode KM, Levy JI, Peters JL. Long-term aircraft noise exposure and risk of hypertension in the Nurses' Health Studies. Environmental Research, 2021; 207:112195. doi: 10.1016/j.envres.2021.112195.

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- UNC: Eric Whitsel, James Stewart

Abbreviations

Add Health	National Longitudinal Study of Adolescent to Adult Health
BMI	Body Mass Index
CVD	Cardiovascular disease
DASH	Dietary Approaches to Stop Hypertension
dB	decibels
DNL	Day-night average sound level
Env Epi	Environmental Epidemiology
EHP	Environmental Health Perspectives
Environ Int	Environment International
Environ Res	Environmental Research
HCHS/SOL	Hispanic Community Health Study/Study of Latinos
Int J Hyg Environ Health	International Journal of Hygiene and Environmental Health
JESEE	Journal of Exposure Science & Environmental Epidemiology
LAN	Light at night
Lnight/NL	Nighttime sound level

NHS	Nurses’ Health Studies
NDVI	Normalized Difference Vegetation Index
NO_2	Nitrogen dioxide
NHS	Nurses’ Health Studies
NO_2	Nitrogen dioxide
nSES	Neighborhood socioeconomic status
PI	Principal Investigator
PM	Project Manager
$PM_{2.5}$	Particulate matter of size equal to or smaller than 2.5 microns
US	United States
WHI	Women’s Health Initiative