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# Air Traffic Control Facility Ambient Sound Levels

August 2026

Final report



U.S. Department of Transportation
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16. Abstract

The Federal Aviation Administration (FAA) Human Factors Design Standard (FAA-HF-STD-001B) provides human factors requirements to the design and testing of FAA systems related to both air traffic and technical operations. Section 5.5.2.8.3 outlines audibility requirements for auditory signals based on ambient sound levels. All auditory signal designs in air traffic control (ATC) facilities must adhere to these auditory requirements. The goal of this project was to measure ambient sound levels from a representative sample of ATC facilities across the United States to inform the design and integration of auditory signals in ATC systems based on this requirement. The final product consisted of several comprehensive reference tables that describe ambient sound level metrics at the various facilities. This information will be shared with FAA ATC acquisition programs as a supplement to Section 5.5.2.8.3 of the Human Factors Design Standard (HFDS) to inform the design of ATC auditory signal sound levels. The information may also be used to inform updates to the current language of Section 5.5.2.8.3 of the HFDS.

An additional aim of this project sought to evaluate the utility of using a smartphone sound level meter (SLM) application to conduct sound measurements in ATC facilities. Being able to utilize smartphone application SLMs instead of professional SLMs for research purposes would improve efficiency and reduce costs associated with research efforts. Ambient sound level measurements obtained from a smartphone SLM app paired with an external microphone were compared to measurements taken simultaneously in the same location with a professional SLM. The results are discussed in-text and in supplementary appendices.

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## Acronyms

| Facility ID | Facility Name |
|---|---|
| ABE | Allentown Tower/TRACON |
| ACY | Atlantic City Tower/TRACON |
| DCA | Washington National Tower |
| DVT | Deer Valley Tower |
| DWH | Houston Hooks Tower |
| FFZ | Falcon Tower |
| FLL | Fort Lauderdale Tower |
| FXE | Fort Lauderdale Executive Tower |
| HOU | Hobby Tower |
| IAH | Houston Intercontinental Tower |
| ILG | Wilmington Tower |
| I90 | Houston TRACON |
| MDT | Harrisburg International Tower/TRACON |
| MIA | Miami Tower/TRACON |
| PBI | West Palm Beach Tower/TRACON |
| PCT | Potomac TRACON |
| PHL | Philadelphia Tower/TRACON |
| PNE | Northeast Philadelphia Tower |
| P50 | Phoenix TRACON |
| SDL | Scottsdale Tower |
| TMB | Tamiami Tower |
| TTN | Trenton Mercer Tower |
| TUS | Tucson Tower |
| U90 | Tucson TRACON |
| VRB | Vero Beach Tower |
| ZDC | Washington Center |
| ZHU | Houston Center |
| ZMA | Miami Center |

| Acronym | Definition |
|---|---|
| ARTCC | Air Route Traffic Control Center |
| ATC | Air Traffic Control |
| ATCT | Airport Traffic Control Tower |
| ATM | Air Traffic Manager |
| ASDE-X | Airport Surface Detection Equipment Model X |
| ASOS | Automated Surface Observing System |
| ATIS | Automatic Terminal Information Service |
| CA | Conflict Alert |
| CHI | Computer Human Interface |
| ETVS | Enhanced Terminal Voice Switch |
| FAA | Federal Aviation Administration |
| FCT | Federal Contract Tower |
| HF | Human Factors |
| HFDS | Human Factors Design Standard |
| ILS | Instrument Landing System |
| LLWAS | Low-Level Windshear Alert System |
| MSAW | Minimum Safe Altitude Warning |
| NAS | National Airspace System |
| NATCA | National Air Traffic Controllers Association |
| NIOSH | National Institute for Occupational Safety and Health |
| RDVS | Rapid Deployment Voice Switch |
| RVR | Runway Visual Range |
| SLM | Sound Level Meter |
| SME | Subject Matter Expert |
| Terminal CHI | Terminal Computer Human Interface |
| TRACON | Terminal Radar Approach Control |
| TMU | Traffic Management Unit |
| WJHTCAA | William J. Hughes Technical Center for Advanced Aerospace |

## Executive summary

The Federal Aviation Administration (FAA) maintains documentation, known as the Human Factors Design Standard (FAA-HF-STD-001B), that contains a compilation of human factors principles critical to the design and testing of FAA systems. The Human Factors Design Standard (HFDS) provides FAA-specific human factors design standards related to air traffic and technical operations systems. Section 5.5.2.8.3 outlines requirements for auditory signals. The requirement states:

> Auditory signals shall exceed the prevailing ambient noise level by at least 10 dB(A), or any maximum sound level with a duration of 30 seconds by at least 5 dB(A), whichever is louder, without exceeding 115 dB(A) for emergency signals or 90 dB(A) for other signals. (Ahlstrom, 2016, p. 237).

This standard established sound level requirements for auditory signals (e.g., alarms, alerts, warnings) based on ambient sound conditions. Applicable FAA programs that have a requirement to adhere to the HFDS must comply with this requirement for all auditory signal designs in ATC (air traffic control) facilities. The goal of the current project was to gather ambient sound measurements from a representative sample of ATC facilities, including Airport Traffic Control Towers (ATCTs), Terminal Radar Approach Control Facilities (TRACONs), and Air Route Traffic Control Centers (ARTCCs), to inform the design and integration of auditory signals in new and/or existing ATC systems based on this existing standard. In this report, "auditory signal" is used to be inclusive of all alarms, alerts, and warnings in ATC facilities. This document provides ambient sound level measurements compiled into several reference tables that outline facility information and ambient sound levels across locations. This data collected from the Brüel & Kjær 2245 professional sound level meter (SLM) will supplement the existing HFDS Standard to inform acquisition programs in the design of ATC auditory signals. The information may also be used to inform future content updates to Section 5.5.2.8.3 of the current HFDS (FAA-HF-STD-001B).

The overall $L_{Aeq,30min}$, the maximum $L_{Aeq,30s}$, and the minimum auditory signal sound level necessary to comply with the HFDS Section 5.5.2.8.3 requirement were reported for each facility. $L_{ASmax,30min}$ and $L_{AFmax,30min}$ measurements were reported in Appendix B for additional detail. The measurements in this report provide only a baseline, informational metric, since facilities vary considerably in their sound and activity levels. For in-house equipment that can adjust the auditory signal sound level, facility management should conduct ambient sound level measurements at each individual facility to confirm adherence to the HFDS requirements before the system sound levels are set.

An additional component of this project sought to compare measurements from professional SLM equipment to measurements from a smartphone application SLM paired with an external microphone. The ability to utilize smartphone app SLM technology in place of professional equipment would reduce costs for equipment and travel for trained personnel to operate the equipment. Ambient sound level measurements were collected using the National Institute for Occupational Safety and Health (NIOSH) Sound Level Meter app. These measurements were captured simultaneously alongside the Brüel & Kjær 2245 professional SLM at each facility. Of note, the external microphone used for the current project was professionally calibrated before data collection began, but no additional calibrations were performed during data collection.

Results indicated that all but one facility's sound level measurements captured by the NIOSH SLM app were consistent within ±2 dB(A) to the professional Brüel & Kjær 2245 SLM's measurements when calculating the overall $L_{Aeq}$ energy-averaged from each approximately 30-minute measurement. Maximum sound level measurements ($L_{ASmax,30min}$) were also compared, but these values were less accurate. The overall $L_{ASmax}$ values captured from the NIOSH SLM app ranged from 3.8 dB to 15.4 dB louder than those obtained by the professional Brüel & Kjær 2245 SLM. The NIOSH SLM app manual recommends calibration before and after each measurement, so it is likely that the lack of additional calibrations resulted in these discrepancies. These findings, although based on the measurements obtained by one app, suggest that smartphone SLM applications, when paired with an external microphone, may be mostly dependable tools to measure $L_{Aeq}$ in ATC facilities, as compared to a professional SLM. However, they are less reliable at measuring $L_{ASmax}$ without calibration before and after each measurement.

The ambient sound level measurements provided in this report will inform FAA ATC acquisition programs in the development of auditory signals for ATC facilities. We recommend that the FAA utilize the data captured from the professional Brüel & Kjær 2245 sound level meter as a supplement to the HFDS Section 5.5.2.8.3 requirement to provide an example of ambient sound measurements across a representative sample of ATC environments. Additionally, we recommend that the current HFDS Section 5.5.2.8.3 requirement (FAA-HF-STD-001B) be updated to incorporate this information as additional context.

# 1 Introduction

The Federal Aviation Administration (FAA) Human Factors Design Standard (FAA-HF-STD-001B) contains requirements stating that the sound level of auditory and voice-based auditory signals (e.g., alarms, alerts, warnings) should be a certain threshold above ambient sound levels to ensure proper audibility (Ahlstrom, 2016). Section 5.5.2.8.3 states the following:

> Auditory signals shall exceed the prevailing ambient noise level by at least 10 dB(A), or any maximum sound level with a duration of 30 seconds by at least 5 dB(A), whichever is louder, without exceeding 115 dB(A) for emergency signals or 90 dB(A) for other signals. (Ahlstrom, 2016, p. 237).

However, the Human Factors Design Standard (HFDS) does not provide data on the typical ambient sound levels that are currently representative across a range of air traffic control (ATC) operating environments (i.e., Airport Traffic Control Towers (ATCTs), Terminal Radar Approach Control Facilities (TRACONs), Air Route Traffic Control Centers (ARTCCs)). Without a baseline reference for typical ambient sound levels in these environments, the appropriate sound level for auditory signals is unclear. The goal of this project was to obtain representative ambient sound levels from a range of ATC facility types (i.e., ATCTs, TRACONs, ARTCCs) with varying facility levels, geographical locations, and ages of building construction/infrastructure.

To support the safety and performance of ATC operations, researchers from the Human-Systems Integration Branch at the William J. Hughes Technical Center for Advanced Aerospace (WJHTCAA) developed in-text reference tables that provide a summary of operational ambient sound levels in several different ATC facilities across the United States and that state the minimum auditory signal sound level according to HFDS Section 5.5.2.8.3 (Ahlstrom, 2016). Appendix B reports the overall facility sound level measurements (energy-averaged and median measurement across trials at each facility) and related descriptive statistics for the Brüel & Kjær 2245 sound level meter (SLM) compiled into one table. The purpose of the reference tables are to improve adherence to the requirements outlined in Section 5.5.2.8.3 of the HFDS (Ahlstrom, 2016), to ensure that FAA ATC auditory signal sound levels are set at appropriately detectable levels to reduce the chances of signals going undetected or being so loud that they become a nuisance. As a supplement to this information, Appendix D contains the individual trial raw sound measurement data at each facility for the Brüel & Kjær 2245 professional SLM.

This project involved the collection of ambient sound measurements from a sample of FAA ATC facilities by human factors experts. To the extent possible, the measurements included sound

level measurements taken during periods of light, moderate, and heavy activity. However, it was not possible to take measurements that would systematically reflect every individual activity level, because many variables affect activity level, including air traffic volume, airspace complexity, weather, and emergency situations. ATC subject matter experts (SMEs) supported the project by documenting air traffic level information at the time of each sound measurement. Section 3 of this report includes the specific air traffic level information.

Sound measurements were taken from several locations within the operational areas of the facilities. Facility management and representatives of the National Air Traffic Controllers Association (NATCA) assisted with the coordination of sound measurement locations to ensure that the data collection did not interfere with operations. Specific measurement locations and information about the perceived activity level at the time of the measurements were documented. With the assistance of ATC SMEs/personnel escorts, any available air traffic system data (e.g., number of arrivals/departures) in the airspace during the measurement intervals were also collected.

These ambient sound measurement datapoints will be beneficial to FAA ATC acquisition programs as guidance for the development of auditory signals in air traffic facilities. Further, the data will inform human factors considerations for the design and integration of new auditory signals into existing ATC systems.

## 1.1 Sound properties and ambient sound

FAA Policy and Guidance defines sound as "energy transferred through the air that our ears detect as small changes in air pressure" (Federal Aviation Administration, 2022, p. 1). Although it is common to use the terms *ambient sound* and *ambient noise* interchangeably, it is important to note that *sound* and *noise* are distinct terms with unique definitions. Noise is a term used to describe sounds that are undesirable. Unlike sound, noise considers a person's unique perception to the sound (Federal Aviation Administration, 2022). For the current project, we will use the term *sound* throughout, as the focus was to capture objective sound measurement data.

Sound travels in waves, and its primary characteristics are amplitude and frequency. Amplitude determines the loudness or intensity of a sound, and measurements express its levels in logarithmic decibels (dB). Frequency is measured in hertz (Hz), and perceived frequency is the pitch of a sound. Each of these properties impact sound and how the human ear perceives sound (National Park Service, 2018). See Appendix H for a glossary of all relevant terms included in this report.

Ambient sound includes all background sounds in an environment (Federal Interagency Committee On Noise, 1992). Anything within an environment can impact ambient sound levels, such as air conditioning, conversations, and technology. Additionally, many factors can influence the ambient sound level, including the construction materials used to build the space and the configuration of the room.

## 1.2 Ambient sound measurements

Specialized sound level meter (SLM) equipment was used to measure ambient sound. These devices measure the loudness of sound by measuring the sound pressure level. Many SLMs contain functionalities that allow the user to apply various filters and weighting variations specific to the use case.

The dB unit, which measures the intensity of sound, is relative to the range of sound pressures that human ears detect as sound. While decibels capture the intensity of sound, human ears also detect varying sound frequencies (pitch). Perceived loudness is not directly related to physical sound measurements (dB), and sounds that differ in frequency (e.g., 30 Hz vs. 1000 Hz) need to be presented at different sound pressure levels (80 dB vs. 40 dB, respectively) to be perceived as equally loud (Goldstein, 1984). Frequency weighting is used to account for the perceived loudness of sound levels of differing frequencies by humans. The dB(A) unit refers to the "A" weighted frequency scale that is used to estimate the intensity of sound as it is perceived by humans, while also considering the range of the frequency spectrum that is most detectable to the human ear. The scale is useful for measuring sound in real-world scenarios, as it considers the differences in the way individuals respond to and perceive sound (Federal Aviation Administration, 2022). Ambient sound measurements are typically reported using the dB(A) unit (International Organization for Standardization, 2016).

A standalone measurement from a singular moment is likely not representative of an environment, because ambient sound levels vary over time (Brüel & Kjær, 1984). For example, in ATC environments, there may be certain times of the day that typically have higher air traffic levels (e.g., afternoon departure or arrival push), resulting in higher ambient sound levels compared to other times. Additionally, depending on the sound source, the duration and characteristics of sound can vary drastically. Intermittent sounds may occur in ATC facilities, such as loud alerts and alarms. Loud sounds that occur sporadically are best detected by measuring the maximum sound level (Federal Aviation Administration, 2022). Other types of sound to consider are continuous sounds, which are constant without any gaps in between (e.g., console fans). Various data metrics exist to report sound measurements with different durations

and characteristics. For the current project, the overall A-weighted Equivalent Continuous Sound Level ($L_{Aeq,30min}$) and the maximum 30-second $L_{Aeq}$ (maximum $L_{Aeq,30s}$) are reported. The A-weighted maximum sound level with slow time constant ($L_{ASmax,30min}$), and A-weighted maximum sound level with fast time constant ($L_{AFmax}$, 30min) are reported in Appendix B for additional detail. Section 2 of this paper will discuss these values, the sound properties that they represent, and the justifications for reporting them.

## 1.3 Impact of high ambient sound in the workplace

High ambient sound levels can be distracting for individuals working in ATC environments (Cluff & McAnulty, 2011). Further, a high ambient sound level can become an issue if it is so high that it masks the auditory signals in a workplace. Many reports of high ambient sound levels impacting ATC environments have been documented over the past several decades. For instance, Semmelink & Clinch (1971) described noise concerns at the ATCT at O'Hare International Airport and the Aurora ARTCC, both located in the Chicago, IL area. The authors described the broad psychological effects of high ambient sound levels in this paper, including interferences to sensory processes (e.g., hearing loss) and negative changes in workers' attitudes towards tasks. Semmelink & Clinch found that the most prevalent sources of sound interference were speaking and loudspeaker communication broadcasts at the measured facilities. The report included recommendations for various mitigations to reduce the need for controllers to raise their voices to be heard, including reducing background sound levels and reverberation in the environment.

Sounds occurring outside a facility can also contribute to increased ambient sound levels inside. Clinch (1972) examined the effects of glare, heat, and noise transfer on ATC controller performance in ATCT cabs. Clinch recommended that mitigations be taken to minimize noise transfer, when possible, to "assure minimum interference with communication" due to external noise (e.g., aircraft sounds from departures/arrivals). Specifically, they recommended using sound-insulating materials in tower cab construction in areas where external sounds are high (Clinch, 1972, pp. 1, 73).

In another instance, facility staff experienced issues with ambient sound levels interrupting work at the FAA's Command Center, located in Warrenton, Virginia. Upon its opening in March 2011, personnel at the facility reported issues related to high ambient sound levels on the Command Center's Operations Floor (Cluff & McAnulty, 2011). Personnel reported that high ambient sound levels were negatively impacting work-life quality and making coordination to manage operations at the facility difficult. They reported problems with hearing conversations

from across the room, struggling to hear nearby conversations, sound from loud console fans, and ringtones that were described as “annoying” (Cluff & McAnulty, 2011, p. 2).

To systematically document these issues, FAA human factors personnel travelled to the Command Center. While there, team members collected sound measurements using a Brüel & Kjær 2260 Observer (Model Number 4189) with a one-half inch free field microphone. These measurements revealed that the average ambient sound level ($L_{Aeq}$) on the Operations Floor was 63.4 dB(A), which was 8.4 dB(A) above the allowable sound level for a room of that size (large workspaces) (Ahlstrom & Longo, 2003; American National Standards Institute & Acoustical Society of America, 2008; Cluff & McAnulty, 2011; Cluff M. S., 2013). Based on these findings, the researchers recommended reducing the overall ambient sound levels in the facility. Several modifications were ultimately made, including installing acoustic treatments in the ceiling and walls to muffle sound and reduce reverberation, adding acoustic glass designed to contain sound across workstations, and modifying door designs to reduce slamming/latching sounds (Cluff M. S., 2013; Polysonics Acoustics & Technology Consulting, 2014). Ambient sound measurements obtained after these modifications were implemented showed reductions in ambient sound levels compared to the pre-modification measurements. Specifically, the modifications reduced reverberation time, reduced background sound, and increased speech intelligibility (Polysonics Acoustics & Technology Consulting, 2014).

Additionally, measuring the full frequency spectra of sound is important to consider when assessing the perception of sound. The current project focused specifically on the ambient sound level intensity in ATC environments, and all sound levels were reported in dB(A). Specific auditory signal sound level/frequencies were not examined and were outside the scope of this project’s goals. Nevertheless, the issue of auditory signals being perceived as too loud, while not the focus of this report, is inherently related to the ambient sound level. Potential explanations for these issues, such as frequency spectrum issues, should be considered in the design of auditory signals before adjustments are made to the sound level of a signal, as perception can be impacted by factors other than the amplitude. While we did not measure specific auditory signal sound levels or frequencies in this project, Appendix F and Appendix G show the energy-averaged $L_{Aeq}$ values across frequencies that were collected with the Brüel & Kjær 2245 SLM.

Previous studies conducted in ATC facilities have highlighted sound perception issues related to frequency spectrum interference. In 2007, Greenville-Spartanburg TRACON and ATCT (GSP) developed a proposal to lower the sound level on the Minimum Safe Altitude Warning (MSAW) and Conflict Alert (CA) systems after operational personnel reported that they were too loud and interfered with ATC communications. Human factors researchers from the FAA William J.

Hughes Technical Center evaluated the compliance of sound levels for these warning systems (Hah, Allendoerfer, & Novak, 2008) based on HFDS requirements (Ahlstrom & Longo, 2003). Measurements showed that the sound level of the MSAW in the GSP ATCT did not meet one of the HFDS requirements, which states that auditory signals must exceed maximum sound levels with a duration of 30 seconds by at least 5 dB(A). The researchers found that the MSAW alert sound level would need to be increased by 3 dB(A) to meet this requirement. In the GSP TRACON, the MSAW alerts were adequately heard during all traffic levels, so the researchers recommended that the alert sound level remain the same. Instead of modifying the sound level of the alerts in the TRACON, Hah et al. (2008) recommended taking other steps to address the concerns that the perceived volume of the alerts interrupted controller communications. Specifically, Hah et al. found that the frequency of the alert signal consisted of several high frequencies that controllers perceived as much louder than ambient sound levels. Therefore, they advised changing the frequency of the MSAW system to a tone that interferes less with human communication. Additionally, they recommended the installation of noise insulating materials to reduce ambient sound levels.

Other research has documented similar issues, where the frequency of an alert has a negative impact on human perception of the sound. Van der Hoek-Snieders, Houben, & Dreschler (2021) examined the audibility of warnings within Dutch train cabins by comparing signal and noise spectrum measurements. Findings revealed that the train cabins did not meet acoustic requirements for alert detectability under several conditions, especially in conditions where the train was travelling at a higher speed. While the signal sound levels fulfilled the ISO 7731 (International Organization for Standardization, 2003) requirement to be within the range of 65–118 dB(A), spectral analyses revealed violations, since some of the alerts measured higher than the acceptable range of 500–2500 Hz, at over 4000 Hz. It is possible that individuals with hearing loss could experience difficulties detecting alerts at this frequency. These projects highlight the importance of considering the impact of the full auditory spectrum when designing auditory signals and not focusing solely on sound intensity above a certain sound level threshold. While outside the scope of this report, future research should examine the sound characteristics, including frequency measurements, of all ATC auditory signals to confirm all signals fall within an acceptable threshold for human perception.

Previous research over the past several decades (Hah, Allendoerfer, & Novak, 2008; van der Hoek-Snieders, Houben, & Dreschler, 2021) has documented concerns about high ambient sound levels (Clinch, 1972; Cluff & McAnulty, 2011; Semmelink & Clinch, 1971) and the impact on auditory perception in safety critical environments. It is essential that designers of auditory signals consider the ambient sound levels in ATC and other high-stakes environments to ensure

signal audibility. The following section further describes the current HFDS (Ahlstrom, 2016) requirements for auditory signal requirements and discusses the relevance of ambient sound levels when measuring auditory signal sound levels and detection.

## 1.4 Human Factors Design Standard

The HFDS (Ahlstrom, 2016) includes audibility requirements for auditory signals. Section 5.5.2.8.3 states the following:

> Auditory signals shall exceed the prevailing ambient sound level by at least 10 dB(A) or any maximum sound level with a duration of 30 seconds by at least 5 dB(A), whichever is louder, without exceeding 115 dB(A) for emergency signals or 90 dB(A) for other signals. (Ahlstrom, 2016, p. 257).

An important purpose of this standard is to inform FAA system development and acquisition programs of the appropriate auditory signal sound levels necessary for detection. However, the sound requirements depend on knowing the ambient sound level. At the time of this writing, the HFDS does not include reference information about typical ambient sound levels across ATC facilities. Additionally, there are other factors that impact perception, such as sound frequencies, that are not considered by the HFDS Section 5.5.2.8.3 standard. Therefore, there may still be audibility issues with an auditory signal, even if the signal meets the HFDS Section 5.5.2.8.3 standard. The current project focused only on collecting ambient sound intensity measurements to inform the current standard. However, in practice, it is important to also take any additional factors (e.g., sound frequencies, facility layouts, structural aspects) into account that may impact perception when evaluating an ATC auditory signal, in addition to ensuring that the auditory signal properties meet the requirements outlined by the HFDS (Ahlstrom, 2016) Section 5.5.2.8.3 standard.

The sound measurement data provided in this report supplements the current standard and provides benchmark information for the design of base auditory signals. The information serves as a resource for the acquisition programs responsible for the design of auditory signals in ATC facilities.

# 2 Methodology

## 2.1 Purpose

This project captured ambient sound levels from a representative sample of FAA ATC facilities. This data was used to form several reference tables containing ambient sound level

measurements to supplement the information documented in the HFDS. The data collected from the Brüel & Kjær 2245 professional SLM may also be used to inform future content updates to Section 5.5.2.8.3 of the HFDS (Ahlstrom, 2016). An additional component of the project sought to evaluate the efficacy of using a smartphone application with an attached external microphone to collect ambient sound levels in ATC facilities as an alternative to professional SLM equipment. If the data is comparable to professional SLM equipment, it may suggest that smartphone SLM applications can be a reliable resource that would improve efficiency and reduce costs for individuals seeking to collect ambient sound level measurements for research purposes.

## 2.2 Facilities

Two engineering research psychologists from the FAA Human-Systems Integration Branch, ANG-E5B, one federal contractor (Diakon Solutions), and several ATC SMEs from the Terminal Computer Human Interface (CHI) team traveled to FAA ATCTs, TRACONs, and ARTCCs. Several of the members from the Terminal CHI team were also NATCA representatives. We coordinated with the Terminal CHI team to develop a comprehensive list of ATC facilities that varied in several characteristics such as facility type, age, geographic location, traffic activity level, and technical specifications. For example, the equipment used in ARTCCs primarily uses visual signals with few auditory signals, while the equipment used in ATCTs and TRACONs use many auditory signals. Therefore, there are typically far fewer auditory signals in ARTCCs. We also considered the age of the facility, since building materials vary based upon the year of construction, and the type of materials used can have an impact on room acoustics. The oldest facility that we visited was constructed in circa 1957, and the newest facility was constructed in circa 2016. We selected geographic areas with a variety of facilities to maximize the number of facilities that we could visit within one trip. Additionally, we considered facility levels to ensure inclusion of facilities across a wide range of air traffic activity levels. FAA facilities are assigned a numerical level from 4 to 12 that is based on several factors, including the number of operations and airspace complexity. Facility level affects the environment in numerous ways, such as staffing/the number of personnel, frequency of aircraft takeoff/landing ambient sound, the number of communications received/given, and more. Facility level determinations can change across years as activity level changes. The facility levels represented in this study were the assigned levels at the time of data collection. One Federal Contract Tower (FCT) was included, as these facilities can contain unique equipment/technology that could affect ambient sound levels.

Data collection took place between February and June 2025. At each facility, data collection took approximately one to three hours. Appendix A outlines the data collection schedule and facility details.

## 2.3 Materials

### 2.3.1 Sound level meters

The research team used a Brüel & Kjær 2245 SLM (2245-W-SC) with a half-inch free field digital microphone (Type 4966) to collect ambient sound measurements at each of the facilities. Calibration checks were performed on the sound level meter periodically throughout the data collection schedule using a Brüel & Kjær handheld calibrator (Type 4231). The Human-Systems Integration Branch purchased the sound level meter, microphone, and calibration checker for this project to replace the older equipment (Brüel & Kjær 2260) used previously (Cluff & McAnulty, 2011; Hah, Allendoerfer, & Novak, 2008).

The logging mode with the Brüel & Kjær 2245 SLM was used to collect measurement data. The logging interval was set to one second, and the measurement duration was preset to 30 minutes. The device has a frequency range of 6 Hz to 20 kHz. The single measurement range is 22.7 dB(A) to 140.6 dB(A) (Brüel & Kjær, 2024). $L_{Aeq,30min}$, $L_{ASmax,30min}$, and $L_{AFmax,30min}$ recorded by the Brüel & Kjær 2245 SLM were included in the report (Brüel & Kjær, 2020). The maximum $L_{Aeq,30s}$ was calculated from the one-second $L_{Aeq}$ sound level values and was also reported.

$L_{Aeq}$ is the A-weighted equivalent continuous sound level over a set period. It represents $L_{eq}$, the Equivalent Continuous Sound Level, combined with an A-frequency-weighting filter. $L_{eq}$ is an energy-averaged sound level that captures the fluctuations of sound levels over a set amount of time as a single value. A-weighting is a method of filtering sound measurements that approximates the relative loudness of sounds based on human perception across frequencies (Federal Aviation Administration, 2022). Taken together, the $L_{Aeq}$ provides a single energy-averaged sound level value measured over a set period of time that is A-weighted to consider human-perceivable frequencies (Centers for Disease Control and Prevention, 2024). We reported the energy-averaged $L_{Aeq}$ across all 30-minute trials per facility ($L_{Aeq,30min}$). To calculate the energy-averaged $L_{Aeq,30min}$ across trials, we converted the $L_{Aeq,30min}$ value for each trial into linear energy values. Next, we took the average of all the trials. Finally, we converted the linear energy average value back to dB(A) to determine the energy-averaged $L_{Aeq,30min}$ across all trials.

Using the one-second data from each 30-minute trial, we also calculated the maximum 30-second $L_{Aeq}$ for each facility (maximum $L_{Aeq,30s}$). For each trial, we first converted the one-

second sound level values into linear energy values. Then, we calculated the rolling 30-second average of the linear energy values and converted the values back to dB(A) to determine the $L_{Aeq,30s}$. Across these values, we identified the maximum $L_{Aeq,30s}$ for each trial. Finally, we identified the overall maximum $L_{Aeq,30s}$ across all trials, to determine the maximum $L_{Aeq,30s}$ for each facility.

$L_{ASmax}$ is the maximum sound level measured over a set period with A-weighting and slow time weighting (NoiseMeters, Inc., n.d.). When the slow time weighting feature is applied, the sound level meter uses a one-second time constant. The slow time weighting smooths quick fluctuations in sound levels, thus resulting in more stable readings. As such, this project reports the $L_{ASmax,30min}$ values to represent the maximum A-weighted sound level measured with slow time weighting across all 30-minute trials per facility. The A-weighting filter was applied to consider human-perceivable frequencies. We reported the maximum $L_{ASmax,30min}$ across all trials per facility.

$L_{AFmax}$ is the maximum sound level captured over a set period with A-weighting and fast time weighting (NoiseMeters, Inc., n.d.). When the fast time weighting feature is applied, the sound level meter uses a 125-millisecond time constant. This fast time weighting makes $L_{AFmax}$ useful for capturing fast, sharp sounds. The $L_{AFmax,30min}$ was reported, in addition to the $L_{ASmax,30min}$, to capture any rapid sound level spikes that occurred during the measurement. $L_{AFmax}$ is more sensitive to quick sound level fluctuations than $L_{ASmax}$, since fast time weighting responds faster to sound level changes than slow time weighting. Therefore, $L_{AFmax}$ values may be higher than $L_{ASmax}$ values for the same period of time if short sound spikes were present. We reported the maximum $L_{AFmax,30min}$ across all trials per facility.

Of note, $L_{Aeq,30min}$ is an energy-averaged value from the 30-minute period. On the other hand, $L_{ASmax,30min}$ and $L_{AFmax,30min}$ are the maximum sound levels captured during the 30-minute trial. $L_{ASmax,30min}$ and $L_{AFmax,30min}$ are not averages; they are the maximum time-weighted sound levels captured during the 30-minute trial.

### 2.3.2 Smartphone applications

Historically, practitioners like human factors specialists and industrial hygienists have needed to use professional-grade SLMs to best capture ambient sound measurements. These devices can be bulky, expensive, and require training to operate (Kardous & Shaw, 2014). There are also often additional expenses, since the devices require periodic factory-based, certified calibration, and trained personnel must travel to facilities to operate the tool.

With advancements in smartphone technology, there is now a growing body of literature suggesting that certain smartphone applications can provide accurate sound measurements when paired with an external calibrated microphone (Kardous & Shaw, 2016). Sound level meter applications do not replace professional equipment for compliance testing purposes, but they can serve as a useful and reliable resource to capture an accurate measurement of current sound levels in an environment (Centers for Disease Control and Prevention, 2024).

To test the efficacy of using smartphone applications to capture sound levels, we collected additional ambient sound measurements using a smartphone app with an attached external microphone. We had two of the same model external microphones that we alternated using for the first six data collection visits (Appendix A). After data collection at Wilmington Tower (ILG), we used only one external microphone for the remainder of data collection. We compared the data from the smartphone app with the professional Brüel & Kjær 2245 SLM data as a preliminary method to explore the use of smartphone apps in measuring ambient sound in ATC environments. The goal of the additional measurements was to provide insight into the utility of smartphone SLM apps for this purpose.

#### *2.3.2.1 National Institute for Occupational Safety and Health (NIOSH) Sound Level Meter app*

For this project, we used the National Institute for Occupational Safety and Health (NIOSH) Sound Level Meter app in conjunction with the professional Brüel & Kjær 2245 device to collect data. NIOSH developed this application as a tool to measure workplace sound levels and detect hazardous noise levels. The app is free to download and is available for iOS devices. According to previous research, the NIOSH SLM app is accurate within ±2 dB(A) (Centers for Disease Control and Prevention, 2024). The benefit of using the NIOSH SLM app (or a similar app) is that it is cost-effective and easily transportable compared to larger and more expensive professional SLMs.

The sound measurements from the NIOSH SLM app and the Brüel & Kjær 2245 SLM were compared to understand smartphone application utility as an alternative to professional equipment for measuring sound levels in ATC facilities (Table 35). Additionally, Appendix C reports the overall facility sound level measurements (energy-averaged and median measurement across trials at each facility) and related descriptive statistics for the NIOSH SLM app compiled into one table. As a supplement to this information, Appendix E contains the individual trial raw sound measurement data at each facility for the NIOSH SLM app.

Like the Brüel & Kjær 2245 SLM, the NIOSH SLM app generated several values for each 30-minute interval. However, the 30-minute measurement time was approximate, as the application could not set automatic duration end-times like the Brüel & Kjær 2245 SLM. $L_{Aeq,30min}$ and

$L_{ASmax,30min}$ were reported from the NIOSH SLM app. These metrics were collected to compare directly to the metrics obtained by the professional SLM. $L_{AFmax}$ was not collected, because only one FAA iPhone was available for data collection, and the NIOSH SLM app functionalities only allow one time weighting filter per measurement.

#### *2.3.2.2 iPhone and microphone*

An FAA-issued iPhone 13 was used to collect data using the NIOSH SLM app. The iPhone was maintained with the latest iOS software for each data collection period. An external microphone (MicW i437L) was attached to the iPhone for all sound measurements (MicW, n.d.). The external microphones were professionally calibrated before being shipped and complied with the IEC 61672 Class 2 SLM standard (International Electrotechnical Commission, 2013). However, additional calibration checks were not conducted throughout data collection, which may have impacted measurement accuracy.

## 2.4 Procedure

From February 2025 until June 2025, the research team traveled to several states across the United States to collect ambient sound measurements from ATC facilities. Locations included FAA ATCTs, TRACONs, ARTCCs, and one FCT.

At each location, the professional Brüel & Kjær 2245 SLM and an FAA-issued iPhone with an attached external microphone, used to run the NIOSH SLM app, were placed in several locations around the facility's operational areas. Based on the schedule and size of the facilities, sound measurements took place over the course of approximately one to three hours over 30-minute intervals. We moved the devices to different locations in the room after each interval, similar to the procedure conducted by Hah et al. (2008). Facility personnel and the research team's NATCA representative assisted in deciding measurement locations to ensure that the SLMs captured representative measurements without interfering with ATC operations. Placement of the SLMs varied based on the type and layout of the facility. The individual diagrams for each facility document the specific location(s) of the sound level meters during the measurements (Appendix I). The diagrams included in this study are not drawn to scale and are intended only to provide a general description about where the SLMs were placed for each trial. For each location, we placed the SLMs face down directly on the surface to prevent distraction by ensuring that the SLMs did not emit light from their screens. The researchers took notes during each visit to document relevant details, including which auditory signals were audible during the measurements, the perceived traffic activity level, the number of personnel in the room, and the general layout/size of the room. When possible, we also collected system data (e.g., traffic count information) for the relevant time periods.

This report documents the energy-averaged $L_{Aeq,30min}$ across all trials, the maximum $L_{Aeq,30s}$ across all trials, and the minimum auditory signal sound level necessary to comply with the HFDS Section 5.5.2.8.3 requirement for each facility. $L_{ASmax,30min}$ and $L_{AFmax,30min}$ values are reported for additional context in Appendix B. The report presents values from each facility in text and provides comprehensive reference tables that contain ambient sound level information for each of the facilities visited. This information supplements the existing HFDS requirements for auditory signals. The information reported from the professional Brüel & Kjær SLM (Appendix B) may also be used to inform future content updates to Section 5.5.2.8.3 of the current HFDS.

Separately, this report also compared the data from a smartphone SLM app with the professional Brüel & Kjær 2245 SLM data as a preliminary method to examine the use of smartphone apps in measuring ambient sound in ATC environments (Table 35; Appendix C, E).

# 3 Results

Our team collected sound measurement data from 28 facilities across 7 states (15 standalone ATCTs, 4 standalone TRACONs, 6 up/down ATCTs with TRACONs, 3 ARTCCs). We present the ambient sound level values by facility type: ATCT, TRACON, and ARTCC. Up/down facilities are ATCTs with TRACONs that operate as one facility under one facility identifier. Many up/down facilities house the ATCT and TRACON in the same building, while others may house the ATCT and TRACON in separate buildings. For up/down facilities, we include the ATCT and the TRACON individually in the respective facility type group (i.e., 21 ATCTs, 10 TRACONs, 3 ARTCCs). Visits to each facility lasted approximately one to three hours, depending on the data collection schedule and the size of the facility. We allotted additional time for larger facilities when possible. At all visits, the research team consisted of at least one federal employee from the Human-Systems Integration Branch (ANG-E5B) and one NATCA Terminal CHI SME. Several visits also included an additional federal employee from ANG-E5B, one federal contractor (Diakon Solutions), and one additional Terminal CHI member. Appendix A outlines details for the research team makeup at each facility visit. At each facility, there was also a non-operational staff member who served as the personnel escort during the visit. The personnel escort assisted with navigating the facility, identifying appropriate locations to place the SLM equipment, and obtaining supplemental data (e.g. traffic count information, weather, building construction details, etc.). At each facility, we collected sound measurements with the Brüel & Kjær 2245 SLM and the NIOSH SLM app simultaneously. In this report, we present the Brüel & Kjær 2245 SLM measurements first with additional facility details. The NIOSH SLM app measurements are presented second.

## 3.1 Brüel & Kjær 2245 SLM

For each facility, we captured detailed notes describing the layout of the space and other relevant information. At the highest level, the results are organized and presented based on facility type, as follows:

1. Standalone ATCTs
2. Standalone TRACONs
3. ATCTs with TRACONs (up/down facilities)
4. ARTCCs

Within each facility description, the results are organized as follows:

1. Facility overview (facility level, year built, square footage)
2. Data collection (date/time, number of trials)
3. Personnel (research team, number of controllers, and any additional personnel in the room during data collection)
4. Environmental factors (weather)
5. Operational information (traffic count, auditory signals deployed during the data collection period, any other *notable sounds** captured)
6. Ambient sound level measurements and auditory signal calculations.
    a. Facility ambient sound measurements
        i. Prevailing ambient sound level: The $L_{Aeq,30min}$ (energy-averaged across trials) was used to determine the prevailing ambient sound level per facility to comply with the first part of HFDS Section 5.5.2.8.3: "Auditory signals shall exceed the prevailing ambient sound level by at least 10 dB(A)…" (Ahlstrom, 2016, p. 237).
        ii. Maximum sound level with a 30 second duration: The maximum $L_{Aeq,30s}$ across trials was used to determine maximum sound level with a duration of 30 seconds per facility to comply with the second part of HFDS Section 5.5.2.8.3: "…or any maximum sound level with a duration of 30 seconds by at least 5 dB(A)" (Ahlstrom, 2016, p. 237).
    b. Auditory signal calculations

i. Prevailing ambient sound level + 10: 10 dB(A) were added to the $L_{Aeq,30min}$ value to determine the minimum auditory signal sound level per facility to comply with the first part of HFDS Section 5.5.2.8.3: "Auditory signals shall exceed the prevailing ambient sound level by at least 10 dB(A)…" (Ahlstrom, 2016, p. 237).

ii. Maximum $L_{Aeq}$ with 30s duration + 5: 5 dB(A)) were added to the maximum $L_{Aeq,30s}$ value to determine the minimum auditory signal sound level per facility to comply with the second part of HFDS Section 5.5.2.8.3: "…or any maximum sound level with a duration of 30 seconds by at least 5 dB(A)" (Ahlstrom, 2016, p. 237).

c. Minimum auditory signal sound level

i. The larger of the two auditory signal calculation values is reported as the minimum auditory signal sound level to comply with HFDS Section 5.5.2.8.3 (Ahlstrom, 2016).

ii. The value must not exceed 115 dB(A) for emergency signals or 90 dB(A) for other signals. None of the calculated values reported exceeded these thresholds (Ahlstrom, 2016).

*For the purposes of this report, *notable sounds* are sounds that were particularly loud and/or atypical for the environment.

Some information could not be obtained at certain facilities. As such, there is slight variation in each facility section, where all information that was able to be collected for that specific location is described. Additionally, ATC facilities are dynamic environments, and the number of personnel in the room was constantly changing over the course of the sound measurements at most facilities when position relief briefs and changing shifts occurred. As a result, the listed number of personnel in the room is an approximation based on the number of people that were in the room for most of the data collection period. Additionally, weather information was not reported for ARTCC locations, since ARTCCs control large areas with several weather differences possible throughout the region. All sound level measurement information per facility is listed in text and in comprehensive reference tables (Appendix B, D).

### 3.1.1 Shakedown data collection

#### *3.1.1.1 Atlantic City Tower/TRACON*

**Facility Overview:** Atlantic City Tower and TRACON (ACY), located in Atlantic City, NJ, is a level 6 up/down facility. ACY Tower was built in circa 1987.

**Data Collection:** The site visit took place on February 11, 2025, from 12:30 p.m. until 1:30 p.m. EST. The first measurement was taken in the TRACON, and the second measurement was taken in the control tower. These measurements were taken as a practice opportunity for the research team to familiarize themselves with the procedure before data collection began. The measurements obtained at ACY Tower and TRACON are included in the facility information appendices (Appendix A-I).

#### *3.1.1.2 ACY ATCT*

**Personnel:** During the visit, there were three controllers in the tower, including one supervisor and four individuals from the research team.

**Environmental Factors:** There was clear visibility outside the tower at the time of data collection.

**Operational Information:** Notable sounds that were captured during the measurement included the sound of a fan running in the tower that was turned off during the trial.

**Ambient Sound Measurements:** Table 1 outlines the $L_{Aeq}$ measurement from the 30-minute recording at ACY ATCT. It also lists the maximum $L_{Aeq,30s}$ measurement. Finally, the table lists the minimum auditory signal sound level required for the facility to comply with HFDS Section 5.5.2.8.3, and the calculations used to determine this value.

Table 1. ACY ATCT Auditory Signal Requirement Based on Sound Levels (B&K SLM)

| Facility Sound Measurements [dB(A)] | | Auditory Signal Calculations [dB(A)] | | HFDS Requirement [dB(A)] |
|---|---|---|---|---|
| Prevailing Ambient[a] | MAX w/ 30s Duration[b] | Prevailing Ambient + 10 | MAX w/ 30s Duration + 5 | MIN Auditory Signal Sound Level |
| 57.9 | 65.2 | 67.9 | 70.2 | **70** |

[a] $L_{Aeq,30min}$

[b] Maximum $L_{Aeq,30s}$

*3.1.1.3 ACY TRACON*

**Personnel:** During the visit, there were four controllers in the room, including one supervisor and four individuals from the research team.

**Environmental Factors:** There was clear visibility outside at the time of data collection.

**Operational Information:** Notable sounds that were captured during the measurements included loudspeaker communications.

**Ambient Sound Measurements:** Table 2 outlines the $L_{Aeq}$ measurement from the 30-minute recording at ACY TRACON. It also lists the maximum $L_{Aeq,30s}$ measurement. Finally, the table lists the minimum auditory signal sound level required for the facility to comply with HFDS Section 5.5.2.8.3, and the calculations used to determine this value.

Table 2. ACY TRACON Auditory Signal Requirement Based on Sound Levels (B&K SLM)

| Facility Sound Measurements [dB(A)] | | Auditory Signal Calculations [dB(A)] | | HFDS Requirement [dB(A)] |
|---|---|---|---|---|
| Prevailing Ambient[a] | MAX w/ 30s Duration[b] | Prevailing Ambient + 10 | MAX w/ 30s Duration + 5 | MIN Auditory Signal Sound Level |
| 57.6 | 69.1 | 67.6 | 74.1 | **74** |

[a] $L_{Aeq,30min}$

[b] Maximum $L_{Aeq,30s}$

## 3.1.2 ATCTs

*3.1.2.1 Trenton Mercer Tower*

**Facility Overview:** Trenton Mercer Tower (TTN), located in Trenton, NJ, is an FCT built in circa 1961. TTN's tower cab is approximately 20 x 20 square feet.

**Data Collection:** The site visit took place on March 25, 2025, from approximately 11:30 a.m. until 1:30 p.m. EST. Four 30-minute sound measurements were recorded from varying positions around the tower cab.

**Personnel:** During the visit, there were two controllers in the cab, one Air Traffic Manager (ATM), and three individuals from the research team.

**Environmental Factors:** During data collection, there was clear visibility outside the tower, and there were strong winds present.

**Operational Information:** There were approximately three departures and five arrivals during the data collection period. Notable sounds that were captured during the measurements included loudspeaker communications and Automated Surface Observing System (ASOS) notifications.

**Ambient Sound Measurements:** Table 3 shows the overall $L_{Aeq,30min}$ for TTN, calculated by energy-averaging the $L_{Aeq,30min}$ values from the four 30-minute trials. It also lists the maximum $L_{Aeq,30s}$ across all trials. Finally, the table lists the minimum auditory signal sound level required for the facility to comply with HFDS Section 5.5.2.8.3, and the calculations used to determine this value.

Table 3. TTN ATCT Auditory Signal Requirement Based on Sound Levels (B&K SLM)

| Facility Sound Measurements [dB(A)] | | Auditory Signal Calculations [dB(A)] | | HFDS Requirement [dB(A)] |
|---|---|---|---|---|
| Prevailing Ambient[a] | MAX w/ 30s Duration[b] | Prevailing Ambient + 10 | MAX w/ 30s Duration + 5 | MIN Auditory Signal Sound Level |
| 57.5 | 65.4 | 67.5 | 70.4 | **70** |

[a] $L_{Aeq,30min}$; Energy-Averaged Across Trials

[b] Maximum $L_{Aeq,30s}$ (Across Trials)

#### *3.1.2.2 Northeast Philadelphia Tower*

**Facility Overview:** Northeast Philadelphia Tower (PNE), located in Philadelphia, PA, is a level 5 facility built in circa 1973.

**Data Collection:** The site visit took place on April 7, 2025, from approximately 2:00 PM until 3:30 PM EST. Three 30-minute sound measurements were recorded from varying positions around the tower cab.

**Personnel:** During the visit, there were four controllers in the tower cab, one ATM, and two individuals from the research team.

**Environmental Factors:** There were rainy conditions at the time of data collection.

**Operational Information:** Notable sounds that were captured during the measurements included loudspeaker communications, CAs, blinds lifting and lowering, an Automatic Terminal Information Service (ATIS) notification, and sounds from aircraft taking off and landing outside the tower.

**Ambient Sound Measurements:** Table 4 shows the overall $L_{Aeq,30min}$ for PNE, calculated by energy-averaging the $L_{Aeq,30min}$ values from the three 30-minute trials. It also lists the maximum $L_{Aeq,30s}$ across all trials. Finally, the table lists the minimum auditory signal sound level required for the facility to comply with HFDS Section 5.5.2.8.3, and the calculations used to determine this value.

Table 4. PNE ATCT Auditory Signal Requirement Based on Sound Levels (B&K SLM)

| Facility Sound Measurements [dB(A)] | | Auditory Signal Calculations [dB(A)] | | HFDS Requirement [dB(A)] |
|---|---|---|---|---|
| Prevailing Ambient[a] | MAX w/ 30s Duration[b] | Prevailing Ambient + 10 | MAX w/ 30s Duration + 5 | MIN Auditory Signal Sound Level |
| 60.8 | 68.5 | 70.8 | 73.5 | **73** |

[a] $L_{Aeq,30min}$; Energy-Averaged Across Trials
[b] Maximum $L_{Aeq,30s}$ (Across Trials)

#### *3.1.2.3 Wilmington Tower*

**Facility Overview:** Wilmington Tower (ILG), located in New Castle, DE, is a level 4 facility built in circa 2001.

**Data Collection:** The site visit took place on April 9, 2025, from approximately 10:00 a.m. until 11:30 a.m. EST. Three 30-minute sound measurements were recorded from varying positions around the tower cab.

**Personnel:** During the visit, there were three controllers in the tower cab, one ATM, and four individuals from the research team.

**Environmental Factors:** There was clear visibility outside the tower at the time of data collection. There were approximately 42 total operations (combined arrivals and departures) during the data collection period.

**Operational Information:** Unlike all data collection measurements that occurred before this date, the iPhone external microphone windscreen was not used for any of the measurements collected at ILG ATCT. This change was inadvertent, as the windscreen for the external

microphone had fallen off during transport to the facility. However, upon examining the data, the measurements showed that the iPhone sound measurements without the windscreen were more comparable with the professional sound level meter, whose microphone also did not have a windscreen. Therefore, the protocol was adjusted to use no windscreen for either device on all subsequent facility visits (Appendix A).

Notable sounds that were captured during the measurements include sounds from aircraft taking off and landing outside the tower, landline phone ringing, CAs, blinds lifting and lowering, ATIS notifications, various loudspeaker communications, and chimes.

**Ambient Sound Measurements:** Table 5 shows the overall $L_{Aeq,30min}$ for ILG, calculated by energy-averaging the $L_{Aeq,30min}$ values from the three 30-minute trials. It also lists the maximum $L_{Aeq,30s}$ across all trials. Finally, the table lists the minimum auditory signal sound level required for the facility to comply with HFDS Section 5.5.2.8.3, and the calculations used to determine this value.

Table 5. ILG ATCT Auditory Signal Requirement Based on Sound Levels (B&K SLM)

| Facility Sound Measurements [dB(A)] | | Auditory Signal Calculations [dB(A)] | | HFDS Requirement [dB(A)] |
|---|---|---|---|---|
| Prevailing Ambient[a] | MAX w/ 30s Duration[b] | Prevailing Ambient + 10 | MAX w/ 30s Duration + 5 | MIN Auditory Signal Sound Level |
| 58.1 | 72.7 | 68.1 | 77.7 | **78** |

[a] $L_{Aeq,30min}$; Energy-Averaged Across Trials

[b] Maximum $L_{Aeq,30s}$ (Across Trials)

#### *3.1.2.4 Washington National Tower*

**Facility Overview:** Washington National Tower (DCA), located in Washington, DC, is a level 9 facility built in circa 1997. DCA's tower cab is roughly 545 square feet.

**Data Collection:** The site visit took place on April 22, 2025, from approximately 1:00 p.m. until 3:00 p.m. EST. Four 30-minute sound measurements were recorded from varying positions around the tower cab.

**Personnel:** During the visit, there were seven controllers in the tower cab, including one supervisor and four individuals from the research team.

**Environmental Factors:** During the visit, there were light winds from the north outside the tower.

**Operational Information:** There was slow to moderate traffic volume for the facility at the time of data collection, according to subjective feedback from the personnel escort. Notable sounds that were captured during the measurements included sound from aircraft taking off and landing outside the tower, landline phone ringing, Low Altitude Alerts, CAs, and loudspeaker communications.

**Ambient Sound Measurements:** Table 6 shows the overall $L_{Aeq,30min}$ for DCA, calculated by energy-averaging the $L_{Aeq,30min}$ values from the four 30-minute trials at DCA. It also lists the maximum $L_{Aeq,30s}$ across all trials. Finally, the table lists the minimum auditory signal sound level required for the facility to comply with HFDS Section 5.5.2.8.3, and the calculations used to determine this value.

Table 6. DCA ATCT Auditory Signal Requirement Based on Sound Levels (B&K SLM)

| Facility Sound Measurements [dB(A)] | | Auditory Signal Calculations [dB(A)] | | HFDS Requirement [dB(A)] |
|---|---|---|---|---|
| Prevailing Ambient[a] | MAX w/ 30s Duration[b] | Prevailing Ambient + 10 | MAX w/ 30s Duration + 5 | MIN Auditory Signal Sound Level |
| 66.4 | 79.9 | 76.4 | 84.9 | **85** |

[a] $L_{Aeq,30min}$; Energy-Averaged Across Trials

[b] Maximum $L_{Aeq,30s}$ (Across Trials)

#### *3.1.2.5 Deer Valley Tower*

**Facility Overview:** Deer Valley Tower (DVT), located in Phoenix, AZ, is a level 8 facility built in circa 2007. DVT's cab environment is 438 square feet, with 253 square feet of floor space.

**Data Collection:** The site visit took place on May 20, 2025, from approximately 9:00 a.m. until 10:30 a.m. MST. Three 30-minute sound measurements were recorded from varying positions around the tower cab.

**Personnel:** During the visit, there were six controllers in the cab, including one supervisor and five individuals from the research team.

**Environmental Factors:** There was clear visibility outside the tower at the time of data collection.

**Operational Information:** Between 9:00 a.m. and 10:00 a.m. MST, there were approximately 87 operations. Between 10:00 AM and 10:45 AM MST, there were approximately 117 operations. Notable sounds that were captured during the measurements included CAs, a beeping

sound from the door's intercom device, and loudspeaker communications. Additionally, there were two large cracks in one tower cab window.

**Ambient Sound Measurements:** Table 7 shows the overall $L_{Aeq,30min}$ for DVT, calculated by energy-averaging the $L_{Aeq,30min}$ values from the three 30-minute trials at DVT. It also lists the maximum $L_{Aeq,30s}$ across all trials. Finally, the table lists the minimum auditory signal sound level required for the facility to comply with HFDS Section 5.5.2.8.3, and the calculations used to determine this value.

Table 7. DVT ATCT Auditory Signal Requirement Based on Sound Levels (B&K SLM)

| Facility Sound Measurements [dB(A)] | | Auditory Signal Calculations [dB(A)] | | HFDS Requirement [dB(A)] |
|---|---|---|---|---|
| Prevailing Ambient[a] | MAX w/ 30s Duration[b] | Prevailing Ambient + 10 | MAX w/ 30s Duration + 5 | MIN Auditory Signal Sound Level |
| 60.7 | 68.9 | 70.7 | 73.9 | **74** |

[a] $L_{Aeq,30min}$; Energy-Averaged Across Trials

[b] Maximum $L_{Aeq,30s}$ (Across Trials)

#### *3.1.2.6 Scottsdale Tower*

**Facility Overview:** Scottsdale Tower (SDL), located in Scottsdale, AZ, is a level 7 facility built in circa 1989. SDL's cab environment was estimated by the research team to be approximately 30 feet in diameter.

**Data Collection:** The site visit took place on May 20, 2025 from approximately 1:00 p.m. until 2:30 p.m. MST. Three approximately 30-minute sound measurements were recorded from varying positions around the tower cab.

**Personnel:** During the visit, there were six controllers present, including one supervisor and five individuals from the research team.

**Environmental Factors:** There was clear visibility outside the tower at the time of data collection.

**Operational Information:** Between 1:00 p.m. and 2:00 p.m. MST, there were approximately 30 total operations. Between 2:00 PM and 2:30 PM MST, there were approximately 25 total operations. Notable sounds that were captured during the measurements included sounds from aircraft taking off and landing outside the tower, Low Altitude Alerts, CAs, landline phone ringing, loudspeaker communications, and low humming from an ice machine.

**Ambient Sound Measurements:** Table 8 shows the overall $L_{Aeq,30min}$ for SDL, calculated by energy-averaging the $L_{Aeq,30min}$ values from the three 30-minute trials at SDL. It also lists the maximum $L_{Aeq,30s}$ across all trials. Finally, the table lists the minimum auditory signal sound level required for the facility to comply with HFDS Section 5.5.2.8.3, and the calculations used to determine this value.

Table 8. SDL ATCT Auditory Signal Requirement Based on Sound Levels (B&K SLM)

| Facility Sound Measurements [dB(A)] | | Auditory Signal Calculations [dB(A)] | | HFDS Requirement [dB(A)] |
|---|---|---|---|---|
| Prevailing Ambient[a] | MAX w/ 30s Duration[b] | Prevailing Ambient + 10 | MAX w/ 30s Duration + 5 | MIN Auditory Signal Sound Level |
| 61.0 | 68.8 | 71.0 | 73.8 | **74** |

[a] $L_{Aeq,30min}$; Energy-Averaged Across Trials

[b] Maximum $L_{Aeq,30s}$ (Across Trials)

*3.1.2.7 Falcon Tower*

**Facility Overview:** Falcon Tower (FFZ), located in Mesa, Arizona is a level 8 facility built in circa 1978. FFZ's cab environment is approximately 16 feet across in diameter.

**Data Collection:** The site visit took place on May 21st, 2025, from approximately 11:00 a.m. until 12:30 p.m. MST. Three 30-minute sound measurements were recorded from varying positions around the tower cab.

**Personnel:** During the visit, there were four controllers in the cab, including one supervisor, in addition to the ATM and two individuals from the research team.

**Environmental Factors:** There was clear visibility outside the tower at the time of data collection.

**Operational Information:** Towards the beginning of the visit, traffic activity levels ranged from moderate to busy activity for the facility, according to subjective feedback we received from the personnel escort. Traffic slowed slightly towards the end of the visit, with light to moderate traffic activity. Notable sounds that were captured during the measurements included CAs, blinds lifting, and a Low Altitude Alert.

**Ambient Sound Measurements:** Table 9 shows the overall $L_{Aeq,30min}$ for FFZ, calculated by energy-averaging the $L_{Aeq,30min}$ values from the three 30-minute trials at FFZ. It also lists the maximum $L_{Aeq,30s}$ across all trials. Finally, the table lists the minimum auditory signal sound

level required for the facility to comply with HFDS Section 5.5.2.8.3, and the calculations used to determine this value.

Table 9. FFZ ATCT Auditory Signal Requirement Based on Sound Levels (B&K SLM)

| Facility Sound Measurements [dB(A)] | | Auditory Signal Calculations [dB(A)] | | HFDS Requirement [dB(A)] |
|---|---|---|---|---|
| Prevailing Ambient[a] | MAX w/ 30s Duration[b] | Prevailing Ambient + 10 | MAX w/ 30s Duration + 5 | MIN Auditory Signal Sound Level |
| 64.1 | 75.8 | 74.1 | 80.8 | **81** |

[a] $L_{Aeq,30min}$; Energy-Averaged Across Trials

[b] Maximum $L_{Aeq,30s}$ (Across Trials)

#### *3.1.2.8 Tucson Tower*

**Facility Overview:** Tucson Tower (TUS), located in Tucson, AZ is a level 6 facility built in circa 2016.

**Data Collection:** The site visit took place on May 22nd, 2025, from approximately 11:30 a.m. until 1:00 p.m. MST. Three 30-minute sound measurements were recorded from varying positions around the tower cab.

**Personnel:** During the visit, there were four controllers in the cab, including one supervisor and two individuals from the research team.

**Environmental Factors:** There was clear visibility outside the tower at the time of data collection.

**Operational Information:** There were approximately 69 total operations during the visit. Notable sounds that were captured during the measurements included CAs, landline phone ringing, loudspeaker communications, ASOS and ATIS notifications, and a notification sound associated with the departure cable arresting system.

**Ambient Sound Measurements:** Table 10 shows the overall $L_{Aeq,30min}$ for TUS, calculated by energy-averaging the $L_{Aeq,30min}$ values from the three 30-minute trials at TUS. It also lists the maximum $L_{Aeq,30s}$ across all trials. Finally, the table lists the minimum auditory signal sound level required for the facility to comply with HFDS Section 5.5.2.8.3, and the calculations used to determine this value.

Table 10. TUS ATCT Auditory Signal Requirement Based on Sound Levels (B&K SLM)

| Facility Sound Measurements [dB(A)] | | Auditory Signal Calculations [dB(A)] | | HFDS Requirement [dB(A)] |
|---|---|---|---|---|
| Prevailing Ambient[a] | MAX w/ 30s Duration[b] | Prevailing Ambient + 10 | MAX w/ 30s Duration + 5 | MIN Auditory Signal Sound Level |
| 56.6 | 67.3 | 66.6 | 72.3 | **72** |

[a] $L_{Aeq,30min}$; Energy-Averaged Across Trials

[b] Maximum $L_{Aeq,30s}$ (Across Trials)

#### *3.1.2.9 Houston Intercontinental Tower*

**Facility Overview**: Houston Intercontinental Tower (IAH), located in Houston, TX is a level 11 facility built in circa 1997.

**Data Collection:** The site visit took place on June 3rd, 2025, from approximately 9:10 a.m. until 10:40 a.m. CST. Three 30-minute sound measurements were recorded from varying positions around the tower cab.

**Personnel:** During the visit, there were six controllers in the tower cab at the start of the first trial, with a peak of nine to ten controllers in the tower cab at once during the third trial. There were three individuals from the research team present.

**Environmental Factors:** There were 10 mph winds during the visit as well as clouds scattered at an altitude of approximately 2,000 feet.

**Operational Information:** Notable sounds that were captured during the measurements included CAs, landline phone ringing, Airport Surface Detection Equipment Model X (ASDE-X) notifications, a radio failure alert, and the sound of flight progress strip plastic holders being periodically dropped in a bucket.

**Ambient Sound Measurements:** Table 11 shows the overall $L_{Aeq,30min}$ for IAH, calculated by energy-averaging the $L_{Aeq,30min}$ values from the three 30-minute trials at IAH. It also lists the maximum $L_{Aeq,30s}$ across all trials. Finally, the table lists the minimum auditory signal sound level required for the facility to comply with HFDS Section 5.5.2.8.3, and the calculations used to determine this value.

Table 11. IAH ATCT Auditory Signal Requirement Based on Sound Levels (B&K SLM)

| Facility Sound Measurements [dB(A)] | | Auditory Signal Calculations [dB(A)] | | HFDS Requirement [dB(A)] |
|---|---|---|---|---|
| Prevailing Ambient[a] | MAX w/ 30s Duration[b] | Prevailing Ambient + 10 | MAX w/ 30s Duration + 5 | MIN Auditory Signal Sound Level |
| 62.9 | 74.3 | 72.9 | 79.3 | **79** |

[a] $L_{Aeq,30min}$; Energy-Averaged Across Trials

[b] Maximum $L_{Aeq,30s}$ (Across Trials)

#### *3.1.2.10 Houston Hooks Tower*

**Facility Overview:** Houston Hooks Tower (DWH), located in Tomball, Texas, is a level 6 facility built in circa 1979.

**Data Collection:** The site visit took place on June 4th, 2025, from approximately 12:20 p.m. until 1:50 p.m. CST. Three 30-minute sound measurements were recorded from varying positions around the tower cab.

**Personnel:** During the visit there were four controllers in the tower, including one supervisor, in addition to the ATM and three individuals from the research team.

**Environmental Factors:** There was clear visibility outside the tower until the end of the second trial when light rain began. During the third trial, there was heavy rain.

**Operational Information:** Notable sounds that were captured during the measurements included CAs, loudspeaker communications, and ASOS notifications. There also was an audible air conditioning system that periodically turned on and off during all three trials. This AC system was much louder than in other facilities that were visited over the course of the project.

**Ambient Sound Measurements:** Table 12 shows the overall $L_{Aeq,30min}$ for DWH, calculated by energy-averaging the $L_{Aeq,30min}$ values from the three 30-minute trials at DWH. It also lists the maximum $L_{Aeq,30s}$ across all trials. Finally, the table lists the minimum auditory signal sound level required for the facility to comply with HFDS Section 5.5.2.8.3, and the calculations used to determine this value.

Table 12. DWH ATCT Auditory Signal Requirement Based on Sound Levels (B&K SLM)

| Facility Sound Measurements [dB(A)] | | Auditory Signal Calculations [dB(A)] | | HFDS Requirement [dB(A)] |
|---|---|---|---|---|
| Prevailing Ambient[a] | MAX w/ 30s Duration[b] | Prevailing Ambient + 10 | MAX w/ 30s Duration + 5 | MIN Auditory Signal Sound Level |
| 65.1 | 74.1 | 75.1 | 79.1 | **79** |

[a] $L_{Aeq,30min}$; Energy-Averaged Across Trials

[b] Maximum $L_{Aeq,30s}$ (Across Trials)

#### *3.1.2.11 Hobby Tower*

**Facility Overview:** Hobby Tower (HOU), located in Houston, Texas, is a level 8 facility built in circa 2000.

**Data Collection:** The site visit took place on June 5th, 2025, from approximately 11:00 p.m. until 12:30 p.m. CST. Three 30-minute sound measurements were recorded from varying positions around the tower cab.

**Personnel:** During the visit, there were six controllers in the tower cab and two individuals from the research team present.

**Environmental Factors:** There was clear visibility outside the tower at the time of data collection.

**Operational Information:** Notable sounds that were captured during the measurements included loudspeaker communications, landline phone rings, and frequent CAs.

**Ambient Sound Measurements:** Table 13 shows the overall $L_{Aeq,30min}$ for HOU, calculated by energy-averaging the $L_{Aeq,30min}$ values from the three, 30-minute trials at HOU. It also lists the maximum $L_{Aeq,30s}$ across all trials. Finally, the table lists the minimum auditory signal sound level required for the facility to comply with HFDS Section 5.5.2.8.3, and the calculations used to determine this value.

Table 13. HOU ATCT Auditory Signal Requirement Based on Sound Levels (B&K SLM)

| Facility Sound Measurements [dB(A)] | | Auditory Signal Calculations [dB(A)] | | HFDS Requirement [dB(A)] |
|---|---|---|---|---|
| Prevailing Ambient[a] | MAX w/ 30s Duration[b] | Prevailing Ambient + 10 | MAX w/ 30s Duration + 5 | MIN Auditory Signal Sound Level |
| 62.1 | 70.1 | 72.1 | 75.1 | **75** |

[a] $L_{Aeq,30min}$; Energy-Averaged Across Trials

[b] Maximum $L_{Aeq,30s}$ (Across Trials)

#### *3.1.2.12 Tamiami Tower*

**Facility Overview:** Tamiami Tower (TMB), located in Miami, FL, is a level 8 facility built in circa 1993. TMB's cab environment is approximately 215 square feet.

**Data Collection:** The site visit took place on June 9, 2025, from approximately 2:00 p.m. until 3:30 p.m. EST. Three 30-minute sound measurements were recorded from varying positions around the tower cab.

**Personnel:** During the visit, there were five controllers in the cab, including one supervisor, and two individuals from the research team.

**Environmental Factors:** There was clear visibility outside the tower at the time of data collection.

**Operational Information:** The traffic activity level was light to moderate for the facility, according to subjective feedback we received from the personnel escort. Notable sounds that were captured during the measurements included CAs, ASOS notifications, a radio failure alert, landline phone ringing, the sound of flight progress strip plastic holders being periodically dropped into a bucket, and sounds from aircraft taking off and landing outside the tower.

**Ambient Sound Measurements:** Table 14 shows the overall $L_{Aeq,30min}$ for TMB, calculated by energy-averaging the $L_{Aeq,30min}$ values from the three 30-minute trials at TMB. It also lists the maximum $L_{Aeq,30s}$ across all trials. Finally, the table lists the minimum auditory signal sound level required for the facility to comply with HFDS Section 5.5.2.8.3, and the calculations used to determine this value.

Table 14. TMB ATCT Auditory Signal Requirement Based on Sound Levels (B&K SLM)

| Facility Sound Measurements [dB(A)] | | Auditory Signal Calculations [dB(A)] | | HFDS Requirement [dB(A)] |
|---|---|---|---|---|
| Prevailing Ambient[a] | MAX w/ 30s Duration[b] | Prevailing Ambient + 10 | MAX w/ 30s Duration + 5 | MIN Auditory Signal Sound Level |
| 62.8 | 73.3 | 72.8 | 78.3 | **78** |

[a] $L_{Aeq,30min}$; Energy-Averaged Across Trials

[b] Maximum $L_{Aeq,30s}$ (Across Trials)

#### *3.1.2.13 Fort Lauderdale Tower*

**Facility Overview:** Fort Lauderdale Tower (FLL), located in Fort Lauderdale, FL, is a level 8 facility built in circa 1985.

**Data Collection:** The site visit took place on June 11, 2025, from approximately 8:00 a.m. until 9:30 a.m. EST. Three 30-minute sound measurements were recorded from varying positions around the tower cab.

**Personnel:** During the visit, there were four controllers in the cab, including one supervisor and three individuals from the research team.

**Environmental Factors:** There was clear visibility outside the tower at the time of data collection.

**Operational Information:** Traffic activity levels were light for the facility at the time of the visit, according to subjective feedback we received from the personnel escort. Notable sounds that were captured during the measurements included the Runway Visual Range (RVR) alarm, loudspeaker communications, coordination chimes, blinds lowering, sounds from aircraft taking off and landing outside the tower, CAs, Low Altitude Alerts, and landline phone ringing. Additionally, the tower's daily checks were performed during the visit, where several of the systems were tested to confirm functionality. Further, the ASDE-X Ground Surface Radar equipment was located on the roof, and the sound of it spinning was audible from inside the tower.

**Ambient Sound Measurements:** Table 15 shows the overall $L_{Aeq,30min}$ for FLL, calculated by energy-averaging the $L_{Aeq,30min}$ values from the three 30-minute trials at FLL. It also lists the maximum $L_{Aeq,30s}$ across all trials. Finally, the table lists the minimum auditory signal sound level required for the facility to comply with HFDS Section 5.5.2.8.3, and the calculations used to determine this value.

Table 15. FLL ATCT Auditory Signal Requirement Based on Sound Levels (B&K SLM)

| Facility Sound Measurements [dB(A)] | | Auditory Signal Calculations [dB(A)] | | HFDS Requirement [dB(A)] |
|---|---|---|---|---|
| Prevailing Ambient[a] | MAX w/ 30s Duration[b] | Prevailing Ambient + 10 | MAX w/ 30s Duration + 5 | MIN Auditory Signal Sound Level |
| 58.7 | 69.3 | 68.7 | 74.3 | **74** |

[a] $L_{Aeq,30min}$; Energy-Averaged Across Trials

[b] Maximum $L_{Aeq,30s}$ (Across Trials)

#### *3.1.2.14 Fort Lauderdale Executive Tower*

**Facility Overview:** Fort Lauderdale Executive Tower (FXE), located in Fort Lauderdale, FL, is a level 7 facility built in circa 2014.

**Data Collection:** The site visit took place on June 11, 2025 from approximately 10:30 a.m. until 12:00 p.m. EST. Three 30-minute sound measurements were recorded from varying positions around the tower cab.

**Personnel:** During the visit, there were four controllers in the cab, including one supervisor and three individuals from the research team.

**Environmental Factors:** There was clear visibility outside the tower at the time of data collection.

**Operational Information:** Between 10:30 a.m. and 12:00 p.m. EST, there were approximately 83 total operations. Notable sounds that were captured during measurements included CAs, loudspeaker communications, landline phone ringing, coordination chimes, sounds from aircraft taking off and landing outside the tower, Low Altitude Alerts, ATIS notifications, and the sound of flight progress strip plastic holders being periodically dropped into a bucket.

**Ambient Sound Measurements:** Table 16 shows the overall $L_{Aeq,30min}$ for FXE, calculated by energy-averaging the $L_{Aeq,30min}$ values from the three 30-minute trials at FXE. It also lists the maximum $L_{Aeq,30s}$ across all trials. Finally, the table lists the minimum auditory signal sound level required for the facility to comply with HFDS Section 5.5.2.8.3, and the calculations used to determine this value.

Table 16. FXE ATCT Auditory Signal Requirement Based on Sound Levels (B&K SLM)

| Facility Sound Measurements [dB(A)] | | Auditory Signal Calculations [dB(A)] | | HFDS Requirement [dB(A)] |
|---|---|---|---|---|
| Prevailing Ambient[a] | MAX w/ 30s Duration[b] | Prevailing Ambient + 10 | MAX w/ 30s Duration + 5 | MIN Auditory Signal Sound Level |
| 61.3 | 73.5 | 71.3 | 78.5 | **79** |

[a] $L_{Aeq,30min}$; Energy-Averaged Across Trials

[b] Maximum $L_{Aeq,30s}$ (Across Trials)

#### *3.1.2.15 Vero Beach Tower*

**Facility Overview:** Vero Beach Tower (VRB), located in Vero Beach, FL, is a level 8 facility built in circa 2003.

**Data Collection:** The site visit took place on June 12, 2025, from approximately 1:30 p.m. until 3:00 p.m. EST. Three 30-minute sound measurements were recorded from varying positions around the tower cab.

**Personnel:** During the visit, there were five controllers in the cab, including one supervisor, plus the ATM and three individuals from the research team.

**Environmental Factors:** There was clear visibility outside the tower at the time of data collection.

**Operational Information:** Traffic activity levels were average for the facility at the time of the visit, according to subjective feedback we received from the personnel escort. There were approximately 34 total operations between 1:30 p.m. and 2:00 p.m. EST, and approximately 108 operations from 2:00 p.m. to 3:00 p.m. EST. Notable sounds that were captured during the measurements included CAs, ASOS notifications, sounds from aircraft taking off and landing outside the tower, and loudspeaker communications.

**Ambient Sound Measurements:** Table 17 shows the overall $L_{Aeq,30min}$ for VRB, calculated by energy-averaging the $L_{Aeq,30min}$ values from the three 30-minute trials at VRB. It also lists the maximum $L_{Aeq,30s}$ across all trials. Finally, the table lists the minimum auditory signal sound level required for the facility to comply with HFDS Section 5.5.2.8.3, and the calculations used to determine this value.

Table 17. VRB ATCT Auditory Signal Requirement Based on Sound Levels (B&K SLM)

| Facility Sound Measurements [dB(A)] | | Auditory Signal Calculations [dB(A)] | | HFDS Requirement [dB(A)] |
|---|---|---|---|---|
| Prevailing Ambient[a] | MAX w/ 30s Duration[b] | Prevailing Ambient + 10 | MAX w/ 30s Duration + 5 | MIN Auditory Signal Sound Level |
| 59.0 | 71.4 | 69.0 | 76.4 | **76** |

[a] $L_{Aeq,30min}$; Energy-Averaged Across Trials

[b] Maximum $L_{Aeq,30s}$ (Across Trials)

## 3.1.3 TRACONs

### *3.1.3.1 Potomac TRACON*

**Facility Overview:** Potomac TRACON (PCT), located in Warrenton, VA is a level 12 consolidated facility built in circa 2002.

**Data Collection:** The site visit took place on April 24, 2025 from approximately 8:00 a.m. until 10:00 a.m. EST. Four 30-minute sound measurements were recorded from varying positions around the TRACON.

**Personnel:** During the visit, there were three individuals from the research team in the TRACON, in addition to the personnel staffing the facility.

**Environmental Factors:** The weather in the area was calm with light winds.

**Operational Information:** There were approximately 111 total operations during the visit. Notable sounds that were captured during the measurements included CAs, loudspeaker communications, landline phone ringing, a go-around chime, Low Altitude Alerts, flight data chimes, coordination chimes, and a Mode C Intruder Alert.

**Ambient Sound Measurements:** Table 18 shows the overall $L_{Aeq,30min}$ for PCT, calculated by energy-averaging the $L_{Aeq,30min}$ values from the four 30-minute trials at PCT. It also lists the maximum $L_{Aeq,30s}$ across all trials. Finally, the table lists the minimum auditory signal sound level required for the facility to comply with HFDS Section 5.5.2.8.3, and the calculations used to determine this value.

Table 18. PCT TRACON Auditory Signal Requirement Based on Sound Levels (B&K SLM)

| Facility Sound Measurements [dB(A)] | | Auditory Signal Calculations [dB(A)] | | HFDS Requirement [dB(A)] |
|---|---|---|---|---|
| Prevailing Ambient[a] | MAX w/ 30s Duration[b] | Prevailing Ambient + 10 | MAX w/ 30s Duration + 5 | MIN Auditory Signal Sound Level |
| 60.1 | 70.5 | 70.1 | 75.5 | **75** |

[a] $L_{Aeq,30min}$; Energy-Averaged Across Trials

[b] Maximum $L_{Aeq,30s}$ (Across Trials)

*3.1.3.2 Phoenix TRACON*

**Facility Overview:** Phoenix TRACON (P50), located in Phoenix, AZ is a level 11, consolidated facility built in circa 2013. P50 TRACON is approximately 3,000 square feet.

**Data Collection:** The site visit took place on May 21, 2025 from approximately 8:00 a.m. until 10:00 a.m. MST. Four 30-minute sound measurements were recorded from varying positions around the tower cab.

**Personnel:** During the visit, five individuals from the research team were present, in addition to the personnel working at the facility.

**Environmental Factors:** There was clear visibility outside the facility at the time of data collection.

**Operational Information:** In the positions where the sound level meters were placed from 8:00 a.m. until 9:00 a.m. MST, the traffic activity level was light to moderate for the facility, according to subjective feedback we received from the personnel escort (Trials 1 and 2). From 9:00 a.m. until 9:30 a.m. MST (Trial 3), the position where the sound level meters were placed had a moderate to busy traffic activity level. From 9:30 a.m. until 10:00 a.m. MST (Trial 4), the devices were placed in the Traffic Management Unit (TMU).

Notable sounds that were captured during the measurements included CAs, loudspeaker communications, and a coordination chime at the TMU.

**Ambient Sound Measurements:** Table 19 shows the overall $L_{Aeq,30min}$ for P50, calculated by energy-averaging the $L_{Aeq,30min}$ values from the four 30-minute trials at P50. It also lists the maximum $L_{Aeq,30s}$ across all trials. Finally, the table lists the minimum auditory signal sound level required for the facility to comply with HFDS Section 5.5.2.8.3, and the calculations used to determine this value.

Table 19. P50 TRACON Auditory Signal Requirement Based on Sound Levels (B&K SLM)

| Facility Sound Measurements [dB(A)] | | Auditory Signal Calculations [dB(A)] | | HFDS Requirement [dB(A)] |
|---|---|---|---|---|
| Prevailing Ambient[a] | MAX w/ 30s Duration[b] | Prevailing Ambient + 10 | MAX w/ 30s Duration + 5 | MIN Auditory Signal Sound Level |
| 60.7 | 66.9 | 70.7 | 71.9 | **72** |

[a] $L_{Aeq,30min}$; Energy-Averaged Across Trials

[b] Maximum $L_{Aeq,30s}$ (Across Trials)

#### *3.1.3.3 Tucson TRACON*

**Facility Overview:** Tucson TRACON (U90), located in Tucson, AZ, is a level 8 facility built in circa 1969.

**Data Collection:** The site visit took place on May 22, 2025 from approximately 8:00 a.m. until 9:30 a.m. MST. Three 30-minute sound measurements were recorded from varying positions around the tower cab.

**Personnel:** During the visit, there were five controllers in the room, including one supervisor and five individuals from the research team.

**Environmental Factors:** There was clear visibility outside the facility at the time of data collection.

**Operational Information:** There were approximately 40 total operations during the data collection period. Notable sounds that were captured during the measurements included landline phone ringing, CAs, loudspeaker communications, and a Lost Line Alert.

**Ambient Sound Measurements:** Table 20 shows the overall $L_{Aeq,30min}$ for U90, calculated by energy-averaging the $L_{Aeq,30min}$ values from the four 30-minute trials at U90. It also lists the maximum $L_{Aeq,30s}$ across all trials. Finally, the table lists the minimum auditory signal sound level required for the facility to comply with HFDS Section 5.5.2.8.3, and the calculations used to determine this value.

Table 20. U90 TRACON Auditory Signal Requirement Based on Sound Levels (B&K SLM)

| Facility Sound Measurements [dB(A)] | | Auditory Signal Calculations [dB(A)] | | HFDS Requirement [dB(A)] |
|---|---|---|---|---|
| Prevailing Ambient[a] | MAX w/ 30s Duration[b] | Prevailing Ambient + 10 | MAX w/ 30s Duration + 5 | MIN Auditory Signal Sound Level |
| 60.5 | 66.9 | 70.5 | 71.9 | **72** |

[a] $L_{Aeq,30min}$; Energy-Averaged Across Trials

[b] Maximum $L_{Aeq,30s}$ (Across Trials)

#### *3.1.3.4 Houston TRACON*

**Facility Overview:** Houston TRACON (I90), located in Houston, TX is a level 12 facility built in circa 2013. I90's TRACON was approximately 18 feet high.

**Data Collection:** The site visit took place on June 3, 2025, from approximately 12:00 p.m. until 1:30 p.m. CST. Three 30-minute sound measurements were recorded from varying positions around the TRACON.

**Personnel:** During the visit, there were eighteen controllers actively working positions, and there were four individuals from the research team present. The sound level meters were placed in the supervisor's location and the arrivals and departures sections of the TRACON.

**Environmental Factors:** There was clear visibility outside the facility at the time of data collection.

**Operational Information:** Notable sounds that were captured during the measurements included CAs and landline phone ringing.

**Ambient Sound Measurements:** Table 21 shows the overall $L_{Aeq,30min}$ for I90, calculated by energy-averaging the $L_{Aeq,30min}$ values from the three 30-minute trials at I90. It also lists the maximum $L_{Aeq,30s}$ across all trials. Finally, the table lists the minimum auditory signal sound level required for the facility to comply with HFDS Section 5.5.2.8.3, and the calculations used to determine this value.

Table 21. I90 TRACON Auditory Signal Requirement Based on Sound Levels (B&K SLM)

| Facility Sound Measurements [dB(A)] | | Auditory Signal Calculations [dB(A)] | | HFDS Requirement [dB(A)] |
|---|---|---|---|---|
| Prevailing Ambient[a] | MAX w/ 30s Duration[b] | Prevailing Ambient + 10 | MAX w/ 30s Duration + 5 | MIN Auditory Signal Sound Level |
| 61.4 | 68.4 | 71.4 | 73.4 | **73** |

[a] $L_{Aeq,30min}$; Energy-Averaged Across Trials

[b] Maximum $L_{Aeq,30s}$ (Across Trials)

## 3.1.4 ATCTs with TRACONs (up/down facilities)

### *3.1.4.1 Harrisburg International Tower/TRACON*

**Facility Overview:** Harrisburg International Tower and TRACON (MDT), located in Middletown, PA, is a level 7 facility built in circa 1989.

**Data Collection:** The site visit took place on March 26, 2025 from approximately 11:30 a.m. until 2:30 a.m. EST. The visit began in the TRACON, where three 30-minute measurements were recorded across varying positions. After these measurements were completed, three additional 30-minutes measurements were recorded from the tower.

#### 3.1.4.1.1 MDT ATCT

**Personnel:** During the visit, there were approximately three controllers working active positions, including one supervisor. The ATM was also present, in addition to four individuals from the research team.

**Environmental Factors:** There was clear visibility outside the tower at the time of data collection.

**Operational Information:** From 1:00 p.m. EST until 2:30 p.m. EST, there were approximately 8 total operations in the tower. Notable sounds that were captured during the measurements included a Low Altitude Alert, ASOS notifications, coordination chimes, and the sound of a train passing outside the tower.

**Ambient Sound Measurements:** Table 22 shows the overall $L_{Aeq,30min}$ for MDT ATCT, calculated by energy-averaging the $L_{Aeq,30min}$ values from the three 30-minute trials at MDT ATCT. It also lists the maximum $L_{Aeq,30s}$ across all trials. Finally, the table lists the minimum auditory signal sound level required for the facility to comply with HFDS Section 5.5.2.8.3, and the calculations used to determine this value.

Table 22 . MDT ATCT Auditory Signal Requirement Based on Sound Levels (B&K SLM)

| Facility Sound Measurements [dB(A)] | | Auditory Signal Calculations [dB(A)] | | HFDS Requirement [dB(A)] |
|---|---|---|---|---|
| Prevailing Ambient[a] | MAX w/ 30s Duration[b] | Prevailing Ambient + 10 | MAX w/ 30s Duration + 5 | MIN Auditory Signal Sound Level |
| 56.2 | 67.0 | 66.2 | 72.0 | **72** |

[a] $L_{Aeq,30min}$; Energy-Averaged Across Trials

[b] Maximum $L_{Aeq,30s}$ (Across Trials)

#### 3.1.4.1.2 MDT TRACON

**Personnel:** During the visit, there were up to 16 people in the room during position relief briefings, including four individuals from the research team. However, after all shift changes occurred, there were five controllers working active positions and four individuals from the research team in the room.

**Environmental Factors:** There was clear visibility at the time of data collection.

**Operational Information:** From 11:30 a.m. EST until 1:00 p.m. EST, there were approximately 57 total operations in the TRACON. Notable sounds that were captured during the measurements included the sound of flight progress strip plastic holders being periodically dropped into a bucket, landline phone ringing, and coordination chimes.

**Ambient Sound Measurements:** Table 23 shows the overall $L_{Aeq,30min}$ for MDT TRACON, calculated by energy-averaging the $L_{Aeq,30min}$ values from the three 30-minute trials at MDT TRACON. It also lists the maximum $L_{Aeq,30s}$ across all trials. Finally, the table lists the minimum auditory signal sound level required for the facility to comply with HFDS Section 5.5.2.8.3, and the calculations used to determine this value.

Table 23. MDT TRACON Auditory Signal Requirement Based on Sound Levels (B&K SLM)

| Facility Sound Measurements [dB(A)] | | Auditory Signal Calculations [dB(A)] | | HFDS Requirement [dB(A)] |
|---|---|---|---|---|
| Prevailing Ambient[a] | MAX w/ 30s Duration[b] | Prevailing Ambient + 10 | MAX w/ 30s Duration + 5 | MIN Auditory Signal Sound Level |
| 61.8 | 74.7 | 71.8 | 79.7 | **80** |

[a] $L_{Aeq,30min}$; Energy-Averaged Across Trials

[b] Maximum $L_{Aeq,30s}$ (Across Trials)

### *3.1.4.2 Allentown Tower/TRACON*

**Facility Overview:** Allentown Tower and TRACON (ABE), located in Allentown, PA is a level 7 facility built in circa 1995.

**Data Collection:** The site visit took place on March 26, 2025 from approximately 8:30 a.m. until 11:30 a.m. EST. The visit began in the TRACON, where three 30-minute measurements were recorded across varying positions. After these measurements were completed, three additional 30-minute measurements were recorded from the tower.

#### 3.1.4.2.1 ABE ATCT

**Personnel:** During the visit, there were two controllers working active positions. The ATM was also present, in addition to four individuals from the research team.

**Environmental Factors:** There was clear visibility outside the tower at the time of data collection.

**Operational Information:** From 10:00 a.m. EST until 11:30 a.m. EST, there were approximately 14 total operations in the tower. Notable sounds that were captured during the measurements included loudspeaker communications, ASOS notifications, coordination chimes, blinds lifting, the sound of a truck reversing outside the tower, and landline phone ringing.

**Ambient Sound Measurements:** Table 24 shows the overall $L_{Aeq,30min}$ for ABE ATCT, calculated by energy-averaging the $L_{Aeq,30min}$ values from the three 30-minute trials at ABE ATCT. It also lists the maximum $L_{Aeq,30s}$ across all trials. Finally, the table lists the minimum auditory signal sound level required for the facility to comply with HFDS Section 5.5.2.8.3, and the calculations used to determine this value.

Table 24. ABE ATCT Auditory Signal Requirement Based on Sound Levels (B&K SLM)

| Facility Sound Measurements [dB(A)] | | Auditory Signal Calculations [dB(A)] | | HFDS Requirement [dB(A)] |
|---|---|---|---|---|
| Prevailing Ambient[a] | MAX w/ 30s Duration[b] | Prevailing Ambient + 10 | MAX w/ 30s Duration + 5 | MIN Auditory Signal Sound Level |
| 56.0 | 66.4 | 66.0 | 71.4 | **71** |

[a] $L_{Aeq,30min}$; Energy-Averaged Across Trials

[b] Maximum $L_{Aeq,30s}$ (Across Trials)

#### 3.1.4.2.2 ABE TRACON

**Personnel:** During the visit, there were four controllers working active positions, including one supervisor. The ATM was also present, in addition to four individuals from the research team.

**Environmental Factors:** There was clear visibility at the time of data collection.

**Operational Information:** The traffic activity level during the visit was light to moderate for the facility, according to subjective feedback received from the personnel escort. Notable sounds that were captured during the measurements included coordination chimes, landline phone ringing, the sound of strips periodically landing in a bucket from the strip shoot, and loudspeaker communications.

**Ambient Sound Measurements:** Table 25 shows the overall $L_{Aeq,30min}$ for ABE TRACON, calculated by energy-averaging the $L_{Aeq,30min}$ values from the three 30-minute trials at ABE TRACON. It also lists the maximum $L_{Aeq,30s}$ across all trials. Finally, the table lists the minimum auditory signal sound level required for the facility to comply with HFDS Section 5.5.2.8.3, and the calculations used to determine this value.

Table 25. ABE TRACON Auditory Signal Requirement Based on Sound Levels (B&K SLM)

| Facility Sound Measurements [dB(A)] | | Auditory Signal Calculations [dB(A)] | | HFDS Requirement [dB(A)] |
|---|---|---|---|---|
| Prevailing Ambient[a] | MAX w/ 30s Duration[b] | Prevailing Ambient + 10 | MAX w/ 30s Duration + 5 | MIN Auditory Signal Sound Level |
| 58.1 | 64.4 | 68.1 | 69.4 | **69** |

[a] $L_{Aeq,30min}$; Energy-Averaged Across Trials

[b] Maximum $L_{Aeq,30s}$ (Across Trials)

#### *3.1.4.3 Philadelphia Tower/TRACON*

**Facility Overview:** Philadelphia Tower and TRACON (PHL), located in Philadelphia, PA, is a level 12 facility. The tower was built in circa 1981, and the TRACON was built in circa 1995.

**Data Collection:** The site visit took place on April 7, 2025 from approximately 10:00 a.m. until 1:00 p.m. EST. The visit began in the TRACON, where three 30-minute measurements were recorded across varying positions. After, three additional measurements were taken in the control tower from various positions. Of note, the Philadelphia ATCT and TRACON are close to each other but are not located within the same building.

##### 3.1.4.3.1 PHL ATCT

**Personnel:** During the visit, there were approximately 112 total operations. There were five controllers in the tower cab, including one supervisor and four individuals from the research team.

**Environmental Factors:** There were rainy weather conditions outside the tower at the time of data collection.

**Operational Information:** Notable sounds that were captured during the measurements included the sound of strips being periodically dropped into a bucket, Low-Level Windshear Alert System (LLWAS) alerts, ASDE-X notifications, coordination chimes, RVR alarms, and sounds from the blinds being lifted and lowered.

**Ambient Sound Measurements:** Table 26 shows the overall $L_{Aeq,30min}$ for PHL ATCT, calculated by energy-averaging the $L_{Aeq,30min}$ values from the three 30-minute trials at PHL ATCT. It also lists the maximum $L_{Aeq,30s}$ across all trials. Finally, the table lists the minimum auditory signal sound level required for the facility to comply with HFDS Section 5.5.2.8.3, and the calculations used to determine this value.

Table 26. PHL ATCT Auditory Signal Requirement Based on Sound Levels (B&K SLM)

| Facility Sound Measurements [dB(A)] | | Auditory Signal Calculations [dB(A)] | | HFDS Requirement [dB(A)] |
|---|---|---|---|---|
| Prevailing Ambient[a] | MAX w/ 30s Duration[b] | Prevailing Ambient + 10 | MAX w/ 30s Duration + 5 | MIN Auditory Signal Sound Level |
| 62.5 | 73.3 | 72.5 | 78.3 | **78** |

[a] $L_{Aeq,30min}$; Energy-Averaged Across Trials

[b] Maximum $L_{Aeq,30s}$ (Across Trials)

#### 3.1.4.3.2 PHL TRACON

**Personnel:** During the visit, there were thirteen controllers and four individuals from the research team present.

**Environmental Factors:** There were rainy weather conditions at the time of data collection.

**Operational Information:** The workflow ongoing in the TRACON during the time of the visit was split into three distinct areas. An area off to the left upon entry was dedicated to the TMU, while the main floor was split between two sectors controlling PHL airspace and Newark, NJ (EWR) airspace.

Notable sounds that were captured during the measurements included loudspeaker communications, CAs, landline phone ringing, coordination chimes, and the sound of flight progress strip plastic holders being periodically dropped into a bucket.

**Ambient Sound Measurements:** Table 27 shows the overall $L_{Aeq,30min}$ for PHL TRACON, calculated by energy-averaging the $L_{Aeq,30min}$ values from the three 30-minute trials at PHL

TRACON. It also lists the maximum $L_{Aeq,30s}$ across all trials. Finally, the table lists the minimum auditory signal sound level required for the facility to comply with HFDS Section 5.5.2.8.3, and the calculations used to determine this value.

Table 27. PHL TRACON Auditory Signal Requirement Based on Sound Levels (B&K SLM)

| Facility Sound Measurements [dB(A)] | | Auditory Signal Calculations [dB(A)] | | HFDS Requirement [dB(A)] |
|---|---|---|---|---|
| Prevailing Ambient[a] | MAX w/ 30s Duration[b] | Prevailing Ambient + 10 | MAX w/ 30s Duration + 5 | MIN Auditory Signal Sound Level |
| 59.6 | 70.3 | 69.6 | 75.3 | **75** |

[a] $L_{Aeq,30min}$; Energy-Averaged Across Trials

[b] Maximum $L_{Aeq,30s}$ (Across Trials)

#### *3.1.4.4 Miami Tower/TRACON*

**Facility Overview:** Miami Tower and TRACON (MIA), located in Miami, FL, is a level 12 facility built in circa 2002.

**Data Collection:** The site visit took place on June 10, 2025, from approximately 11:00 AM until 1:00 PM EST. The visit began at the TRACON, where two 30-minute measurements were recorded across varying positions. After, two additional measurements were taken in the control tower from various positions.

##### 3.1.4.4.1 MIA ATCT

**Personnel:** During the visit, there were seven controllers in the cab, including one supervisor and three individuals from the research team.

**Environmental Factors:** There was clear visibility outside the tower at the time of data collection.

**Operational Information:** The traffic activity level during the visit was light to moderate for the facility, according to subjective feedback we received from the personnel escort. Notable sounds that were captured during the measurements included CAs, landline phone ringing, sounds from aircraft taking off and landing outside the tower, and a humming sound from strip lights on the ceiling that continued for the duration of the visit.

**Ambient Sound Measurements:** Table 28 shows the overall $L_{Aeq,30min}$ for MIA ATCT, calculated by energy-averaging the $L_{Aeq,30min}$ values from the two 30-minute trials at MIA ATCT. It also lists the maximum $L_{Aeq,30s}$ across all trials. Finally, the table lists the minimum auditory

signal sound level required for the facility to comply with HFDS Section 5.5.2.8.3, and the calculations used to determine this value.

Table 28. MIA ATCT Auditory Signal Requirement Based on Sound Levels (B&K SLM)

| Facility Sound Measurements [dB(A)] | | Auditory Signal Calculations [dB(A)] | | HFDS Requirement [dB(A)] |
|---|---|---|---|---|
| Prevailing Ambient[a] | MAX w/ 30s Duration[b] | Prevailing Ambient + 10 | MAX w/ 30s Duration + 5 | MIN Auditory Signal Sound Level |
| 61.1 | 69.0 | 71.1 | 74.0 | **74** |

[a] $L_{Aeq,30min}$; Energy-Averaged Across Trials

[b] Maximum $L_{Aeq,30s}$ (Across Trials)

#### 3.1.4.4.2 MIA TRACON

**Personnel:** During the visit, there were 12 personnel in the room, and there were three individuals from the research team present.

**Environmental Factors:** There was clear visibility at the time of data collection.

**Operational Information:** Notable sounds that were captured during the measurements included CAs, LLWAS alerts, loudspeaker communications, and landline phone ringing.

**Ambient Sound Measurements:** Table 29 shows the overall $L_{Aeq,30min}$ for MIA TRACON, calculated by energy-averaging the $L_{Aeq,30min}$ values from the two, 30-minute trials at MIA TRACON. It also lists the maximum $L_{Aeq,30s}$ across all trials. Finally, the table lists the minimum auditory signal sound level required for the facility to comply with HFDS Section 5.5.2.8.3, and the calculations used to determine this value.

Table 29. MIA TRACON Auditory Signal Requirement Based on Sound Levels (B&K SLM)

| Facility Sound Measurements [dB(A)] | | Auditory Signal Calculations [dB(A)] | | HFDS Requirement [dB(A)] |
|---|---|---|---|---|
| Prevailing Ambient[a] | MAX w/ 30s Duration[b] | Prevailing Ambient + 10 | MAX w/ 30s Duration + 5 | MIN Auditory Signal Sound Level |
| 62.2 | 67.7 | 72.2 | 72.7 | **73** |

[a] $L_{Aeq,30min}$; Energy-Averaged Across Trials

[b] Maximum $L_{Aeq,30s}$ (Across Trials)

#### *3.1.4.5 West Palm Beach Tower/TRACON*

**Facility Overview:** West Palm Beach Tower and TRACON (PBI), located in West Palm Beach, FL, is a level 9 facility. The tower construction was completed in circa 2011. The addition of the TRACON onto the existing structure was completed in circa 2016.

**Data Collection:** The site visit took place on June 12, 2025 from approximately 8:00 a.m. until 10:00 a.m. EST. The visit began in the tower, where two 30-minute measurements were recorded across varying positions. After, two additional measurements were taken in the TRACON from various positions.

##### 3.1.4.5.1 PBI ATCT

**Personnel:** During the visit, there were three controllers in the cab, including one supervisor and two individuals from the research team.

**Environmental Factors:** There was clear visibility outside the tower during the time of data collection.

**Operational Information:** The traffic activity level during the visit was light for the facility, according to subjective feedback we received from the personnel escort. Notable sounds that were captured during the measurements included CAs, loudspeaker communications, coordination chimes, Low Altitude Alerts, and landline phone ringing.

**Ambient Sound Measurements:** Table 30 shows the overall $L_{Aeq,30min}$ for PBI ATCT, calculated by energy-averaging the $L_{Aeq,30min}$ values from the two 30-minute trials at PBI ATCT. It also lists the maximum $L_{Aeq,30s}$ across all trials. Finally, the table lists the minimum auditory signal sound level required for the facility to comply with HFDS Section 5.5.2.8.3, and the calculations used to determine this value.

Table 30. PBI ATCT Auditory Signal Requirement Based on Sound Levels (B&K SLM)

| Facility Sound Measurements [dB(A)] | | Auditory Signal Calculations [dB(A)] | | HFDS Requirement [dB(A)] |
|---|---|---|---|---|
| Prevailing Ambient[a] | MAX w/ 30s Duration[b] | Prevailing Ambient + 10 | MAX w/ 30s Duration + 5 | MIN Auditory Signal Sound Level |
| 60.5 | 68.5 | 70.5 | 73.5 | **74** |

[a] $L_{Aeq,30min}$; Energy-Averaged Across Trials

[b] Maximum $L_{Aeq,30s}$ (Across Trials)

#### 3.1.4.5.2 PBI TRACON

**Personnel:** During the visit, there were five controllers working, including one supervisor and three individuals from the research team.

**Environmental Factors:** There was clear visibility at the time of data collection.

**Operational Information:** The traffic activity level during the visit was light to moderate for the facility, based on subjective feedback we received from the personnel escort. Notable sounds that were captured during the measurements included CAs, landline phone ringing, an Instrument Landing System (ILS) alarm, and loudspeaker communications.

**Ambient Sound Measurements:** Table 31 shows the overall $L_{Aeq,30min}$ for PBI TRACON, calculated by energy-averaging the $L_{Aeq,30min}$ values from the two 30-minute trials at PBI TRACON. It also lists the maximum $L_{Aeq,30s}$ across all trials. Finally, the table lists the minimum auditory signal sound level required for the facility to comply with HFDS Section 5.5.2.8.3, and the calculations used to determine this value.

Table 31. PBI TRACON Auditory Signal Requirement Based on Sound Levels (B&K SLM)

| Facility Sound Measurements [dB(A)] | | Auditory Signal Calculations [dB(A)] | | HFDS Requirement [dB(A)] |
|---|---|---|---|---|
| Prevailing Ambient[a] | MAX w/ 30s Duration[b] | Prevailing Ambient + 10 | MAX w/ 30s Duration + 5 | MIN Auditory Signal Sound Level |
| 59.4 | 67.4 | 69.4 | 72.4 | **72** |

[a] $L_{Aeq,30min}$; Energy-Averaged Across Trials

[b] Maximum $L_{Aeq,30s}$ (Across Trials)

## 3.1.5 ARTCCs

### *3.1.5.1 Washington Center*

**Facility Overview:** Washington ARTCC (ZDC), located in Leesburg, VA, is a level 12 facility built in circa 1964.

**Data Collection:** The site visit took place on April 23, 2025 from approximately 10:00 a.m. until 12:00 p.m. EST. Four 30-minute sound measurements were recorded from various positions around the center's TMU and Operational Area.

**Personnel:** During the visit, there were four individuals from the research team present in addition to the personnel working the center's operations.

**Operational Information:** The traffic activity level during the visit ranged from light to moderate to busy for the facility, according to subjective feedback we received from the personnel escort. The area that was observed during trial two had moderate to busy traffic; the area observed during trial three had light traffic; and the area observed during trial four had moderate traffic. Notable sounds that were captured during the measurements included loudspeaker communications and landline phone ringing.

**Ambient Sound Measurements:** Table 32 shows the overall $L_{Aeq,30min}$ for ZDC, calculated by energy-averaging the $L_{Aeq,30min}$ values from the four 30-minute trials at ZDC ARTCC. It also lists the maximum $L_{Aeq,30s}$ across all trials. Finally, the table lists the minimum auditory signal sound level required for the facility to comply with HFDS Section 5.5.2.8.3, and the calculations used to determine this value.

Table 32. ZDC ARTCC Auditory Signal Requirement Based on Sound Levels (B&K SLM)

| Facility Sound Measurements [dB(A)] | | Auditory Signal Calculations [dB(A)] | | HFDS Requirement [dB(A)] |
|---|---|---|---|---|
| Prevailing Ambient[a] | MAX w/ 30s Duration[b] | Prevailing Ambient + 10 | MAX w/ 30s Duration + 5 | MIN Auditory Signal Sound Level |
| 61.2 | 68.6 | 71.2 | 73.6 | **74** |

[a] $L_{Aeq,30min}$; Energy-Averaged Across Trials

[b] Maximum $L_{Aeq,30s}$ (Across Trials)

#### *3.1.5.2 Houston Center*

**Facility Overview:** Houston ARTCC (ZHU), located in Houston, TX, is a level 11 facility built in circa 1965.

**Data Collection:** The site visit took place on June 3, 2025, from approximately 2:00 p.m. until 3:30 p.m. CST. Three 30-minute sound measurements were recorded from varying positions around the center's Operational Area.

**Personnel:** During the visit, there were three individuals from the research team in addition to the personnel working the center’s operations.

**Operational Information:** The traffic activity level during the visit was moderate to busy for the facility, according to subjective feedback we received from the personnel escort. Notable sounds captured during the measurements included loudspeaker communications and landline phone ringing.

**Ambient Sound Measurements:** Table 33 shows the overall $L_{Aeq,30min}$ for ZHU, calculated by energy-averaging the $L_{Aeq,30min}$ values from the three 30-minute trials at ZHU's ARTCC. It also lists the maximum $L_{Aeq,30s}$ across all trials. Finally, the table lists the minimum auditory signal sound level required for the facility to comply with HFDS Section 5.5.2.8.3, and the calculations used to determine this value.

Table 33. ZHU ARTCC Auditory Signal Requirement Based on Sound Levels (B&K SLM)

| Facility Sound Measurements [dB(A)] | | Auditory Signal Calculations [dB(A)] | | HFDS Requirement [dB(A)] |
|---|---|---|---|---|
| Prevailing Ambient[a] | MAX w/ 30s Duration[b] | Prevailing Ambient + 10 | MAX w/ 30s Duration + 5 | MIN Auditory Signal Sound Level |
| 68.0 | 77.1 | 78.0 | 82.1 | **82** |

[a] $L_{Aeq,30min}$; Energy-Averaged Across Trials

[b] Maximum $L_{Aeq,30s}$ (Across Trials)

### *3.1.5.3 Miami Center*

**Facility Overview:** Miami ARTCC (ZMA), located in Miami, FL, is a level 11 facility built in circa 1957.

**Data Collection:** The site visit took place on June 10, 2025, from approximately 8:00 a.m. until 10:00 a.m. EST. Four 30-minute sound measurements were recorded from varying positions around the center's Operational Area and TMU.

**Personnel:** During the visit, there were three individuals from the research team present in addition to the personnel working the center's operations.

**Operational Information:** The traffic activity level during the visit was light to moderate for the facility, based on subjective feedback we received from the personnel escort. Notable sounds that were captured during the measurements included loudspeaker communications and landline phone ringing.

**Ambient Sound Measurements:** Table 34 shows the overall $L_{Aeq,30min}$ for ZMA, calculated by energy-averaging the $L_{Aeq,30min}$ values from the four 30-minute trials. It also lists the maximum $L_{Aeq,30s}$ across all trials. Finally, the table lists the minimum auditory signal sound level required for the facility to comply with HFDS Section 5.5.2.8.3, and the calculations used to determine this value.

Table 34. ZMA ARTCC Auditory Signal Requirement Based on Sound Levels (B&K SLM)

| Facility Sound Measurements [dB(A)] | | Auditory Signal Calculations [dB(A)] | | HFDS Requirement [dB(A)] |
|---|---|---|---|---|
| Prevailing Ambient[a] | MAX w/ 30s Duration[b] | Prevailing Ambient + 10 | MAX w/ 30s Duration + 5 | MIN Auditory Signal Sound Level |
| 61.1 | 68.8 | 71.1 | 73.8 | **74** |

[a] $L_{Aeq,30min}$; Energy-Averaged Across Trials

[b] Maximum $L_{Aeq,30s}$ (Across Trials)

## 3.2 Results – NIOSH SLM Application

In parallel to the Brüel & Kjær 2245 SLM measurements, ambient sound levels were also measured at each facility with the iPhone NIOSH SLM app. The measurements between the two devices were compared to understand smartphone application utility as an alternative to professional equipment for measuring sound levels in ATC facilities, as smartphone apps are more cost-effective and easier to transport than more costly professional SLMs. The sound measurements captured by the NIOSH SLM app were not used to determine the minimum auditory signal level to comply with HFDS Section 5.5.2.8.3. Only the Brüel & Kjær 2245 professional SLM measurements were used to determine sound levels for compliance with this requirement. Rather, the measurements collected using the NIOSH SLM app were compared to the $L_{Aeq,30min}$ and $L_{ASmax,30min}$ captured with the Brüel & Kjær 2245 professional SLM to evaluate the differences.

Like the Brüel & Kjær 2245 SLM, the NIOSH SLM app generated several values for each 30-minute interval. However, the 30-minute measurement duration was approximate, as the application could not set automatic duration end-times like the Brüel & Kjær SLM. Instead, the researchers kept track of time and manually pressed stop as close to the 30-minute time mark as possible. Despite minor differences in trial duration with the NIOSH SLM app, no additional duration-weighting was applied during the energy-averaging calculation to ensure that all trials were equally considered and to be consistent with the calculations conducted for the Brüel & Kjær 2245 professional SLM values. Each trial was conducted at a different location around the facility, so any additional duration-weighting could have inappropriately overrepresented one location. Across all locations, 100 individual recordings were captured. The researchers were able to stop the recording on the NIOSH SLM app within seconds of the Brüel & Kjær SLM in most instances. However, since the recordings were captured in an operational environment, there were some trials where the researcher could not access the device to end the recording at the 30-minute stop time and instead had to wait several moments to access the device. For Table

35, which compared the differences in measurements between the two devices, we excluded any individual trials where the NIOSH SLM app recording exceeded the Brüel & Kjær SLM recording by one minute or more (11 out of 100 trials). We retained these trials in all other appendices that contain NIOSH SLM app measurements (Appendix C, E), since the other appendices do not directly compare the NIOSH SLM app measurements with the Brüel & Kjær 2245 SLM measurements. All other trials' measurement lengths were within ±1 minute of each other and were included in all relevant tables and appendices.

Additionally, while the external microphone (MicW, n.d.) used with the NIOSH SLM app was calibrated at the factory before being shipped for data collection and complied with the IEC 61672 Class 2 SLM standard (International Electrotechnical Commission, 2013), additional calibrations were not performed during data collection. The NIOSH SLM app manual recommends that the app be calibrated before and after every measurement (Centers for Disease Control and Prevention, 2024). Thus, differences between measurements may be due to the lack of additional calibration before measurements. Future research should compare the performance between devices with proper calibration procedures in place, as recommended by the NIOSH SLM app manual.

Table 35 reports the energy-averaged $L_{Aeq,30min}$ across trials and the $L_{ASmax,30min}$ across trials measured by the Brüel & Kjær 2245 SLM and the NIOSH SLM app. The differences between the device measurements are also reported. $L_{AFmax}$ was not collected because only one FAA iPhone was available for data collection, and the NIOSH SLM app functionalities only allow one filter selection per measurement.

Table 35. NIOSH SLM APP compared to Brüel & Kjær 2245 SLM

| Facility Type | Facility Name | Number of Trials | $L_{Aeq}$[a] [dB(A)] | | $L_{ASmax}$[b] [dB(A)] | | Difference Between SLMs (NIOSH SLM - B&K SLM) [dB] | |
|---|---|---|---|---|---|---|---|---|
| | | | NIOSH SLM APP | Brüel & Kjær 2245 SLM | NIOSH SLM APP | Brüel & Kjær 2245 SLM | LAeq | LASmax |
| ATCT | Washington National Tower (DCA) | 4 | 67.0 | 66.4 | 99.6 | 89.8 | 0.7 | 9.8 |
| ATCT | Deer Valley Tower (DVT) | 3 | 61.1 | 60.7 | 85.0 | 77.8 | 0.4 | 7.2 |
| ATCT | Houston Hooks Tower (DWH) | 3 | 65.5 | 65.1 | 95.6 | 88.2 | 0.4 | 7.4 |
| ATCT | Falcon Tower (FFZ) | 3 | 65.1 | 64.1 | 97.0 | 89.6 | 1.0 | 7.4 |
| ATCT | Fort Lauderdale Tower (FLL) | 3 | 59.2 | 58.7 | 91.1 | 82.7 | 0.5 | 8.4 |
| ATCT | Fort Lauderdale Executive Tower (FXE) | 2[c] | 60.5 | 59.8 | 88.8 | 81.7 | 0.7 | 7.1 |
| ATCT | Hobby Tower (HOU) | 3 | 62.8 | 62.1 | 91.9 | 82.6 | 0.7 | 9.3 |

| Facility Type | Facility Name | Number of Trials | $L_{Aeq}$[a] [dB(A)] | | $L_{ASmax}$[b] [dB(A)] | | Difference Between SLMs (NIOSH SLM - B&K SLM) [dB] | |
|---|---|---|---|---|---|---|---|---|
| | | | NIOSH SLM APP | Brüel & Kjær 2245 SLM | NIOSH SLM APP | Brüel & Kjær 2245 SLM | LAeq | LASmax |
| ATCT | Houston Intercontinental Tower (IAH) | 3 | 64.4 | 62.9 | 95.0 | 83.0 | 1.5 | 12.0 |
| ATCT | Wilmington Tower (ILG) | 3 | 68.6 | 58.1 | 101.0 | 85.6 | 10.4 | 15.4 |
| ATCT | Northeast Philadelphia Tower (PNE) | 2[c] | 62.1 | 61.2 | 83.9 | 78.1 | 0.9 | 5.8 |
| ATCT | Scottsdale Tower (SDL) | 2[c] | 62.0 | 61.9 | 86.4 | 78.0 | 0.04 | 8.4 |
| ATCT | Tamiami Tower (TMB) | 2[c] | 64.5 | 62.9 | 96.6 | 86.3 | 1.52 | 10.4 |
| ATCT | Trenton Mercer Tower (TTN) | 4 | 59.4 | 57.5 | 83.4 | 74.8 | 2.0 | 8.6 |
| ATCT | Tucson Tower (TUS) | 3 | 56.7 | 56.6 | 82.5 | 75.8 | 0.1 | 6.7 |
| ATCT | Vero Beach Tower (VRB) | 3 | 59.3 | 59.0 | 90.2 | 83.5 | 0.4 | 6.7 |

| Facility Type | Facility Name | Number of Trials | $L_{Aeq}$[a] [dB(A)] | | $L_{ASmax}$[b] [dB(A)] | | Difference Between SLMs (NIOSH SLM - B&K SLM) [dB] | |
|---|---|---|---|---|---|---|---|---|
| | | | NIOSH SLM APP | Brüel & Kjær 2245 SLM | NIOSH SLM APP | Brüel & Kjær 2245 SLM | LAeq | LASmax |
| TRACON | Houston TRACON (I90) | 3 | 62.1 | 61.4 | 82.6 | 75.3 | 0.8 | 7.3 |
| TRACON | Pheonix TRACON (P50) | 3[c] | 61.4 | 61.1 | 84.7 | 78.3 | 0.3 | 6.4 |
| TRACON | Potomac TRACON (PCT) | 4 | 60.6 | 60.1 | 85.1 | 78.2 | 0.6 | 6.9 |
| TRACON | Tucson TRACON (U90) | 3 | 60.9 | 60.5 | 86.3 | 77.8 | 0.4 | 8.5 |
| ATCT with TRACON | Allentown Tower (ABE) | 2[c] | 56.9 | 56.7 | 88.0 | 79.9 | 0.2 | 8.1 |
| | Allentown TRACON (ABE) | 2[c] | 58.9 | 58.2 | 85.7 | 77.2 | 0.7 | 8.5 |
| ATCT with TRACON | Atlantic City Tower (ACY) | 1 | 57.7 | 57.9 | 77.2 | 73.4 | -0.2 | 3.8 |
| | Atlantic City TRACON (ACY) | 0[c] | - | - | - | - | N/A | N/A |

| Facility Type | Facility Name | Number of Trials | $L_{Aeq}$[a] [dB(A)] | | $L_{ASmax}$[b] [dB(A)] | | Difference Between SLMs (NIOSH SLM - B&K SLM) [dB] | |
|---|---|---|---|---|---|---|---|---|
| | | | NIOSH SLM APP | Brüel & Kjær 2245 SLM | NIOSH SLM APP | Brüel & Kjær 2245 SLM | LAeq | LASmax |
| ATCT with TRACON | Harrisburg International Tower (MDT) | 3 | 57.1 | 56.2 | 88.2 | 79.8 | 0.9 | 8.4 |
| | Harrisburg International TRACON (MDT) | 3 | 63.0 | 61.8 | 93.1 | 87.9 | 1.2 | 5.2 |
| ATCT with TRACON | Miami Tower (MIA) | 2 | 61.7 | 61.1 | 93.2 | 79.6 | 0.6 | 13.6 |
| | Miami TRACON (MIA) | 2 | 62.7 | 62.2 | 81.4 | 74.3 | 0.5 | 7.2 |
| ATCT with TRACON | West Palm Beach Tower (PBI) | 2 | 61.7 | 60.5 | 84.3 | 77.5 | 1.2 | 6.8 |
| | West Palm Beach TRACON (PBI) | 2 | 60.3 | 59.4 | 89.8 | 79.9 | 0.8 | 9.9 |
| ATCT with TRACON | Philadelphia Tower (PHL) | 2[c] | 64.1 | 62.6 | 91.9 | 85.6 | 1.5 | 6.3 |
| | Philadelphia TRACON (PHL) | 2[c] | 61.3 | 60.0 | 88.9 | 78.2 | 1.3 | 10.7 |

| Facility Type | Facility Name | Number of Trials | $L_{Aeq}$[a] [dB(A)] | | $L_{ASmax}$[b] [dB(A)] | | Difference Between SLMs (NIOSH SLM - B&K SLM) [dB] | |
|---|---|---|---|---|---|---|---|---|
| | | | NIOSH SLM APP | Brüel & Kjær 2245 SLM | NIOSH SLM APP | Brüel & Kjær 2245 SLM | LAeq | LASmax |
| ARTCC | Washington Center (ZDC) | 3[c] | 62.3 | 61.9 | 81.0 | 75.0 | 0.4 | 6.0 |
| ARTCC | Houston Center (ZHU) | 3 | 66.9 | 68.0 | 96.7 | 83.7 | -1.0 | 13.0 |
| ARTCC | Miami Center (ZMA) | 4 | 61.6 | 61.1 | 84.8 | 76.6 | 0.5 | 8.2 |

*Note.* "-" indicates that no measurements are reported. N/A indicates that the differences were not calculated because no trial measurements are reported.

[a] $L_{aeq,30min}$; Energy-Averaged Across Trials

[b] $L_{ASmax,30min}$; Maximum A-weighted sound level, slow time weighting (1s) (Across Trials)

[c] One trial excluded from comparison due to recording length variation exceeding one minute between devices

# 4 Discussion

## 4.1 Overview

High ambient sound levels create potential for distracting workplace environments (Cluff & McAnulty, 2011) and can impact the perception of auditory signals, a particular concern in safety critical settings (Hah, Allendoerfer, & Novak, 2008; van der Hoek-Snieders, Houben, & Dreschler, 2021). It is essential to consider ambient sound levels in the design of ATC auditory signals to ensure that signals are clearly audible. The FAA's HFDS (Ahlstrom, 2016) established auditory requirements for ATC auditory signals that address these considerations. This information is intended to be a resource for acquisition programs responsible for the design of auditory signals. In Section 5.5.2.8.3, the standard states:

> Auditory signals shall exceed the prevailing ambient sound level by at least 10 dB(A) or any maximum sound level with a duration of 30 seconds by at least 5 dB(A), whichever is louder, without exceeding 115 dB(A) for emergency signals or 90 dB(A) for other signals [Source: MIL-STD-1472G, 2012; NUREG-0700, 1981]" (Ahlstrom, 2016, p. 257).

This standard provides auditory requirements for how loud auditory signals should be compared to the surrounding ambient sound level to ensure adequate detection. However, no reference information exists that compiles typical ambient sound levels in various ATC environments. The goal of this project was to capture baseline ambient sound measurements across a representative sample of ATC facilities and compile several comprehensive reference tables that list this information.

Separately, this project also evaluated the utility of using a smartphone SLM app with an external microphone to conduct ambient sound measurements in ATC facilities for research purposes in lieu of a professional sound level meter. Professional SLMs are expensive and require training to operate. Further, they generate additional expenses when used as a data collection tool, since trained personnel must travel to the desired location to operate the device. Using a smartphone app to conduct sound measurements instead of a professional device would allow for easier and more cost-effective methods of obtaining sound measurements from ATC facilities. Previous research has provided evidence that some smartphone applications may provide accurate sound measurements when the device is paired with an external calibrated microphone (Kardous & Shaw, 2016). While they are not a replacement for professional devices or an adequate tool for compliance testing purposes, prior research suggests that smartphone

SLM apps, when paired with an external microphone, are a reliable tool to capture sound levels in an environment (Centers for Disease Control and Prevention, 2024). The current project used the NIOSH Sound Level Meter iOS app with an external microphone and the professional Brüel & Kjær 2245 SLM to measure ambient sound levels in ATC facilities.

## 4.2 Primary findings

From February 2025 through June 2025, we captured ambient sound measurements at 28 ATC facilities around the United States, including ATCTs, TRACONs, and ARTCCs. At each facility, we captured several 30-minute-long sound measurements from various locations around the facility's operational area using the professional Brüel & Kjær 2245 SLM and the iPhone NIOSH SLM app. For the Brüel & Kjær 2245 SLM, we reported the energy-averaged $L_{Aeq,30min}$ across all trials, the maximum $L_{Aeq,30s}$, and the minimum auditory signal sound level necessary to comply with the HFDS Section 5.5.2.8.3 requirement for each facility. We reported the results of the facility visits in text and compiled them in comprehensive reference tables (Appendix B, D) that list facility information and additional sound level measurements provided for further detail. Of note, facilities vary considerably in their sound and activity level based on numerous factors, including but not limited to the traffic level and construction materials used for the building. Therefore, while this report provides general baseline information about typical ambient sound levels in ATC facilities, sound measurements will vary per facility.

For the iPhone NIOSH SLM app, we reported the energy-averaged $L_{Aeq}$ across all trials, the maximum $L_{ASmax}$ across all trials, and the measurement differences between the iPhone NIOSH SLM app and the Brüel & Kjær 2245 SLM $L_{ASmax}$ per facility (Table 35). We also reported these sound measurements, along with additional descriptive statistics, in Appendix C and E. The data obtained from the NIOSH SLM app was accurate within ±2 dB(A) to the professional Brüel & Kjær 2245 sound level meter's measurements when calculating the $L_{Aeq}$ across each 30-minute measurement for all facility measurements but one (ILG). The energy-averaged $L_{Aeq}$ measured by the NIOSH SLM app at ILG was 10.4 dB higher than the energy-averaged $L_{Aeq}$ measurement captured from the professional Brüel & Kjær 2245 SLM. It is unclear why there were such extreme differences between the sound level meters' $L_{Aeq}$ metrics at this facility. However, all the other NIOSH SLM app facility sound measurements ($L_{Aeq}$) were consistent with the Brüel & Kjær 2245 SLM within ±2 dB(A). However, the $L_{ASmax}$ values captured from the NIOSH SLM app ranged from 3.8 to 15.4 dB louder than the values obtained by the professional Brüel & Kjær 2245 SLM.

Prior research from NIOSH indicated that when properly calibrated, the NIOSH SLM app is accurate within ±2 dB(A) compared to other sound measuring applications (Centers for Disease Control and Prevention, 2024). The external microphone (MicW, n.d.) used with the NIOSH SLM app was professionally calibrated at the factory before being shipped for data collection and complied with the IEC 61672 Class 2 SLM standard (International Electrotechnical Commission, 2013). However, additional calibrations were not performed during data collection. Since the NIOSH SLM app manual recommends that calibrations be conducted before and after each measurement (Centers for Disease Control and Prevention, 2024), the lack of calibrations for the current project is likely a factor in the discrepancies between $L_{ASmax}$ measurements between the two devices and for the discrepancy in $L_{Aeq}$ measurements between the devices at ILG.

Despite not performing additional calibrations before and after each trial, our measurements showed accurate measurements within ±2 dB(A) for the $L_{Aeq}$ values at all facilities except for one, compared to the measurements captured by the professional Brüel & Kjær 2245 SLM. Thus, although we used only one app, the data suggests that when paired with an external microphone, smartphone SLM applications may be mostly dependable tools to measure A-weighted equivalent continuous sound levels over time in ATC facilities. However, users should be cautioned that they must perform calibrations before and after each measurement to obtain accurate $L_{ASmax}$ measurements.

## 4.3 Limitations and future research

This project had several limitations. Most notably, we sampled a small number of ATC facilities across the United States. While we made every effort to collect sound measurements from a representative sample of facilities, the sample size itself was small compared to the large number of ATC facilities in the United States. Additionally, it was not possible to control for several variables that likely impacted sound perception during the data collection periods. For instance, it was not feasible to schedule facility visits to control for weather conditions, hourly traffic activity level predictions, or specific staffing numbers. Instead, we created the most practical travel schedule based on available time and resources and documented potentially influential variables at the time of data collection. We coordinated with escorts at each facility to understand the perceived traffic activity level at the time of the visit, in addition to collecting objective traffic activity data when possible. The perceived activity levels were based on the personnel escort's knowledge of the facility traffic trends. However, this information was inherently subjective input and presents a limitation for this project. Further, the SLM placement location for each 30-minute measurement trial varied per facility to ensure no interference with

operations. The placement of the SLM trials was based upon constraints related to the variability of layouts and staffing set-ups at each facility. Additionally, the NIOSH SLM app did not allow for preset durations like the Brüel & Kjær 2245 SLM. Therefore, while the research team stopped each trial on the NIOSH SLM app as close as possible to the 30-minute mark, there were slight time differences between devices. This limitation mostly impacts the reporting of the $L_{ASmax}$ measurements, since the $L_{Aeq}$ measurements are an energy-average over the full-time duration and are thus less impacted by slight variation. However, the $L_{ASmax}$ measurement is a single one-second sound level, making it more susceptible to variation in reporting the overall $L_{ASmax}$ differences between devices when the measurement times are even slightly different, if the maximum sound level occurred during the delta. To help address this factor, we only retained trials that were within ±1 minute in length of each other for Table 35, which directly compared measurements between the devices. However, future research should ensure that the time durations are exact between the two devices.

Future research should also seek to capture ambient sound measurements from additional ATC facilities to bolster the current sample. Additionally, to the extent possible, future efforts should control for variables that may impact ambient sound including the expected hourly traffic activity. Future research to understand the most prevalent sounds that contribute to high ambient sound levels may provide insight regarding mitigations to limit their impact on auditory signal perception and general operations. Future research should also examine the frequencies of all ATC auditory signals to confirm all signals fall within an acceptable threshold for human perception.

Further, efforts should be taken to clarify the language in the HFDS Section 5.5.2.8.3 requirement. The requirement should specify the acoustic metric to measure "prevailing ambient noise level" (Ahlstrom, 2016, p. 237). For this report, we used $L_{Aeq,30min}$ to measure prevailing ambient sound levels. Additionally, the requirement should specify the acoustic metric to measure "any maximum sound level with a duration of 30 seconds" (Ahlstrom, 2016, p. 237). This statement is ambiguous because "maximum sound level" typically refers to a short-term exponential maximum sound level (i.e., $L_{ASmax}$, $L_{AFmax}$, etc.) or a maximum instantaneous sound level (i.e., $L_{peak}$), but "with a duration of 30 seconds" indicates a sustained, continuous, energy-averaged measurement over time (i.e., $L_{Aeq}$). Using the short-term exponential maximum or instantaneous maximum sound level to determine compliance with this requirement would be inappropriate, as they do not capture durations of 30 seconds and could result in auditory signals that are much louder than necessary. For these reasons, we used the maximum $L_{Aeq,30s}$ to measure the maximum sound level with a 30-second duration for this report. We recommend revising the

current HFDS Section 5.5.2.8.3 requirement to specify the acoustic metrics to measure to satisfy the requirement.

Regarding smartphone SLM apps, a limitation is that we only used one smartphone SLM application to compare measurements with the professional Brüel & Kjær 2245 SLM. Other apps may produce different measurements than the app used for this project. Future work should include other sound level meter models (e.g., smartphone apps, traditional SLMs) to explore the reliability and validity of using smartphone apps to measure ambient sound levels compared to professional devices. Future methodologies using smartphone SLMs should involve calibrating the app before and after each measurement trial, as recommended by the NIOSH SLM app manual (Centers for Disease Control and Prevention, 2024).

Finally, according to the HFDS (Ahlstrom, 2016) Section 5.10.12.2, the acceptable noise level for operational areas/tower cabs is 65 dB(A). The acceptable noise level for large workspaces (e.g., ARTCCs) is 55 dB(A). While most of the sound measurements captured at the facilities included in this report fell within this range (energy-averaged $L_{Aeq}$), several facilities exceeded these sound level requirements. These findings may warrant future research to explore methods to reduce these sound levels.

# 5 Conclusions

The current project involved collecting baseline ambient sound measurement data from 28 ATC facilities across the United States (15 standalone ATCTs, 4 standalone TRACONs, 6 up/down ATCTs with TRACONs, 3 ARTCCs). This information is a resource for FAA acquisition programs to consider in the design of ATC auditory signals.

Separately, the use of smartphone SLM apps in lieu of professional sound level meters for research purposes suggests that smartphone SLM apps, when paired with an external microphone, may provide mostly consistent and reliable measurements of A-weighted equivalent continuous sound levels. However, maximum sound levels are less accurate without proper calibration before and after each measurement.

Before equipping an auditory signal system in any environment, one should consider local sound levels, because they vary across facilities.

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# A Schedule and facility details

| Dates | Location | Facility Name | Facility Type | Facility Level | Year Built | Research Team Members | iPhone Windscreen Use |
|---|---|---|---|---|---|---|---|
| 2/11/2025 | Atlantic City, NJ | Atlantic City Tower/TRACON (ACY) | ATCT; TRACON | 6 | c. 1987 | 3 HF researchers; 2 Terminal CHI members (1 NATCA representative) | Yes |
| 3/25/2025 | Ewing, NJ | Trenton Mercer Tower (TTN) | ATCT | -- | c. 1961 | 2 HF researchers; 2 Terminal CHI members (1 NATCA representative) | Yes |
| 3/26/2025 | Middletown, PA | Harrisburg International Tower/TRACON (MDT) | ATCT; TRACON | 7 | c. 1989 | 2 HF researchers; 2 Terminal CHI members (1 NATCA representative) | Yes |
| 3/27/2025 | Allentown, PA | Allentown Tower/TRACON (ABE) | ATCT; TRACON | 7 | c. 1995 | 2 HF researchers; 2 Terminal CHI members (1 NATCA representative) | Yes |
| 4/7/2025 | Philadelphia, PA | Philadelphia Tower/TRACON (PHL) | ATCT; TRACON | 12 | ATCT: c. 1981; TRACON: c. 1995 | 3 HF researchers; 1 Terminal CHI member (NATCA representative) | Yes |
| 4/7/2025 | Philadelphia, PA | Northeast Philadelphia Tower (PNE) | ATCT | 5 | c. 1973 | 3 HF researchers; 1 Terminal CHI member (NATCA representative) | Yes |
| 4/9/2025 | New Castle, DE | Wilmington Tower (ILG) | ATCT | 4 | c. 2001 | 3 HF researchers; 1 Terminal CHI member (NATCA representative) | No |
| 4/22/2025 | Washington, DC | Washington National Tower (DCA) | ATCT | 9 | c. 1997 | 3 HF researchers; 1 Terminal CHI member (NATCA representative) | No |
| 4/23/2025 | Leesburg, VA | Washington ARTCC (ZDC) | ARTCC | 12 | c. 1964 | 3 HF researchers; 1 Terminal CHI member (NATCA representative) | No |
| 4/24/2025 | Warrenton, VA | Potomac TRACON (PCT) | TRACON | 12 | c. 2002 | 3 HF researchers; 1 Terminal CHI member (NATCA representative) | No |

| Dates | Location | Facility Name | Facility Type | Facility Level | Year Built | Research Team Members | iPhone Windscreen Use |
|---|---|---|---|---|---|---|---|
| 5/20/2025 | Phoenix, AZ | Deer Valley Tower (DVT) | ATCT | 8 | c. 2007 | 3 HF researchers; 2 Terminal CHI members (1 NATCA representative) | No |
| 5/20/2025 | Scottsdale, AZ | Scottsdale Tower (SDL) | ATCT | 7 | c. 1989 | 3 HF researchers; 2 Terminal CHI members (1 NATCA representative) | No |
| 5/21/2025 | Phoenix, AZ | Phoenix TRACON (P50) | TRACON | 11 | c. 2013 | 3 HF researchers; 2 Terminal CHI members (1 NATCA representative) | No |
| 5/21/2025 | Mesa, AZ | Falcon Tower (FFZ) | ATCT | 8 | c. 1978 | 3 HF researchers; 2 Terminal CHI members (1 NATCA representative) | No |
| 5/22/2025 | Tucson, AZ | Tucson TRACON (U90) | TRACON | 8 | c. 1969 | 3 HF researchers; 2 Terminal CHI members (1 NATCA representative) | No |
| 5/22/2025 | Tucson, AZ | Tucson Tower (TUS) | ATCT | 6 | c. 2016 | 3 HF researchers; 2 Terminal CHI members (1 NATCA representative) | No |
| 6/3/2025 | Houston, TX | Houston Intercontinental Tower (IAH) | ATCT | 11 | c. 1997 | 2 HF researchers; 2 Terminal CHI members (1 NATCA representative) | No |
| 6/3/2025 | Houston, TX | Houston TRACON (I90) | TRACON | 12 | c. 2013 | 2 HF researchers; 2 Terminal CHI members (1 NATCA representative) | No |
| 6/3/2025 | Houston, TX | Houston ARTCC (ZHU) | ARTCC | 11 | c. 1965 | 2 HF researchers; 2 Terminal CHI members (1 NATCA representative) | No |
| 6/4/2025 | Tomball, TX | Houston Hooks Tower (DWH) | ATCT | 6 | c 1979 | 2 HF researchers; 2 Terminal CHI members (1 NATCA representative) | No |
| 6/5/2025 | Houston, TX | Hobby Tower (HOU) | ATCT | 8 | c. 2000 | 2 HF researchers; 2 Terminal CHI members (1 NATCA representative) | No |

| Dates | Location | Facility Name | Facility Type | Facility Level | Year Built | Research Team Members | iPhone Windscreen Use |
|---|---|---|---|---|---|---|---|
| 6/9/2025 | Miami, FL | Tamiami Tower (TMB) | ATCT | 8 | c. 1993 | 3 HF researchers; 1 Terminal CHI member (NATCA representative) | No |
| 6/10/2025 | Miami, FL | Miami ARTCC (ZMA) | ARTCC | 11 | c. 1957 | 3 HF researchers; 1 Terminal CHI member (NATCA representative) | No |
| 6/10/2025 | Miami, FL | Miami Tower/TRACON (MIA) | ATCT; TRACON | 12 | c. 2002 | 3 HF researchers; 1 Terminal CHI member (NATCA representative) | No |
| 6/11/2025 | Fort Lauderdale, FL | Fort Lauderdale Tower (FLL) | ATCT | 8 | c. 1985 | 3 HF researchers; 1 Terminal CHI member (NATCA representative) | No |
| 6/11/2025 | Fort Lauderdale, FL | Fort Lauderdale Executive Tower (FXE) | ATCT | 7 | c. 2014 | 3 HF researchers; 1 Terminal CHI member (NATCA representative) | No |
| 6/12/2025 | West Palm Beach, FL | West Palm Beach Tower/TRACON (PBI) | ATCT; TRACON | 9 | ATCT: c. 2011; TRACON: c. 2016 | 3 HF researchers; 1 Terminal CHI member (NATCA representative) | No |
| 6/12/2025 | Vero Beach, FL | Vero Beach Tower (VRB) | ATCT | 8 | c. 2003 | 3 HF researchers; 1 Terminal CHI member (NATCA representative) | No |

# B Facility sound levels: Brüel & Kjær 2245 SLM

| Facility Type | Facility Name | Number of Trials | $L_{Aeq,30min}$ [dB(A)] | | | $L_{Aeq,30s}$ [dB(A)] | $L_{ASmax,30min}$ [dB(A)] | | | $L_{AFmax,30min}$ [dB(A)] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Energy-Average[a] | Mdn | Range (Min-Max) | Max[b] | Max[c] | Mdn | Range (Min-Max) | Max[d] | Mdn | Range (Min-Max) |
| ATCT | Washington National Tower (DCA) | 4 | 66.4 | 66.2 | 65.1 – 67.4 | 79.9 | 89.8 | 83.2 | 79.9 – 89.8 | 97.3 | 90.2 | 85.5 – 97.3 |
| ATCT | Deer Valley Tower (DVT) | 3 | 60.7 | 60.2 | 59.9 – 61.7 | 68.9 | 77.8 | 74.7 | 71.3 – 77.8 | 86.2 | 81.5 | 76.8 – 86.2 |
| ATCT | Houston Hooks Tower (DWH) | 3 | 65.1 | 65.4 | 64.1 – 65.6 | 74.1 | 88.2 | 83.0 | 79.7 – 88.2 | 96.3 | 90.6 | 85.1 – 96.3 |
| ATCT | Falcon Tower (FFZ) | 3 | 64.1 | 63.4 | 60.3 – 66.6 | 75.8 | 89.6 | 74.9 | 74.4 – 89.6 | 97.9 | 78.8 | 78.6 – 97.9 |
| ATCT | Fort Lauderdale Tower (FLL) | 3 | 58.7 | 57.3 | 55.9 – 61.0 | 69.3 | 82.7 | 75.4 | 74.9 – 82.7 | 90.7 | 83.2 | 82.8 – 90.7 |
| ATCT | Fort Lauderdale Executive Tower (FXE) | 3 | 61.3 | 60.6 | 58.8 – 63.4 | 73.5 | 87.0 | 81.7 | 72.8 – 87.0 | 94.7 | 89.9 | 80.7 – 94.7 |
| ATCT | Hobby Tower (HOU) | 3 | 62.1 | 62.3 | 60.0 – 63.3 | 70.1 | 82.6 | 81.5 | 77.6 – 82.6 | 90.5 | 89.3 | 84.5 – 90.5 |
| ATCT | Houston Intercontinental Tower (IAH) | 3 | 62.9 | 62.7 | 62.1 – 63.8 | 74.3 | 83.0 | 82.1 | 77.9 – 83.0 | 90.4 | 89.9 | 86.0 – 90.4 |
| ATCT | Wilmington Tower (ILG) | 3 | 58.1 | 58.1 | 56.9 – 59.1 | 72.7 | 85.6 | 82.4 | 76.4 – 85.6 | 92.4 | 90.2 | 83.2 – 92.4 |
| ATCT | Northeast Philadelphia Tower (PNE) | 3 | 60.8 | 60.1 | 59.6 – 62.1 | 68.5 | 78.1 | 76.3 | 74.7 – 78.1 | 82.7 | 81.1 | 80.4 – 82.7 |
| ATCT | Scottsdale Tower (SDL) | 3 | 61.0 | 61.4 | 58.2 – 62.4 | 68.8 | 79.7 | 78.0 | 75.2 – 79.7 | 86.5 | 85.7 | 79.5 – 86.5 |
| ATCT | Tamiami Tower (TMB) | 3 | 62.8 | 62.5 | 61.3 – 64.1 | 73.3 | 86.3 | 83.9 | 79.4 – 86.3 | 93.3 | 91.2 | 87.3 – 93.3 |
| ATCT | Trenton Mercer Tower (TTN) | 4 | 57.5 | 58.0 | 54.3 – 58.4 | 65.4 | 74.8 | 72.2 | 70.5 – 74.8 | 81.2 | 78.9 | 76.1 – 81.2 |
| ATCT | Tucson Tower (TUS) | 3 | 56.6 | 52.6 | 50.8 – 60.3 | 67.3 | 75.8 | 69.6 | 66.2 – 75.8 | 83.2 | 77.4 | 73.1 – 83.2 |

| Facility Type | Facility Name | Number of Trials | $L_{Aeq,30min}$ [dB(A)] | | | $L_{Aeq,30s}$ [dB(A)] | $L_{ASmax,30min}$ [dB(A)] | | | $L_{AFmax,30min}$ [dB(A)] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Energy-Average[a] | Mdn | Range (Min-Max) | Max[b] | Max[c] | Mdn | Range (Min-Max) | Max[d] | Mdn | Range (Min-Max) |
| ATCT | Vero Beach Tower (VRB) | 3 | 59.0 | 58.6 | 55.8 – 61.0 | 71.4 | 83.5 | 73.9 | 71.4 – 83.5 | 90.1 | 79.3 | 79.1 – 90.1 |
| TRACON | Houston TRACON (I90) | 3 | 61.4 | 60.0 | 57.4 – 64.1 | 68.4 | 75.3 | 74.5 | 73.8 – 75.3 | 81.3 | 81.2 | 80.7 – 81.3 |
| TRACON | Pheonix TRACON (P50) | 4 | 60.7 | 60.6 | 59.4 – 61.9 | 66.9 | 78.3 | 73.4 | 71.9 – 78.3 | 86.6 | 80.5 | 78.2 – 86.6 |
| TRACON | Potomac TRACON (PCT) | 4 | 60.1 | 59.2 | 59.0 – 62.0 | 70.5 | 78.2 | 72.0 | 70.6 – 78.2 | 82.9 | 79.4 | 77.9 – 82.9 |
| TRACON | Tucson TRACON (U90) | 3 | 60.5 | 60.6 | 58.1 – 61.9 | 66.9 | 77.8 | 75.6 | 71.9 – 77.8 | 84.9 | 80.8 | 78.1 – 84.9 |
| ATCT with TRACON | Allentown Tower (ABE) | 3 | 56.0 | 55.0 | 54.2 – 57.9 | 66.4 | 79.9 | 74.6 | 70.6 – 79.9 | 88.2 | 82.2 | 78.2 – 88.2 |
| ATCT with TRACON | Allentown TRACON (ABE) | 3 | 58.1 | 57.8 | 57.1 – 59.1 | 64.4 | 77.2 | 76.2 | 73.7 – 77.2 | 85.3 | 83.6 | 81.6 – 85.3 |
| ATCT with TRACON | Atlantic City Tower (ACY) | 1 | 57.9 | 57.9 | N/A | 65.2 | 73.4 | 73.4 | N/A | 77.6 | 77.6 | N/A |
| ATCT with TRACON | Atlantic City TRACON (ACY) | 1 | 57.6 | 57.6 | N/A | 69.1 | 80.2 | 80.2 | N/A | 84.7 | 84.7 | N/A |
| ATCT with TRACON | Harrisburg International Tower (MDT) | 3 | 56.2 | 56.0 | 55.8 – 56.8 | 67.0 | 79.8 | 79.3 | 72.1 – 79.8 | 87.2 | 85.7 | 79.8 – 87.2 |
| ATCT with TRACON | Harrisburg International TRACON (MDT) | 3 | 61.8 | 60.8 | 59.8 – 63.8 | 74.7 | 87.9 | 83.6 | 79.6 – 87.9 | 95.4 | 91.1 | 87.3 – 95.4 |
| ATCT with TRACON | Miami Tower (MIA) | 2 | 61.1 | 61.0 | 60.0 – 62.0 | 69.0 | 79.6 | 78.2 | 76.9 – 79.6 | 86.9 | 85.3 | 83.8 – 86.9 |
| ATCT with TRACON | Miami TRACON (MIA) | 2 | 62.2 | 62.0 | 61.0 – 63.1 | 67.7 | 74.3 | 72.9 | 71.6 – 74.3 | 80.3 | 78.9 | 77.6 – 80.3 |
| ATCT with TRACON | West Palm Beach Tower (PBI) | 2 | 60.5 | 60.4 | 60.0 – 60.9 | 68.5 | 77.5 | 76.9 | 76.2 – 77.5 | 81.9 | 81.8 | 81.7 – 81.9 |
| ATCT with TRACON | West Palm Beach TRACON (PBI) | 2 | 59.4 | 59.4 | 59.2 – 59.7 | 67.4 | 79.9 | 77.5 | 75.1 – 79.9 | 87.3 | 84.9 | 82.4 – 87.3 |

| Facility Type | Facility Name | Number of Trials | $L_{Aeq,30min}$ [dB(A)] | | | $L_{Aeq,30s}$ [dB(A)] | $L_{ASmax,30min}$ [dB(A)] | | | $L_{AFmax,30min}$ [dB(A)] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Energy-Average[a] | Mdn | Range (Min-Max) | Max[b] | Max[c] | Mdn | Range (Min-Max) | Max[d] | Mdn | Range (Min-Max) |
| ATCT with TRACON | Philadelphia Tower (PHL) | 3 | 62.5 | 62.4 | 60.8 – 63.9 | 73.3 | 85.6 | 78.8 | 76.0 – 85.6 | 90.8 | 86.6 | 83.3 – 90.8 |
| ATCT with TRACON | Philadelphia TRACON (PHL) | 3 | 59.6 | 58.8 | 58.4 – 61.2 | 70.3 | 83.2 | 78.2 | 74.4 – 83.2 | 89.8 | 86.3 | 80.7 – 89.8 |
| ARTCC | Washington Center (ZDC) | 4 | 61.2 | 61.1 | 57.9 – 63.1 | 68.6 | 75.0 | 74.0 | 69.3 – 75.0 | 81.3 | 78.7 | 74.9 – 81.3 |
| ARTCC | Houston Center (ZHU) | 3 | 68.0 | 67.3 | 61.4 – 70.8 | 77.1 | 83.7 | 82.4 | 77.9 – 83.7 | 90.7 | 88.2 | 84.2 – 90.7 |
| ARTCC | Miami Center (ZMA) | 4 | 61.1 | 61.4 | 57.7 – 62.6 | 68.8 | 76.6 | 74.3 | 73.9 – 76.6 | 84.8 | 81.8 | 80.8 – 84.8 |

*Note.* N/A indicates that the range was not calculated because only one trial was collected at the facility.

[a] $L_{aeq,30min}$; Energy-averaged across trials

[b] Maximum $L_{Aeq,30s}$ was calculated by converting 1s sound level values across 30-min trial into linear energy values for each trial. Then, we calculated the rolling 30s average and converted back to dB(A) to determine the $L_{Aeq,30s}$. We identified the maximum $L_{Aeq,30s}$ for each trial. Then, we reported the maximum $L_{Aeq,30s}$ across all trials.

[c] $L_{ASmax,30min}$; Maximum A-weighted sound level, slow time weighting (1s) (Across Trials)

[d] $L_{AFmax,30min}$; Maximum A-weighted sound level, fast time weighting (125 ms) (Across Trials)

# C Facility sound levels: NIOSH SLM app with external microphone

| Facility Type | Facility Name | Number of Trials | $L_{Aeq}$ [dB(A)] | | | $L_{ASmax}$ [dB(A)] | | |
|---|---|---|---|---|---|---|---|---|
| | | | Energy-Average[a] | Mdn | Range (Min-Max) | Max[b] | Mdn | Range (Min-Max) |
| ATCT | Washington National Tower (DCA) | 4 | 67.0 | 66.6 | 65.5 – 68.6 | 99.6 | 89.1 | 84.1 – 99.6 |
| ATCT | Deer Valley Tower (DVT) | 3 | 61.1 | 60.7 | 60.4 – 62.1 | 85.0 | 82.7 | 78.8 – 85.0 |
| ATCT | Houston Hooks Tower (DWH) | 3 | 65.5 | 65.8 | 64.9 – 65.8 | 95.6 | 90.9 | 85.6 – 95.6 |
| ATCT | Falcon Tower (FFZ) | 3 | 65.1 | 64.6 | 60.3 – 67.6 | 97.0 | 80.8 | 78.6 – 97.0 |
| ATCT | Fort Lauderdale Tower (FLL) | 3 | 59.2 | 58.0 | 56.5 – 61.5 | 91.1 | 84.5 | 83.3 – 91.1 |
| ATCT | Fort Lauderdale Executive Tower (FXE) | 3 | 61.8 | 61.2 | 59.7 – 63.5 | 93.2 | 88.8 | 81.5 – 93.2 |
| ATCT | Hobby Tower (HOU) | 3 | 62.8 | 63.0 | 61.0 – 63.8 | 91.9 | 90.3 | 86.0 – 91.9 |
| ATCT | Houston Intercontinental Tower (IAH) | 3 | 64.4 | 64.5 | 63.4 – 65.1 | 95.0 | 90.4 | 87.4 – 95.0 |
| ATCT | Wilmington Tower (ILG) | 3 | 68.6 | 68.4 | 67.2 – 69.7 | 101.0 | 100.0 | 94.0 – 101.0 |
| ATCT | Northeast Philadelphia Tower (PNE) | 3 | 61.8 | 61.4 | 61.0 – 62.7 | 83.9 | 81.3 | 81.2 – 83.9 |
| ATCT | Scottsdale Tower (SDL) | 3 | 61.1 | 61.1 | 58.6 – 62.7 | 88.1 | 86.4 | 78.9 – 88.1 |
| ATCT | Tamiami Tower (TMB) | 3 | 64.2 | 63.8 | 62.7 – 65.7 | 96.6 | 92.6 | 88.2 – 96.6 |
| ATCT | Trenton Mercer Tower (TTN) | 4 | 59.4 | 59.3 | 55.9 – 61.5 | 83.4 | 79.6 | 78.2 – 83.4 |
| ATCT | Tucson Tower (TUS) | 3 | 56.7 | 53.4 | 51.1 – 60.3 | 82.5 | 78.3 | 73.4 – 82.5 |
| ATCT | Vero Beach Tower (VRB) | 3 | 59.3 | 58.8 | 55.9 – 61.5 | 90.2 | 79.2 | 77.7 – 90.2 |
| TRACON | Houston TRACON (I90) | 3 | 62.1 | 61.1 | 58.1 – 64.7 | 82.6 | 82.1 | 81.8 – 82.6 |
| TRACON | Pheonix TRACON (P50) | 4 | 61.1 | 60.9 | 59.7 – 62.4 | 84.7 | 79.6 | 77.6 – 84.7 |
| TRACON | Potomac TRACON (PCT) | 4 | 60.6 | 60.1 | 59.6 – 62.3 | 85.1 | 78.7 | 78.1 – 85.1 |
| TRACON | Tucson TRACON (U90) | 3 | 60.9 | 60.9 | 58.6 – 62.3 | 86.3 | 80.9 | 78.8 – 86.3 |
| ATCT with TRACON | Allentown Tower (ABE) | 3 | 56.6 | 55.9 | 55.7 – 57.8 | 88.0 | 82.9 | 78.2 – 88.0 |
| ATCT with TRACON | Allentown TRACON (ABE) | 3 | 58.8 | 58.7 | 57.9 – 59.7 | 85.7 | 84.4 | 82.7 – 85.7 |
| ATCT with TRACON | Atlantic City Tower (ACY) | 1 | 57.7 | 57.7 | N/A | 77.2 | 77.2 | N/A |
| ATCT with TRACON | Atlantic City TRACON (ACY) | 1 | 58.2 | 58.2 | N/A | 92.8 | 92.8 | N/A |

| Facility Type | Facility Name | Number of Trials | $L_{Aeq}$ [dB(A)] | | | $L_{ASmax}$ [dB(A)] | | |
|---|---|---|---|---|---|---|---|---|
| | | | Energy-Average[a] | Mdn | Range (Min-Max) | Max[b] | Mdn | Range (Min-Max) |
| ATCT with TRACON | Harrisburg International Tower (MDT) | 3 | 57.1 | 57.1 | 56.3 – 57.8 | 88.2 | 87.8 | 86.4 – 88.2 |
| ATCT with TRACON | Harrisburg International TRACON (MDT) | 3 | 63.0 | 62.6 | 62.1 – 64.1 | 93.1 | 92.5 | 91.3 – 93.1 |
| ATCT with TRACON | Miami Tower (MIA) | 2 | 61.7 | 61.6 | 60.5 – 62.7 | 93.2 | 89.0 | 84.8 – 93.2 |
| ATCT with TRACON | Miami TRACON (MIA) | 2 | 62.7 | 62.6 | 61.4 – 63.7 | 81.4 | 80.0 | 78.5 – 81.4 |
| ATCT with TRACON | West Palm Beach Tower (PBI) | 2 | 61.7 | 61.7 | 61.1 – 62.2 | 84.3 | 84.1 | 83.9 – 84.3 |
| ATCT with TRACON | West Palm Beach TRACON (PBI) | 2 | 60.3 | 60.3 | 59.8 – 60.7 | 89.8 | 86.6 | 83.3 – 89.8 |
| ATCT with TRACON | Philadelphia Tower (PHL) | 3 | 64.0 | 63.8 | 62.0 – 65.5 | 91.9 | 87.7 | 84.0 – 91.9 |
| ATCT with TRACON | Philadelphia TRACON (PHL) | 3 | 60.8 | 59.8 | 59.6 – 62.4 | 90.2 | 88.9 | 85.0 – 90.2 |
| ARTCC | Washington Center (ZDC) | 4 | 61.6 | 61.4 | 58.2 – 63.7 | 81.0 | 80.0 | 74.7 – 81.0 |
| ARTCC | Houston Center (ZHU) | 3 | 66.9 | 68.2 | 62.1 – 68.2 | 96.7 | 95.2 | 84.8 – 96.7 |
| ARTCC | Miami Center (ZMA) | 4 | 61.6 | 61.9 | 57.8 – 63.2 | 84.8 | 82.6 | 80.3 – 84.8 |

*Note.* N/A indicates that the range was not calculated because only one trial was collected at the facility.

[a] $L_{aeq,30min}$; Energy-averaged across trials

[b] $L_{ASmax,30min}$; Maximum A-weighted sound level, slow time weighting (1s) (Across Trials)

# D Facility sound levels – individual trial raw data: Brüel & Kjær 2245 SLM

| Facility Type | Facility Name | Number of Trials | $L_{Aeq,30min}$ | | | | $L_{ASmax,30min}$ | | | | $L_{AFmax,30min}$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Trial 1 [dB(A)] | Trial 2 [dB(A)] | Trial 3 [dB(A)] | Trial 4 [dB(A)] | Trial 1 [dB(A)] | Trial 2 [dB(A)] | Trial 3 [dB(A)] | Trial 4 [dB(A)] | Trial 1 [dB(A)] | Trial 2 [dB(A)] | Trial 3 [dB(A)] | Trial 4 [dB(A)] |
| ATCT | Washington National Tower (DCA) | 4 | 65.1 | 67.2 | 67.4 | 65.2 | 81.3 | 85.2 | 89.8 | 79.9 | 88.6 | 91.7 | 97.3 | 85.5 |
| ATCT | Deer Valley Tower (DVT) | 3 | 60.2 | 61.7 | 59.9 | - | 74.7 | 77.8 | 71.3 | - | 81.5 | 86.2 | 76.8 | - |
| ATCT | Houston Hooks Tower (DWH) | 3 | 65.4 | 65.6 | 64.1 | - | 79.7 | 88.2 | 83.0 | - | 85.1 | 96.3 | 90.6 | - |
| ATCT | Falcon Tower (FFZ) | 3 | 63.4 | 66.6 | 60.3 | - | 74.9 | 89.6 | 74.4 | - | 78.8 | 97.9 | 78.6 | - |
| ATCT | Fort Lauderdale Tower (FLL) | 3 | 61.0 | 55.9 | 57.3 | - | 82.7 | 74.9 | 75.4 | - | 90.7 | 82.8 | 83.2 | - |
| ATCT | Fort Lauderdale Executive Tower (FXE) | 3 | 63.4 | 60.6 | 58.8 | - | 87.0 | 81.7 | 72.8 | - | 94.7 | 89.9 | 80.7 | - |
| ATCT | Hobby Tower (HOU) | 3 | 60.0 | 62.3 | 63.3 | - | 82.6 | 81.5 | 77.6 | - | 90.5 | 89.3 | 84.5 | - |
| ATCT | Houston Intercontinental Tower (IAH) | 3 | 62.1 | 63.8 | 62.7 | - | 82.1 | 77.9 | 83.0 | - | 89.9 | 86.0 | 90.4 | - |
| ATCT | Wilmington Tower (ILG) | 3 | 58.1 | 59.1 | 56.9 | - | 82.4 | 85.6 | 76.4 | - | 90.2 | 92.4 | 83.2 | - |
| ATCT | Northeast Philadelphia Tower (PNE) | 3 | 62.1 | 59.6 | 60.1 | - | 78.1 | 76.3 | 74.7 | - | 82.7 | 81.1 | 80.4 | - |
| ATCT | Scottsdale Tower (SDL) | 3 | 62.4 | 58.2 | 61.4 | - | 78.0 | 79.7 | 75.2 | - | 85.7 | 86.5 | 79.5 | - |
| ATCT | Tamiami Tower (TMB) | 3 | 61.3 | 62.5 | 64.1 | - | 79.4 | 83.9 | 86.3 | - | 87.3 | 91.2 | 93.3 | - |
| ATCT | Trenton Mercer Tower (TTN) | 4 | 58.4 | 54.3 | 57.6 | 58.4 | 74.8 | 70.5 | 73.7 | 70.6 | 80.8 | 76.1 | 81.2 | 76.9 |
| ATCT | Tucson Tower (TUS) | 3 | 50.8 | 52.6 | 60.3 | - | 69.6 | 66.2 | 75.8 | - | 77.4 | 73.1 | 83.2 | - |
| ATCT | Vero Beach Tower (VRB) | 3 | 58.6 | 61.0 | 55.8 | - | 71.4 | 83.5 | 73.9 | - | 79.1 | 90.1 | 79.3 | - |
| TRACON | Houston TRACON (I90) | 3 | 60.0 | 64.1 | 57.4 | - | 73.8 | 74.5 | 75.3 | - | 80.7 | 81.2 | 81.3 | - |
| TRACON | Phoenix TRACON (P50) | 4 | 60.5 | 61.9 | 60.7 | 59.4 | 74.6 | 78.3 | 71.9 | 72.3 | 82.1 | 86.6 | 78.9 | 78.2 |

| Facility Type | Facility Name | Number of Trials | $L_{Aeq,30min}$ | | | | $L_{ASmax,30min}$ | | | | $L_{AFmax,30min}$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Trial 1 [dB(A)] | Trial 2 [dB(A)] | Trial 3 [dB(A)] | Trial 4 [dB(A)] | Trial 1 [dB(A)] | Trial 2 [dB(A)] | Trial 3 [dB(A)] | Trial 4 [dB(A)] | Trial 1 [dB(A)] | Trial 2 [dB(A)] | Trial 3 [dB(A)] | Trial 4 [dB(A)] |
| TRACON | Potomac TRACON (PCT) | 4 | 59.2 | 59.0 | 62.0 | 59.2 | 71.3 | 72.7 | 78.2 | 70.6 | 78.2 | 80.5 | 82.9 | 77.9 |
| TRACON | Tucson TRACON (U90) | 3 | 60.6 | 61.9 | 58.1 | - | 71.9 | 75.6 | 77.8 | - | 78.1 | 80.8 | 84.9 | - |
| ATCT with TRACON | Allentown Tower (ABE) | 3 | 57.9 | 55.0 | 54.2 | - | 79.9 | 74.6 | 70.6 | - | 88.2 | 82.2 | 78.2 | - |
| ATCT with TRACON | Allentown TRACON (ABE) | 3 | 57.8 | 57.1 | 59.1 | - | 73.7 | 77.2 | 76.2 | - | 81.6 | 85.3 | 83.6 | - |
| ATCT with TRACON | Atlantic City Tower (ACY) | 1 | 57.9 | - | - | - | 73.4 | - | - | - | 77.6 | - | - | - |
| ATCT with TRACON | Atlantic City TRACON (ACY) | 1 | 57.6 | - | - | - | 80.2 | - | - | - | 84.7 | - | - | - |
| ATCT with TRACON | Harrisburg International Tower (MDT) | 3 | 56.0 | 55.8 | 56.8 | - | 72.1 | 79.8 | 79.3 | - | 79.8 | 87.2 | 85.7 | - |
| ATCT with TRACON | Harrisburg International TRACON (MDT) | 3 | 59.8 | 63.8 | 60.8 | - | 79.6 | 87.9 | 83.6 | - | 87.3 | 95.4 | 91.1 | - |
| ATCT with TRACON | Miami Tower (MIA) | 2 | 62.0 | 60.0 | - | - | 79.6 | 76.9 | - | - | 86.9 | 83.8 | - | - |
| ATCT with TRACON | Miami TRACON (MIA) | 2 | 61.0 | 63.1 | - | - | 71.6 | 74.3 | - | - | 77.6 | 80.3 | - | - |
| ATCT with TRACON | West Palm Beach Tower (PBI) | 2 | 60.0 | 60.9 | - | - | 77.5 | 76.2 | - | - | 81.7 | 81.9 | - | - |
| ATCT with TRACON | West Palm Beach TRACON (PBI) | 2 | 59.7 | 59.2 | - | - | 75.1 | 79.9 | - | - | 82.4 | 87.3 | - | - |
| ATCT with TRACON | Philadelphia Tower (PHL) | 3 | 63.9 | 62.4 | 60.8 | - | 85.6 | 76.0 | 78.8 | - | 90.8 | 83.3 | 86.6 | - |
| ATCT with TRACON | Philadelphia TRACON (PHL) | 3 | 58.4 | 58.8 | 61.2 | - | 74.4 | 83.2 | 78.2 | - | 80.7 | 89.8 | 86.3 | - |
| ARTCC | Washington Center (ZDC) | 4 | 57.9 | 63.1 | 60.7 | 61.5 | 69.3 | 75.0 | 73.6 | 74.4 | 74.9 | 81.3 | 79.1 | 78.4 |
| ARTCC | Houston Center (ZHU) | 3 | 70.8 | 61.4 | 67.3 | - | 83.7 | 77.9 | 82.4 | - | 88.2 | 84.2 | 90.7 | - |
| ARTCC | Miami Center (ZMA) | 4 | 60.8 | 62.0 | 62.6 | 57.7 | 76.6 | 74.2 | 74.3 | 73.9 | 84.8 | 82.4 | 81.1 | 80.8 |

*Note.* "-" indicates that no data was collected for the trial.

# E Facility sound levels – individual trial raw data: NIOSH SLM app with external microphone

| Facility Type | Facility Name | Number of Trials | $L_{Aeq}$ | | | | $L_{ASmax}$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Trial 1 [dB(A)] | Trial 2 [dB(A)] | Trial 3 [dB(A)] | Trial 4 [dB(A)] | Trial 1 [dB(A)] | Trial 2 [dB(A)] | Trial 3 [dB(A)] | Trial 4 [dB(A)] |
| ATCT | Washington National Tower (DCA) | 4 | 65.5 | 67.5 | 68.6 | 65.7 | 87.3 | 90.8 | 99.6 | 84.1 |
| ATCT | Deer Valley Tower (DVT) | 3 | 60.7 | 62.1 | 60.4 | - | 82.7 | 85.0 | 78.8 | - |
| ATCT | Houston Hooks Tower (DWH) | 3 | 65.8 | 65.8 | 64.9 | - | 85.6 | 95.6 | 90.9 | - |
| ATCT | Falcon Tower (FFZ) | 3 | 64.6 | 67.6 | 60.3 | - | 80.8 | 97.0 | 78.6 | - |
| ATCT | Fort Lauderdale Tower (FLL) | 3 | 61.5 | 56.5 | 58.0 | - | 91.1 | 83.3 | 84.5 | - |
| ATCT | Fort Lauderdale Executive Tower (FXE) | 3 | 63.5 | 61.2 | 59.7 | - | 93.2 | 88.8 | 81.5 | - |
| ATCT | Hobby Tower (HOU) | 3 | 61.0 | 63.0 | 63.8 | - | 91.9 | 90.3 | 86.0 | - |
| ATCT | Houston Intercontinental Tower (IAH) | 3 | 63.4 | 65.1 | 64.5 | - | 90.4 | 87.4 | 95.0 | - |
| ATCT | Wilmington Tower (ILG) | 3 | 68.4 | 69.7 | 67.2 | - | 100.0 | 101.0 | 94.0 | - |
| ATCT | Northeast Philadelphia Tower (PNE) | 3 | 62.7 | 61.0 | 61.4 | - | 83.9 | 81.2 | 81.3 | - |
| ATCT | Scottsdale Tower (SDL) | 3 | 62.7 | 58.6 | 61.1 | - | 86.4 | 88.1 | 78.9 | - |
| ATCT | Tamiami Tower (TMB) | 3 | 62.7 | 63.8 | 65.7 | - | 88.2 | 92.6 | 96.6 | - |
| ATCT | Trenton Mercer Tower (TTN) | 4 | 61.5 | 55.9 | 58.7 | 59.9 | 83.4 | 78.2 | 79.9 | 79.3 |
| ATCT | Tucson Tower (TUS) | 3 | 51.1 | 53.4 | 60.3 | - | 78.3 | 73.4 | 82.5 | - |
| ATCT | Vero Beach Tower (VRB) | 3 | 58.8 | 61.5 | 55.9 | - | 77.7 | 90.2 | 79.2 | - |
| TRACON | Houston TRACON (I90) | 3 | 61.1 | 64.7 | 58.1 | - | 81.8 | 82.6 | 82.1 | - |

| Facility Type | Facility Name | Number of Trials | $L_{Aeq}$ | | | | $L_{ASmax}$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Trial 1 [dB(A)] | Trial 2 [dB(A)] | Trial 3 [dB(A)] | Trial 4 [dB(A)] | Trial 1 [dB(A)] | Trial 2 [dB(A)] | Trial 3 [dB(A)] | Trial 4 [dB(A)] |
| TRACON | Phoenix TRACON (P50) | 4 | 60.9 | 62.4 | 60.8 | 59.7 | 80.5 | 84.7 | 77.6 | 78.6 |
| TRACON | Potomac TRACON (PCT) | 4 | 59.9 | 59.6 | 62.3 | 60.2 | 79.1 | 78.1 | 85.1 | 78.2 |
| TRACON | Tucson TRACON (U90) | 3 | 60.9 | 62.3 | 58.6 | - | 78.8 | 80.9 | 86.3 | - |
| ATCT with TRACON | Allentown Tower (ABE) | 3 | 57.8 | 55.7 | 55.9 | - | 88.0 | 82.9 | 78.2 | - |
| ATCT with TRACON | Allentown TRACON (ABE) | 3 | 58.7 | 57.9 | 59.7 | - | 82.7 | 85.7 | 84.4 | - |
| ATCT with TRACON | Atlantic City Tower (ACY) | 1 | 57.7 | - | - | - | 77.2 | - | - | - |
| ATCT with TRACON | Atlantic City TRACON (ACY) | 1 | 58.2 | - | - | - | 92.8 | - | - | - |
| ATCT with TRACON | Harrisburg International Tower (MDT) | 3 | 57.1 | 56.3 | 57.8 | - | 88.2 | 86.4 | 87.8 | - |
| ATCT with TRACON | Harrisburg International TRACON (MDT) | 3 | 62.6 | 64.1 | 62.1 | - | 91.3 | 92.5 | 93.1 | - |
| ATCT with TRACON | Miami Tower (MIA) | 2 | 62.7 | 60.5 | - | - | 93.2 | 84.8 | - | - |
| ATCT with TRACON | Miami TRACON (MIA) | 2 | 61.4 | 63.7 | - | - | 78.5 | 81.4 | - | - |
| ATCT with TRACON | West Palm Beach Tower (PBI) | 2 | 61.1 | 62.2 | - | - | 83.9 | 84.3 | - | - |
| ATCT with TRACON | West Palm Beach TRACON (PBI) | 2 | 60.7 | 59.8 | - | - | 83.3 | 89.8 | - | - |
| ATCT with TRACON | Philadelphia Tower (PHL) | 3 | 65.5 | 63.8 | 62.0 | - | 91.9 | 84.0 | 87.7 | - |
| ATCT with TRACON | Philadelphia TRACON (PHL) | 3 | 59.8 | 59.6 | 62.4 | - | 85.0 | 90.2 | 88.9 | - |
| ARTCC | Washington Center (ZDC) | 4 | 58.2 | 63.7 | 61.0 | 61.7 | 74.7 | 81.0 | 80.6 | 79.4 |
| ARTCC | Houston Center (ZHU) | 3 | 68.2 | 62.1 | 68.2 | - | 95.2 | 84.8 | 96.7 | - |
| ARTCC | Miami Center (ZMA) | 4 | 61.2 | 62.5 | 63.2 | 57.8 | 84.8 | 83.1 | 82.0 | 80.3 |

*Note.* "-" indicates that no data was collected for the trial.

# F $L_{Aeq}$ across frequency spectrum data (12.5 Hz – 500 Hz)

| Facility Information | | Energy-Averaged $L_{Aeq,30min}$ [dB(A)] (Across Trials) | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Type** | **ID** | **12.5 Hz** | **16 Hz** | **20 Hz** | **25 Hz** | **31.5 Hz** | **40 Hz** | **50 Hz** | **63 Hz** | **80 Hz** | **100 Hz** | **125 Hz** | **160 Hz** | **200 Hz** | **250 Hz** | **315 Hz** | **400 Hz** | **500 Hz** |
| ATCT | DCA | -9.5 | 0.1 | 3.9 | 7.9 | 17.4 | 22.3 | 26.4 | 28.4 | 30.9 | 34.6 | 39.7 | 43.2 | 46.2 | 48.2 | 51.9 | 56.5 | 59.3 |
| ATCT | DVT | -1.2 | 0.7 | 4.8 | 5.9 | 12.9 | 19.4 | 25.3 | 25.4 | 30.8 | 35.4 | 40.4 | 38.6 | 40.4 | 45.2 | 47.3 | 51.0 | 52.5 |
| ATCT | DWH | 8.1 | 20.9 | 17.7 | 22.8 | 31.2 | 26.8 | 31.6 | 35.5 | 36.9 | 37.6 | 41.9 | 44.1 | 45.0 | 47.7 | 48.9 | 53.5 | 56.1 |
| ATCT | FFZ | 4.1 | 6.7 | 15.5 | 15.8 | 21.1 | 30.5 | 34.6 | 38.1 | 39.4 | 40.6 | 44.4 | 47.8 | 46.4 | 47.3 | 48.7 | 51.5 | 56.5 |
| ATCT | FLL | 5.6 | 8.6 | 19.8 | 18.6 | 24.4 | 31.1 | 32.5 | 34.2 | 35.0 | 33.2 | 32.9 | 34.0 | 38.7 | 41.0 | 42.1 | 46.2 | 49.3 |
| ATCT | FXE | -4.1 | 0.6 | 4.4 | 7.3 | 10.0 | 14.8 | 18.6 | 23.1 | 27.4 | 29.0 | 33.1 | 34.1 | 39.2 | 42.7 | 43.4 | 47.3 | 50.4 |
| ATCT | HOU | 6.6 | 8.8 | 25.9 | 18.8 | 17.9 | 26.2 | 28.9 | 32.5 | 33.6 | 34.4 | 39.0 | 40.2 | 43.0 | 46.8 | 46.5 | 50.3 | 53.7 |
| ATCT | IAH | -4.3 | 1.8 | 5.4 | 9.4 | 20.6 | 24.1 | 27.5 | 28.9 | 29.5 | 33.4 | 37.4 | 36.5 | 41.4 | 46.0 | 45.6 | 50.2 | 54.1 |
| ATCT | ILG | -4.1 | 2.7 | 9.0 | 16.5 | 22.1 | 28.6 | 27.8 | 31.0 | 32.3 | 32.1 | 35.1 | 34.4 | 37.2 | 41.6 | 43.8 | 47.9 | 51.0 |
| ATCT | PNE | -3.7 | 0.5 | 7.4 | 8.9 | 16.0 | 18.9 | 22.8 | 24.0 | 27.4 | 31.5 | 36.0 | 44.1 | 44.6 | 44.9 | 47.4 | 51.7 | 54.0 |
| ATCT | SDL | 0.9 | 8.0 | 10.4 | 16.7 | 18.0 | 21.7 | 27.6 | 29.6 | 32.5 | 32.4 | 36.2 | 37.9 | 40.7 | 44.3 | 47.1 | 50.0 | 53.6 |
| ATCT | TMB | 2.7 | 1.9 | 4.8 | 11.7 | 17.7 | 17.3 | 22.8 | 25.8 | 31.0 | 30.4 | 35.8 | 40.3 | 42.5 | 45.4 | 47.7 | 51.7 | 54.4 |
| ATCT | TTN | -4.9 | -0.9 | 5.1 | 16.1 | 21.7 | 20.6 | 22.6 | 22.7 | 25.7 | 27.0 | 33.8 | 31.0 | 35.3 | 40.2 | 43.8 | 47.3 | 50.5 |
| ATCT | TUS | -13.8 | -10.0 | 0.9 | -1.6 | 5.9 | 9.2 | 11.7 | 16.8 | 18.6 | 22.6 | 30.6 | 33.6 | 34.1 | 39.6 | 43.3 | 45.1 | 49.5 |
| ATCT | VRB | -7.8 | -2.2 | 0.3 | 6.7 | 10.0 | 15.3 | 16.6 | 21.1 | 25.6 | 29.4 | 36.5 | 36.5 | 37.6 | 42.0 | 44.9 | 48.1 | 51.1 |
| TRACON | I90 | -10.9 | -4.6 | 1.6 | 4.9 | 12.4 | 18.0 | 19.0 | 22.4 | 29.8 | 34.2 | 37.8 | 36.6 | 41.9 | 48.8 | 47.7 | 52.5 | 55.0 |

| Facility Information | | Energy-Averaged $L_{Aeq,30min}$ [dB(A)] (Across Trials) | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Type** | **ID** | **12.5 Hz** | **16 Hz** | **20 Hz** | **25 Hz** | **31.5 Hz** | **40 Hz** | **50 Hz** | **63 Hz** | **80 Hz** | **100 Hz** | **125 Hz** | **160 Hz** | **200 Hz** | **250 Hz** | **315 Hz** | **400 Hz** | **500 Hz** |
| TRACON | P50 | -11.2 | -2.1 | 4.5 | 7.5 | 14.0 | 18.3 | 22.4 | 24.2 | 31.4 | 35.1 | 35.4 | 34.9 | 39.2 | 44.8 | 47.6 | 50.6 | 52.9 |
| TRACON | PCT | -7.0 | -2.7 | 2.6 | 7.8 | 14.4 | 18.7 | 22.3 | 24.3 | 27.7 | 31.1 | 34.7 | 34.2 | 38.3 | 44.6 | 48.7 | 49.4 | 51.6 |
| TRACON | U90 | -8.4 | -2.8 | 3.0 | 10.5 | 16.5 | 17.3 | 24.2 | 29.2 | 29.9 | 35.1 | 36.2 | 35.8 | 42.5 | 44.9 | 48.4 | 52.4 | 53.7 |
| ATCT w/ TRACON | ABE ATCT | -10.2 | -8.5 | 3.5 | 3.6 | 13.1 | 16.8 | 17.1 | 20.3 | 25.2 | 31.3 | 29.6 | 33.9 | 35.5 | 36.7 | 40.6 | 45.7 | 47.0 |
| ATCT w/ TRACON | ABE TRACON | -5.0 | 5.5 | 7.8 | 19.7 | 26.5 | 27.6 | 31.7 | 34.8 | 35.3 | 36.9 | 37.8 | 38.0 | 42.0 | 43.0 | 46.7 | 48.5 | 50.1 |
| ATCT w/ TRACON | ACY ATCT | -11.6 | -7.1 | -1.3 | 6.5 | 7.6 | 18.8 | 18.6 | 21.0 | 27.3 | 29.7 | 34.0 | 38.5 | 43.2 | 42.8 | 45.1 | 48.0 | 52.4 |
| ATCT w/ TRACON | ACY TRACON | -1.3 | 2.6 | 3.1 | 12.0 | 19.0 | 25.5 | 30.2 | 28.2 | 31.8 | 33.7 | 38.4 | 35.2 | 40.8 | 44.3 | 44.7 | 47.7 | 50.1 |
| ATCT w/ TRACON | MDT ATCT | -4.6 | 2.0 | 9.6 | 15.1 | 22.4 | 23.0 | 26.7 | 26.5 | 29.4 | 32.4 | 35.4 | 37.2 | 37.0 | 40.4 | 41.9 | 46.8 | 48.6 |
| ATCT w/ TRACON | MDT TRACON | -2.7 | -1.0 | 4.2 | 10.0 | 15.4 | 19.3 | 27.2 | 27.8 | 32.7 | 34.7 | 37.7 | 40.7 | 43.7 | 45.5 | 46.4 | 49.3 | 51.8 |
| ATCT w/ TRACON | MIA ATCT | -5.0 | -2.1 | 3.5 | 6.6 | 16.7 | 32.1 | 26.9 | 33.0 | 30.9 | 31.4 | 34.2 | 36.9 | 41.6 | 44.3 | 44.3 | 49.3 | 52.6 |
| ATCT w/ TRACON | MIA TRACON | 11.5 | 8.8 | 14.0 | 22.5 | 24.1 | 29.2 | 31.2 | 36.3 | 31.3 | 33.4 | 36.1 | 35.0 | 44.5 | 45.1 | 46.5 | 50.5 | 55.1 |
| ATCT w/ TRACON | PBI ATCT | -4.2 | -1.3 | 3.8 | 2.4 | 9.4 | 17.6 | 22.2 | 26.6 | 26.9 | 31.5 | 32.3 | 34.0 | 37.1 | 41.6 | 46.4 | 51.1 | 54.0 |
| ATCT w/ TRACON | PBI TRACON | -2.7 | -2.7 | 5.2 | 7.7 | 12.9 | 15.1 | 15.8 | 19.0 | 26.4 | 28.6 | 35.1 | 35.2 | 37.7 | 40.1 | 45.4 | 48.2 | 50.0 |
| ATCT w/ TRACON | PHL ATCT | -3.9 | -1.8 | 10.8 | 22.6 | 14.1 | 19.1 | 22.9 | 23.9 | 25.7 | 31.2 | 37.3 | 38.0 | 42.8 | 45.1 | 47.7 | 50.6 | 54.5 |
| ATCT w/ TRACON | PHL TRACON | -3.9 | 2.4 | 6.6 | 14.8 | 22.1 | 26.6 | 35.4 | 39.5 | 36.5 | 40.0 | 43.2 | 41.0 | 43.4 | 43.9 | 44.4 | 48.7 | 50.2 |
| ARTCC | ZDC | -2.8 | 4.4 | 9.4 | 13.7 | 18.3 | 23.5 | 25.2 | 28.6 | 28.6 | 31.3 | 35.3 | 39.2 | 40.8 | 44.3 | 45.8 | 49.7 | 52.8 |
| ARTCC | ZHU | -7.8 | -0.1 | 8.8 | 14.2 | 12.8 | 17.1 | 23.4 | 24.1 | 29.8 | 35.5 | 38.8 | 43.7 | 45.8 | 48.7 | 49.6 | 54.3 | 61.1 |
| ARTCC | ZMA | 0.8 | 2.4 | 6.0 | 13.4 | 17.1 | 20.9 | 25.4 | 29.0 | 33.0 | 35.9 | 40.7 | 39.4 | 42.8 | 46.1 | 47.7 | 49.9 | 54.0 |

# G $L_{Aeq}$ across frequency spectrum data (630 Hz – 20 kHz)

| Facility Information | | Energy-Averaged $L_{Aeq,30min}$ [dB(A)] (Across Trials) | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Type** | **ID** | **630 Hz** | **800 Hz** | **1 kHz** | **1.25 kHz** | **1.6 kHz** | **2 kHz** | **2.5 kHz** | **3.15 kHz** | **4 kHz** | **5 kHz** | **6.3 kHz** | **8 kHz** | **10 kHz** | **12.5 kHz** | **16 kHz** | **20 kHz** |
| ATCT | DCA | 60.0 | 56.2 | 54.0 | 53.6 | 53.0 | 51.9 | 51.6 | 51.0 | 49.9 | 47.5 | 45.0 | 42.0 | 37.5 | 31.6 | 26.1 | 23.2 |
| ATCT | DVT | 53.1 | 51.3 | 48.5 | 48.9 | 49.2 | 47.4 | 46.0 | 45.3 | 43.4 | 40.8 | 38.1 | 35.6 | 30.7 | 25.8 | 21.1 | 15.7 |
| ATCT | DWH | 58.1 | 56.2 | 54.5 | 54.5 | 54.4 | 52.3 | 51.3 | 48.4 | 46.7 | 44.4 | 42.5 | 39.9 | 35.9 | 31.0 | 28.5 | 26.0 |
| ATCT | FFZ | 57.8 | 54.3 | 51.7 | 51.9 | 52.3 | 52.2 | 49.7 | 45.4 | 45.2 | 43.1 | 41.0 | 38.3 | 33.2 | 27.0 | 21.3 | 16.0 |
| ATCT | FLL | 49.7 | 48.8 | 49.2 | 47.4 | 48.2 | 46.8 | 45.7 | 45.1 | 44.0 | 43.1 | 40.0 | 36.6 | 32.9 | 27.8 | 22.7 | 22.9 |
| ATCT | FXE | 50.8 | 49.8 | 49.8 | 49.7 | 51.0 | 50.8 | 50.5 | 50.7 | 49.9 | 48.9 | 46.8 | 44.2 | 39.5 | 33.7 | 27.5 | 20.8 |
| ATCT | HOU | 54.1 | 51.0 | 51.4 | 51.5 | 51.7 | 49.8 | 48.7 | 47.9 | 46.1 | 44.5 | 41.6 | 39.7 | 34.7 | 27.9 | 22.1 | 18.5 |
| ATCT | IAH | 54.6 | 53.0 | 52.4 | 51.0 | 51.5 | 51.5 | 51.6 | 49.9 | 48.8 | 47.9 | 45.2 | 41.3 | 36.6 | 30.2 | 23.6 | 25.0 |
| ATCT | ILG | 50.4 | 46.8 | 46.7 | 46.6 | 45.8 | 45.4 | 45.7 | 43.1 | 40.4 | 37.8 | 35.1 | 32.4 | 28.7 | 24.2 | 27.7 | 14.1 |
| ATCT | PNE | 53.7 | 50.4 | 47.6 | 47.8 | 48.6 | 46.3 | 44.7 | 42.7 | 40.2 | 38.3 | 35.9 | 33.0 | 29.0 | 23.6 | 17.4 | 12.6 |
| ATCT | SDL | 54.5 | 51.2 | 49.4 | 49.4 | 50.0 | 47.1 | 45.3 | 43.0 | 41.9 | 39.9 | 38.1 | 35.8 | 32.2 | 27.2 | 22.4 | 19.0 |
| ATCT | TMB | 54.7 | 51.9 | 52.2 | 51.5 | 52.3 | 50.2 | 50.2 | 49.5 | 47.2 | 45.8 | 43.2 | 40.2 | 35.8 | 30.2 | 24.2 | 18.9 |
| ATCT | TTN | 49.3 | 45.2 | 43.9 | 46.3 | 46.3 | 44.1 | 44.4 | 42.4 | 38.8 | 45.1 | 40.3 | 32.6 | 30.6 | 25.3 | 18.5 | 10.7 |
| ATCT | TUS | 51.3 | 46.0 | 43.7 | 43.5 | 43.5 | 42.2 | 41.4 | 40.9 | 38.1 | 36.1 | 34.6 | 32.3 | 28.9 | 23.0 | 17.7 | 12.2 |
| ATCT | VRB | 51.2 | 48.5 | 46.5 | 48.2 | 48.1 | 46.8 | 44.8 | 43.2 | 43.1 | 41.9 | 39.0 | 35.9 | 32.0 | 26.6 | 21.6 | 16.4 |
| TRACON | I90 | 53.5 | 50.2 | 47.9 | 49.1 | 49.2 | 47.7 | 45.8 | 44.6 | 40.7 | 38.9 | 36.3 | 33.3 | 28.7 | 22.9 | 17.4 | 11.7 |
| TRACON | P50 | 53.4 | 50.6 | 48.3 | 49.4 | 50.0 | 47.7 | 46.8 | 43.2 | 42.9 | 41.9 | 38.6 | 35.9 | 31.7 | 26.3 | 20.1 | 14.3 |

| Facility Information | | Energy-Averaged $L_{Aeq,30min}$ [dB(A)] (Across Trials) | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Type** | **ID** | **630 Hz** | **800 Hz** | **1 kHz** | **1.25 kHz** | **1.6 kHz** | **2 kHz** | **2.5 kHz** | **3.15 kHz** | **4 kHz** | **5 kHz** | **6.3 kHz** | **8 kHz** | **10 kHz** | **12.5 kHz** | **16 kHz** | **20 kHz** |
| TRACON | PCT | 52.7 | 50.5 | 48.5 | 49.2 | 49.4 | 46.5 | 45.0 | 43.4 | 40.8 | 38.9 | 36.5 | 33.8 | 29.8 | 23.3 | 17.6 | 12.5 |
| TRACON | U90 | 52.4 | 49.6 | 48.5 | 47.9 | 48.2 | 45.5 | 44.9 | 42.3 | 41.2 | 39.4 | 35.8 | 33.4 | 28.6 | 23.4 | 21.8 | 13.4 |
| ATCT w/ TRACON | ABE ATCT | 47.8 | 44.8 | 43.8 | 44.0 | 44.0 | 43.9 | 43.9 | 43.9 | 43.0 | 41.5 | 39.7 | 36.5 | 30.0 | 24.1 | 18.8 | 12.8 |
| ATCT w/ TRACON | ABE TRACON | 49.4 | 47.4 | 46.7 | 46.4 | 45.0 | 44.5 | 44.1 | 42.2 | 40.6 | 39.6 | 36.9 | 33.8 | 31.0 | 24.9 | 19.6 | 21.1 |
| ATCT w/ TRACON | ACY ATCT | 50.9 | 45.8 | 44.9 | 43.9 | 44.1 | 41.7 | 40.8 | 41.8 | 38.2 | 35.6 | 33.1 | 30.9 | 25.6 | 19.7 | 14.2 | 8.4 |
| ATCT w/ TRACON | ACY TRACON | 50.2 | 48.0 | 44.6 | 44.8 | 43.8 | 43.0 | 45.4 | 40.1 | 38.2 | 36.6 | 32.8 | 29.3 | 25.3 | 19.5 | 23.3 | 9.9 |
| ATCT w/ TRACON | MDT ATCT | 48.5 | 46.2 | 44.0 | 44.7 | 43.0 | 41.1 | 44.7 | 40.3 | 38.0 | 36.4 | 33.2 | 29.6 | 25.9 | 19.9 | 13.9 | 13.6 |
| ATCT w/ TRACON | MDT TRACON | 53.1 | 51.1 | 50.7 | 50.0 | 50.3 | 50.0 | 49.7 | 49.6 | 49.7 | 47.6 | 45.5 | 41.8 | 38.1 | 32.1 | 24.5 | 18.3 |
| ATCT w/ TRACON | MIA ATCT | 51.9 | 51.1 | 51.8 | 50.2 | 51.5 | 49.3 | 48.5 | 46.8 | 45.0 | 42.7 | 40.1 | 37.3 | 33.6 | 28.8 | 22.4 | 20.6 |
| ATCT w/ TRACON | MIA TRACON | 56.5 | 51.8 | 49.7 | 50.2 | 50.0 | 47.4 | 46.8 | 43.9 | 40.7 | 38.1 | 35.8 | 32.8 | 29.0 | 23.6 | 18.5 | 12.7 |
| ATCT w/ TRACON | PBI ATCT | 52.6 | 51.4 | 48.9 | 47.1 | 48.3 | 46.2 | 45.4 | 45.2 | 43.1 | 40.1 | 38.0 | 34.9 | 30.7 | 25.2 | 19.5 | 15.0 |
| ATCT w/ TRACON | PBI TRACON | 50.6 | 49.5 | 48.2 | 48.1 | 51.5 | 45.9 | 44.8 | 44.5 | 44.3 | 44.0 | 42.3 | 39.8 | 34.8 | 26.9 | 18.8 | 12.4 |
| ATCT w/ TRACON | PHL ATCT | 54.5 | 52.4 | 51.1 | 50.4 | 50.3 | 48.6 | 49.2 | 48.4 | 49.2 | 48.9 | 48.2 | 43.5 | 39.1 | 32.3 | 26.3 | 32.5 |
| ATCT w/ TRACON | PHL TRACON | 50.2 | 47.7 | 46.8 | 47.9 | 49.1 | 48.3 | 47.5 | 46.1 | 44.7 | 44.9 | 41.7 | 39.3 | 35.8 | 29.0 | 21.0 | 15.0 |
| ARTCC | ZDC | 53.3 | 52.7 | 50.8 | 50.7 | 50.6 | 48.7 | 46.5 | 45.6 | 43.1 | 40.9 | 37.4 | 35.3 | 31.2 | 25.8 | 19.7 | 14.4 |
| ARTCC | ZHU | 61.8 | 57.1 | 55.0 | 56.0 | 57.9 | 55.8 | 54.2 | 53.0 | 51.1 | 49.0 | 45.1 | 41.5 | 37.7 | 32.5 | 25.8 | 19.5 |
| ARTCC | ZMA | 53.5 | 51.1 | 48.9 | 49.9 | 49.8 | 47.8 | 46.7 | 45.1 | 42.6 | 41.4 | 38.7 | 35.9 | 31.3 | 25.6 | 21.4 | 15.9 |

# H Glossary

| Term | Definition |
|---|---|
| A-frequency-weighting filter | A method of filtering sound measurements to consider the frequencies that the human ear is most sensitive to over the frequencies that are not as perceivable (FAA, 2022) |
| Ambient Sound | Includes all background sounds in an environment (Federal Interagency Committee on Noise, 1992) |
| Amplitude | Sound wave relative strength; perceived as loudness of sound (NPS, 2018) |
| Decibels (dB) | Unit used to measure the intensity of sound; measured on a logarithmic scale (FAA, 2022). |
| dB(A) | Unit to estimate the intensity of sound as it is perceived by humans, while also considering the range of the frequency spectrum that is most detectable to the human ear (FAA, 2022) |
| Fast time weighting | Time weighting with a 125 ms time constant; beneficial to show fast, sharp variations in sound (NoiseMeters Inc., n.d.) |
| Frequency | The number of vibrations that occur at a certain point in one second; perceived as pitch of sound (NPS, 2018) |
| Hertz (Hz) | Unit for expressing frequency (NPS, 2018) |
| $L_{Aeq}$ | Equivalent continuous sound level in A-weighted decibels (CDC, 2024) |
| $L_{AFmax}$ | The maximum sound level captured over a set period with A-weighting and fast time weighting applied (NoiseMeters Inc., n.d.) |
| $L_{ASmax}$ | The maximum sound level captured over a set period with A-weighting and slow time weighting applied (NoiseMeters Inc., n.d.) |
| $L_{eq}$ | Equivalent continuous sound level; average acoustic energy over a set period of time to take account of the cumulative effect of multiple noise events (FAA, 2022) |
| $L_{peak}$ | The maximum value reached by the sound level meter with no time weighting filter applied (NoiseMeters, Inc., n.d.) |
| Slow time weighting | Time weighting with a 1 second time constant; beneficial to reduce large spikes in measurement due to quick, sharp sounds, as it smooths out quick sound variations that do not extend beyond one second (NoiseMeters Inc., n.d.) |

# I Sound level meter placements

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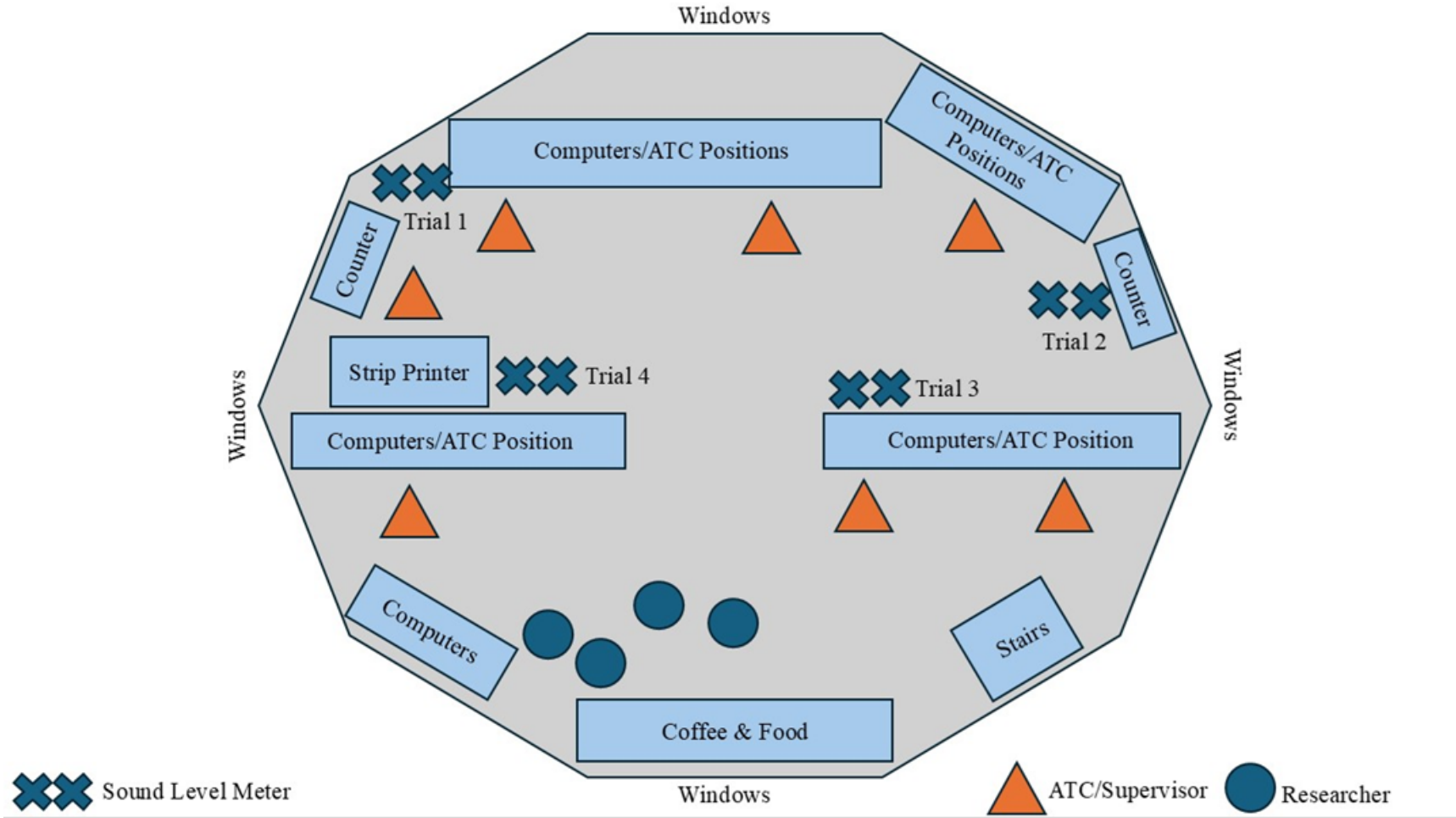



Figure I-1. DCA ambient sound measurement trial locations

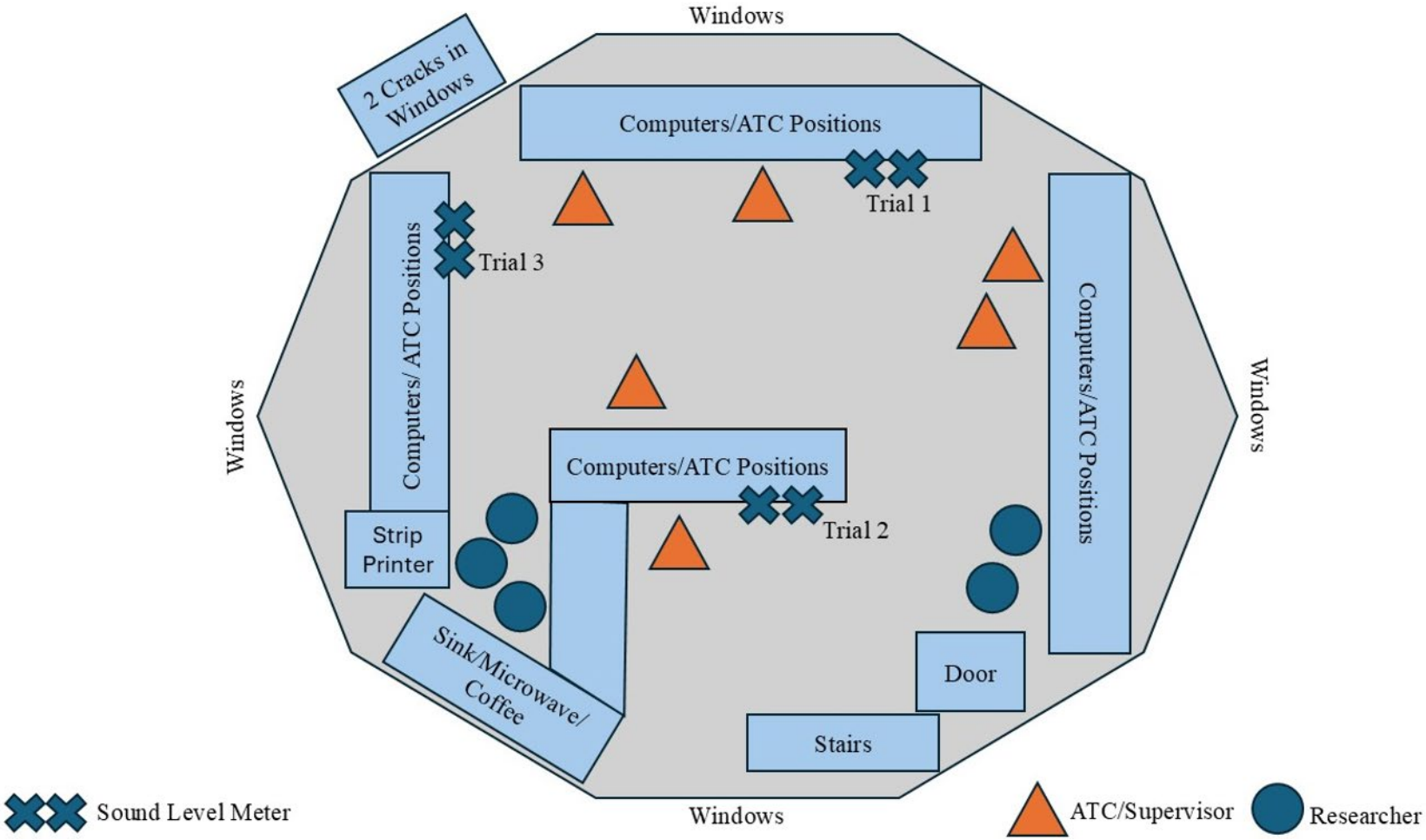



Figure I-2. DVT ambient sound measurement trial locations

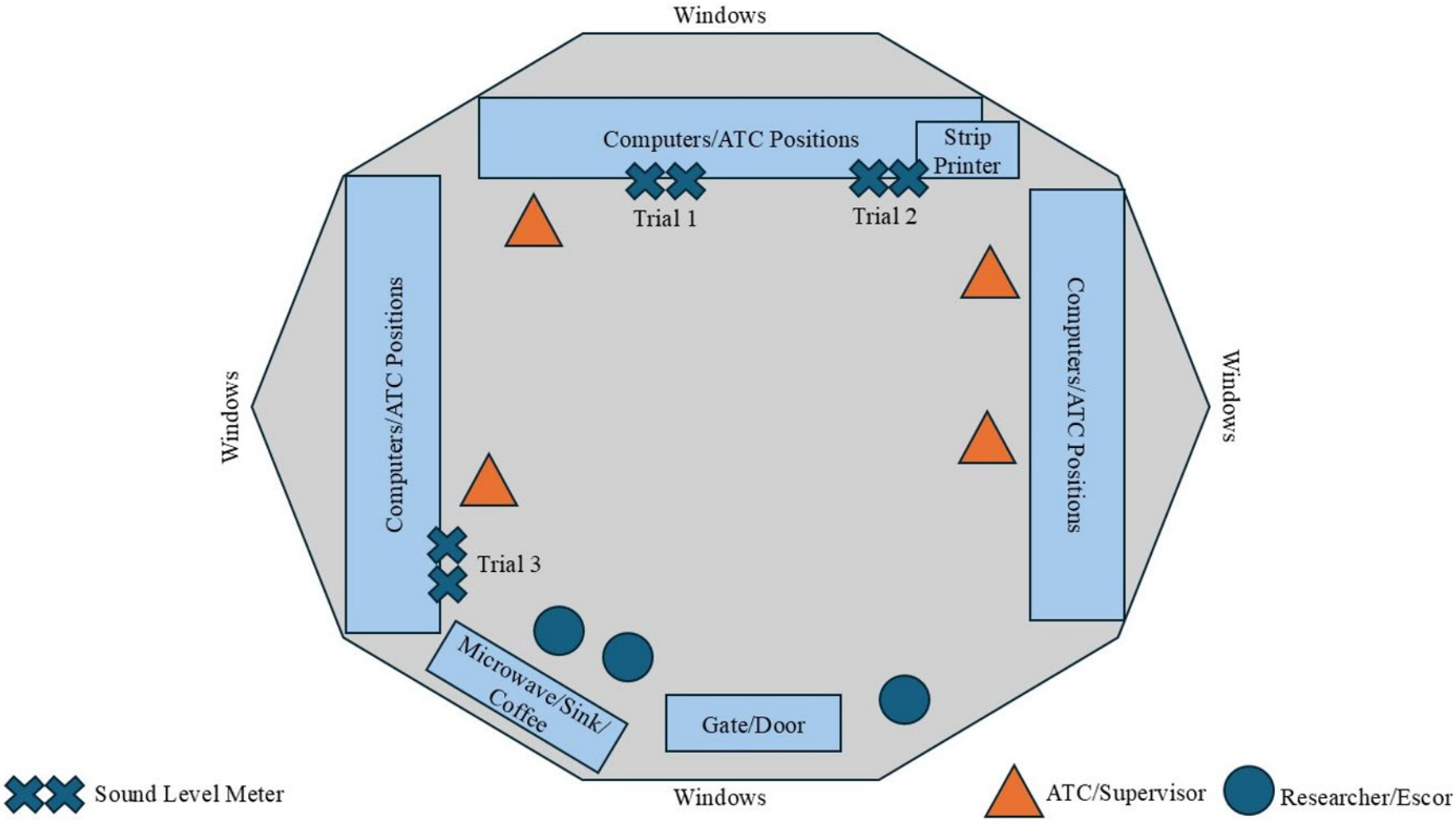



Figure I-3. DWH ambient sound measurement trial locations

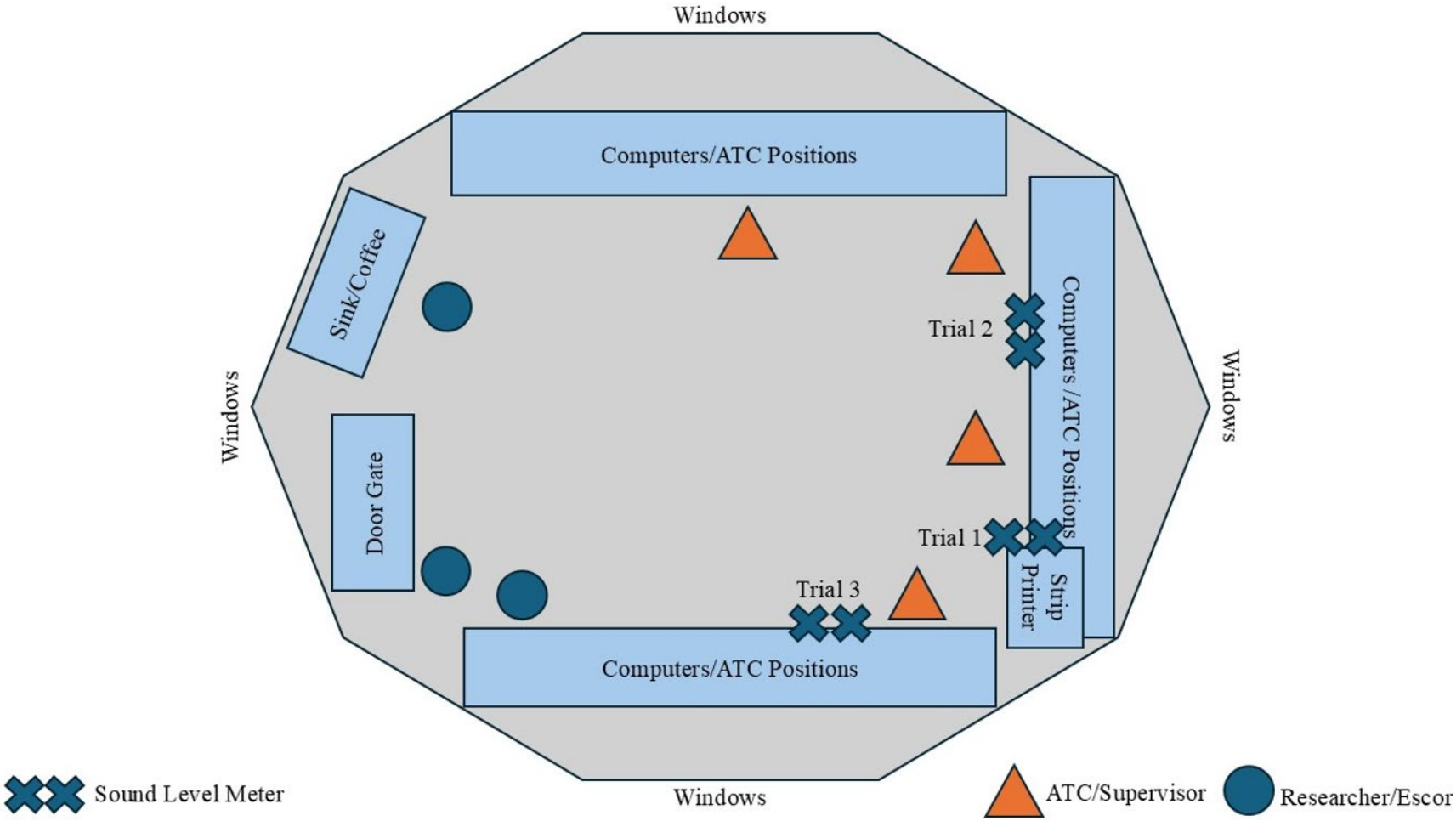



Figure I-4. FFZ ambient sound measurement trial locations

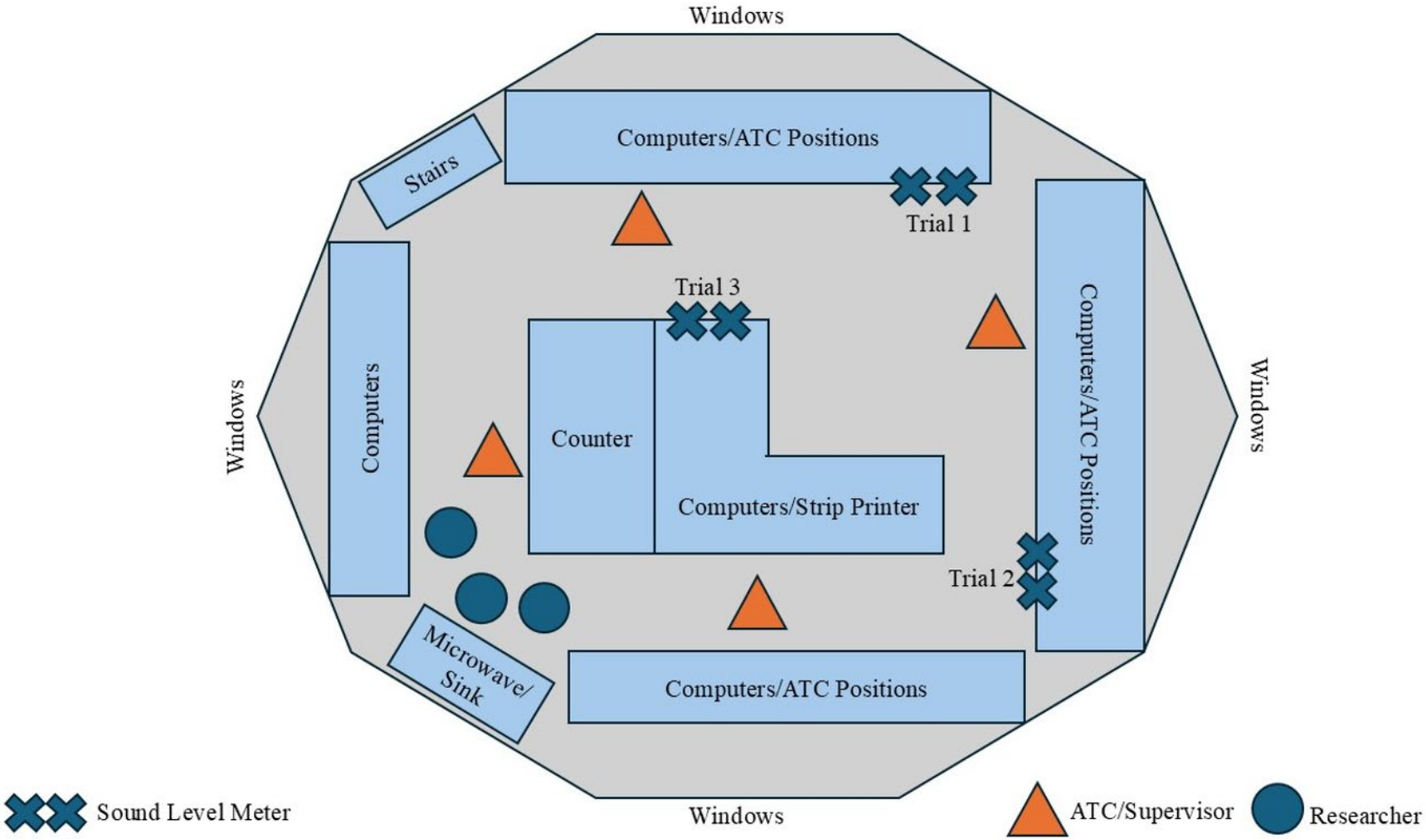



Figure I-5. FLL ambient sound measurement trial locations

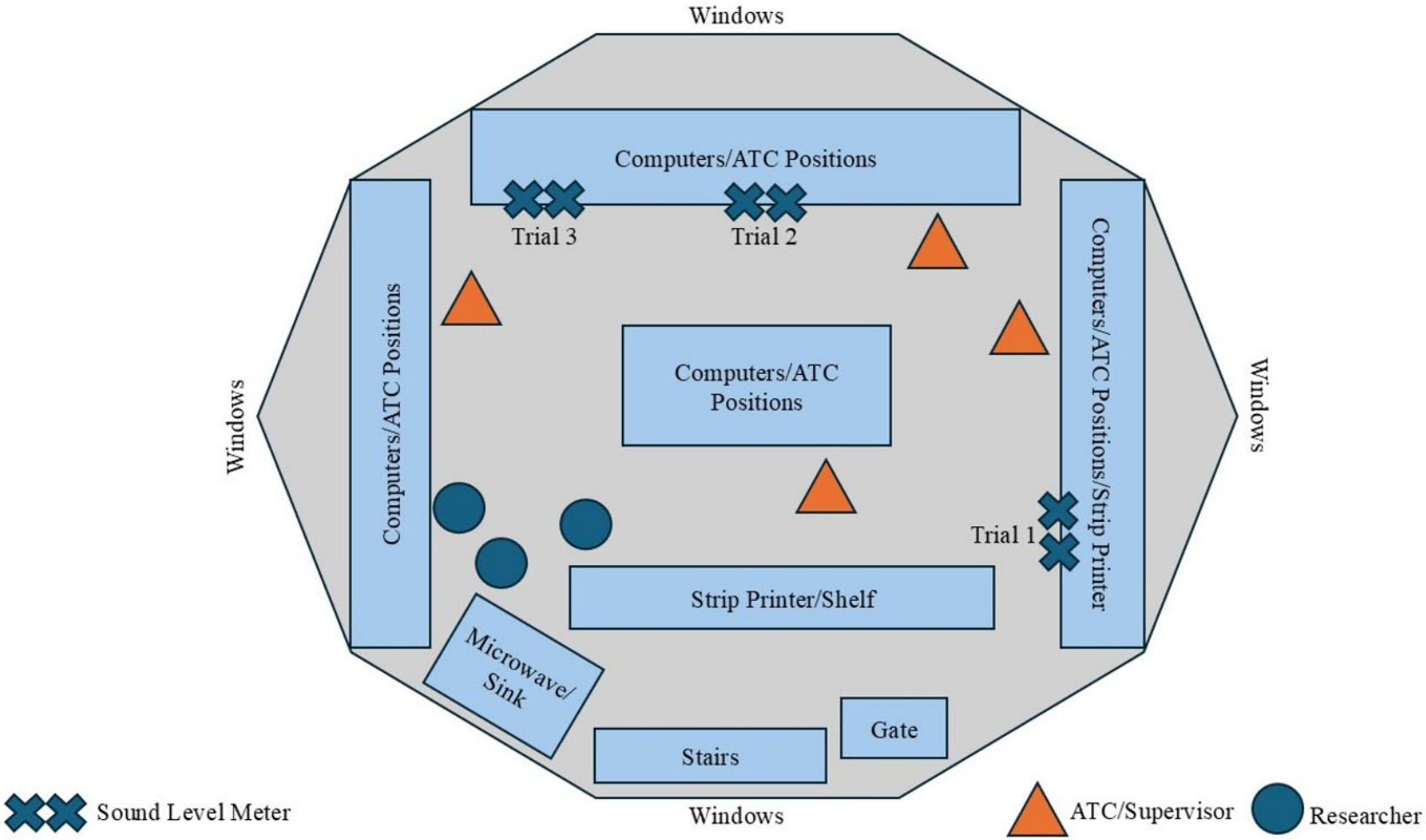



Figure I-6. FXE ambient sound measurement trial locations

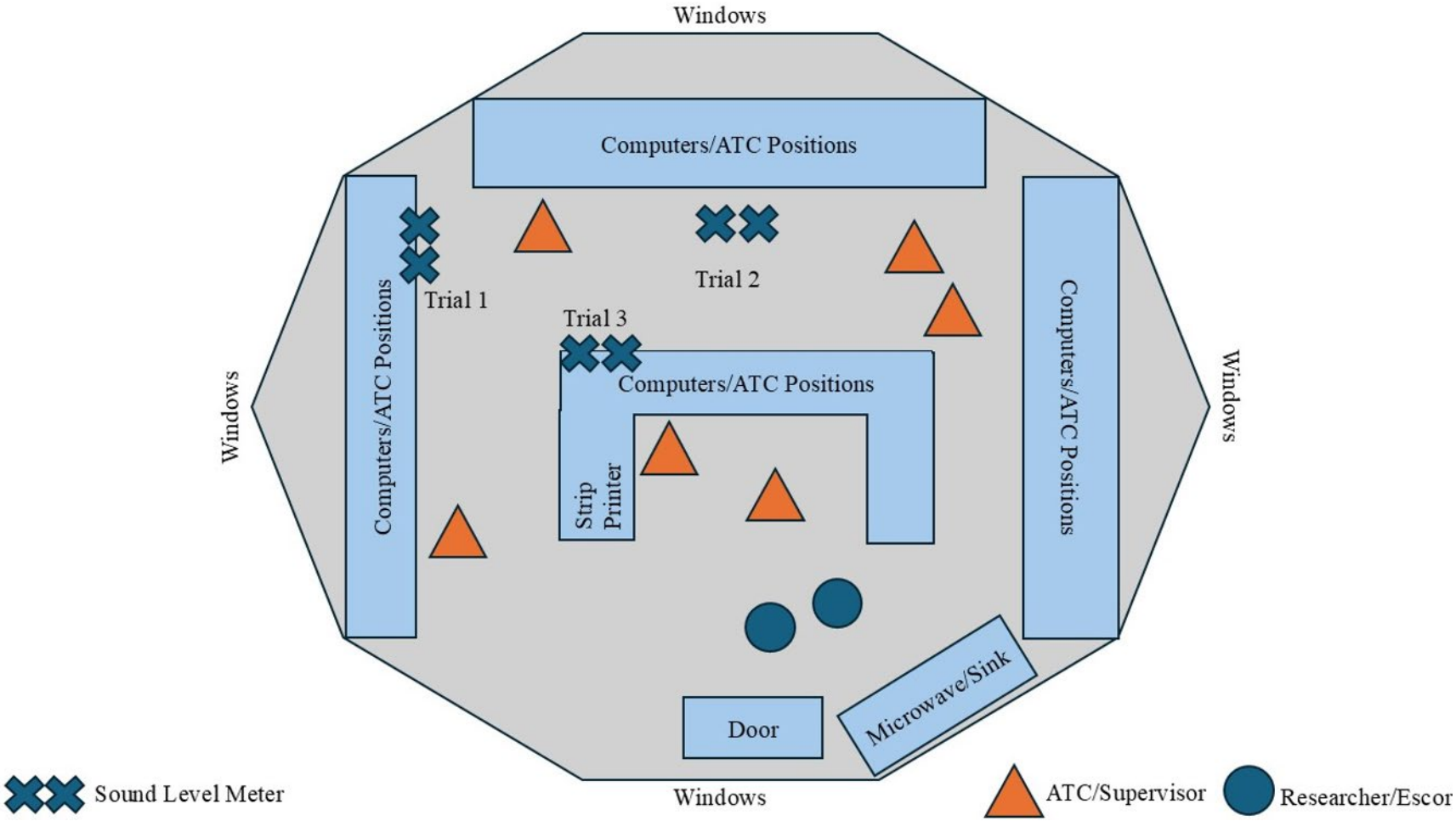



Figure I-7. HOU ambient sound measurement trial locations

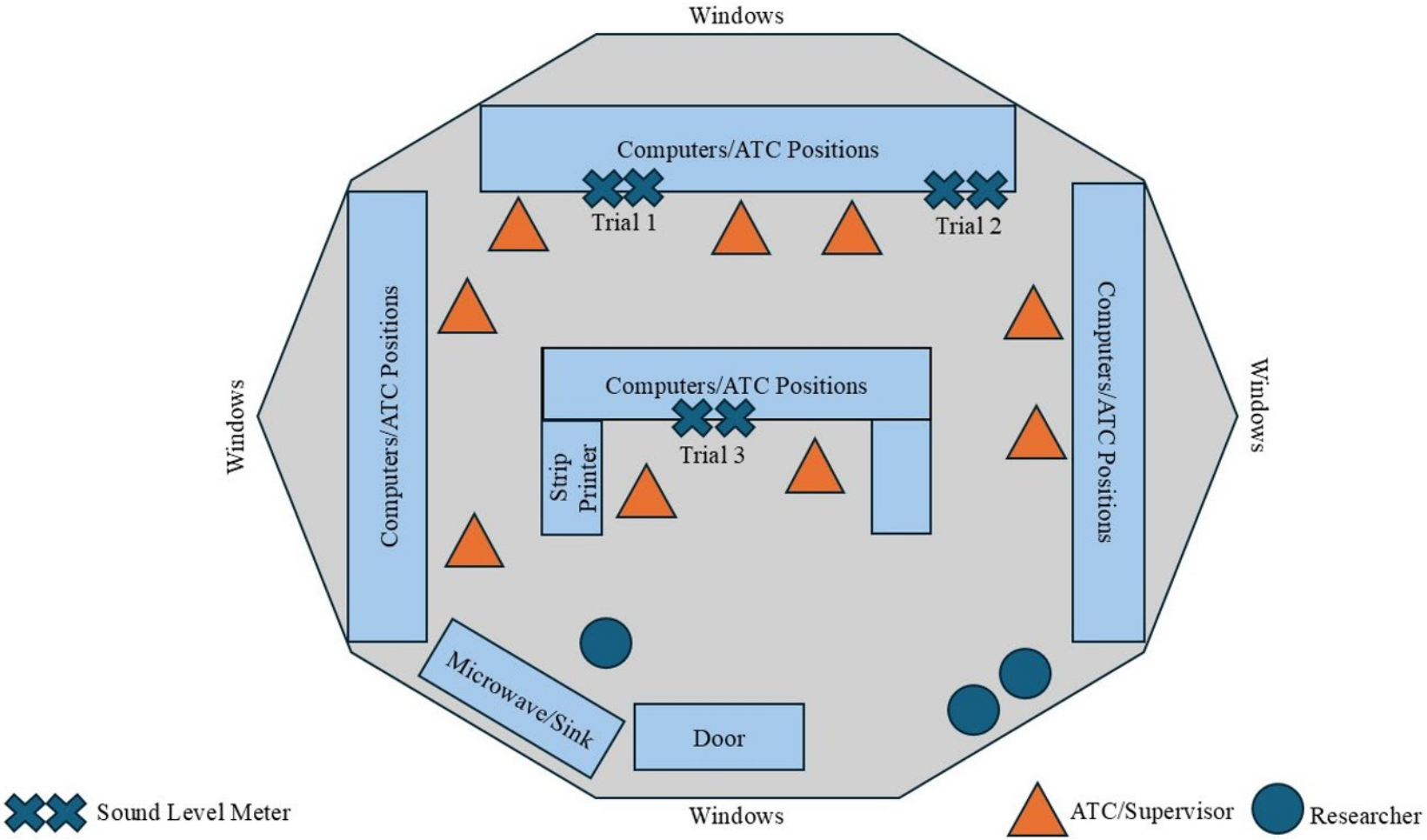



Figure I-8. IAH ambient sound measurement trial locations

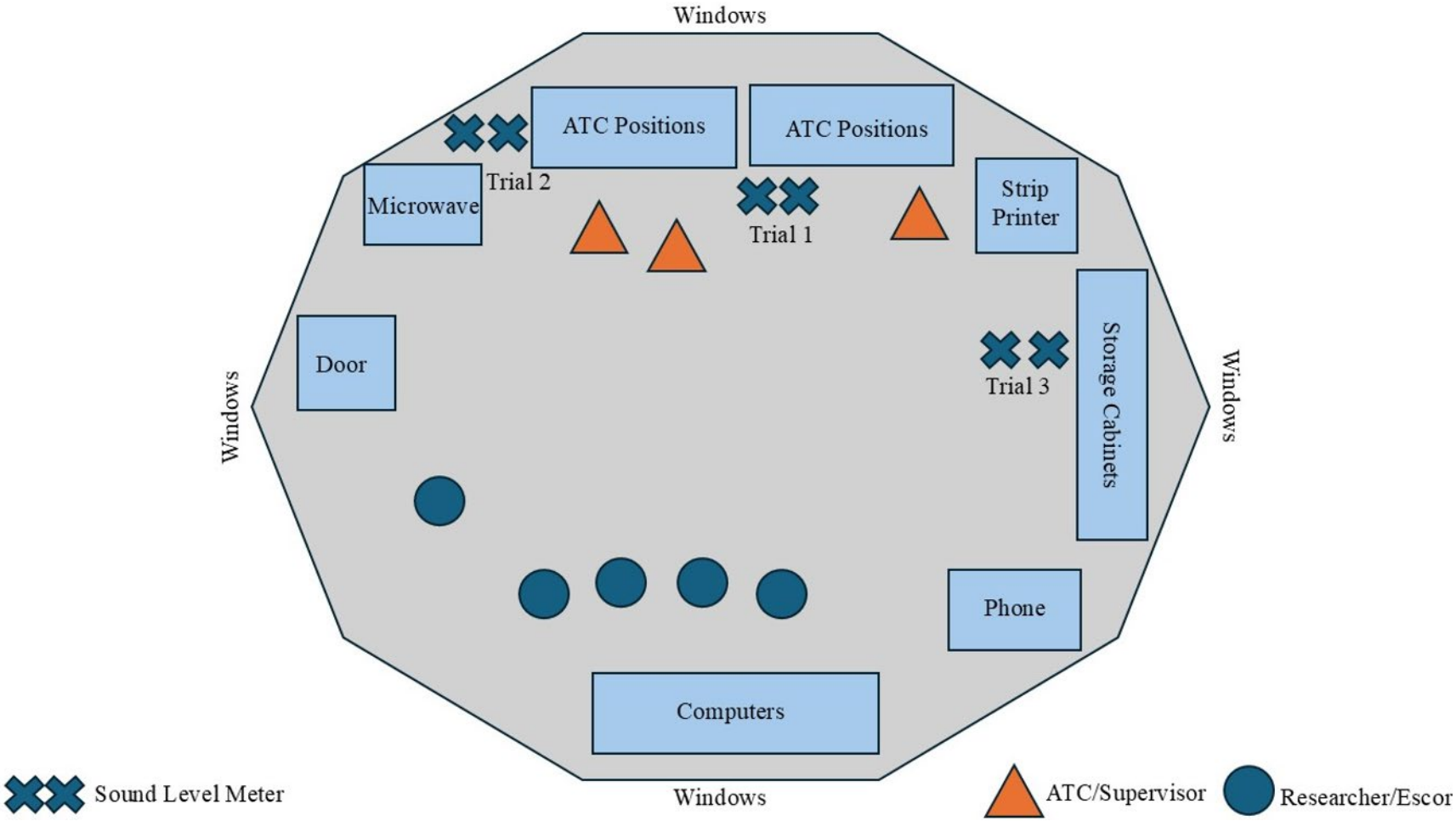



Figure I-9. ILG ambient sound measurement trial locations

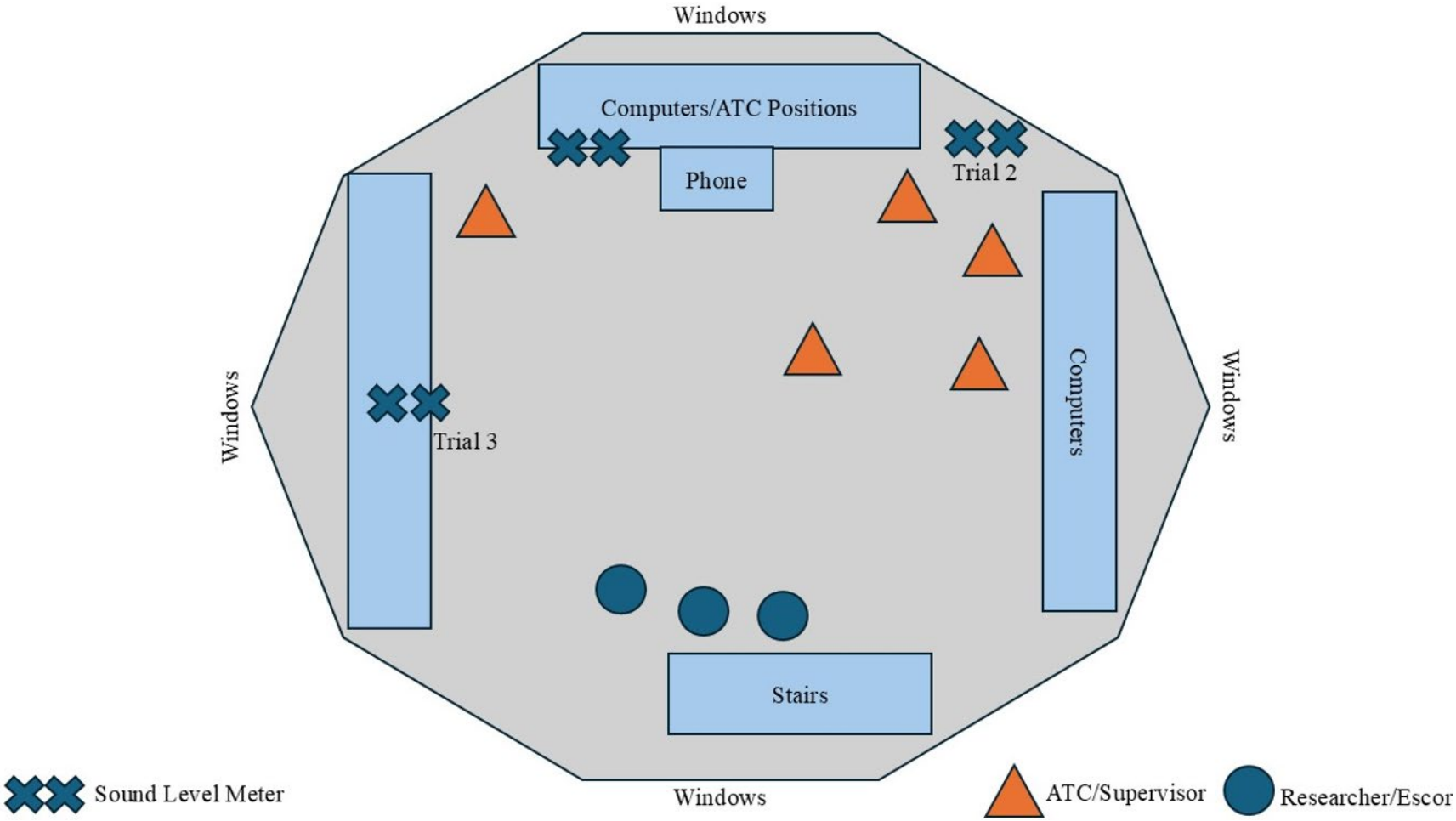



Figure I-10. PNE ambient sound measurement trial locations

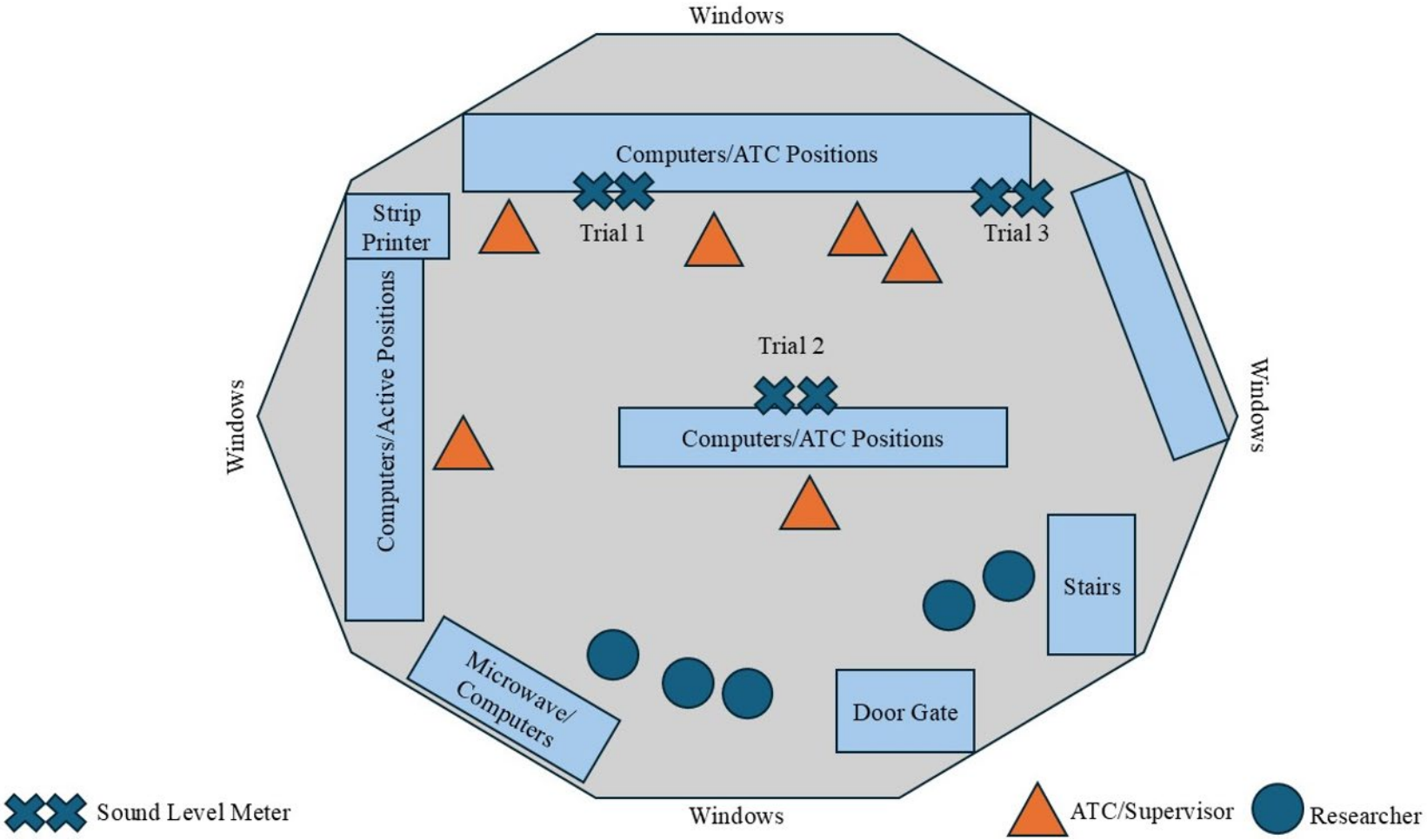



Figure I-11. SDL ambient sound measurement trial locations

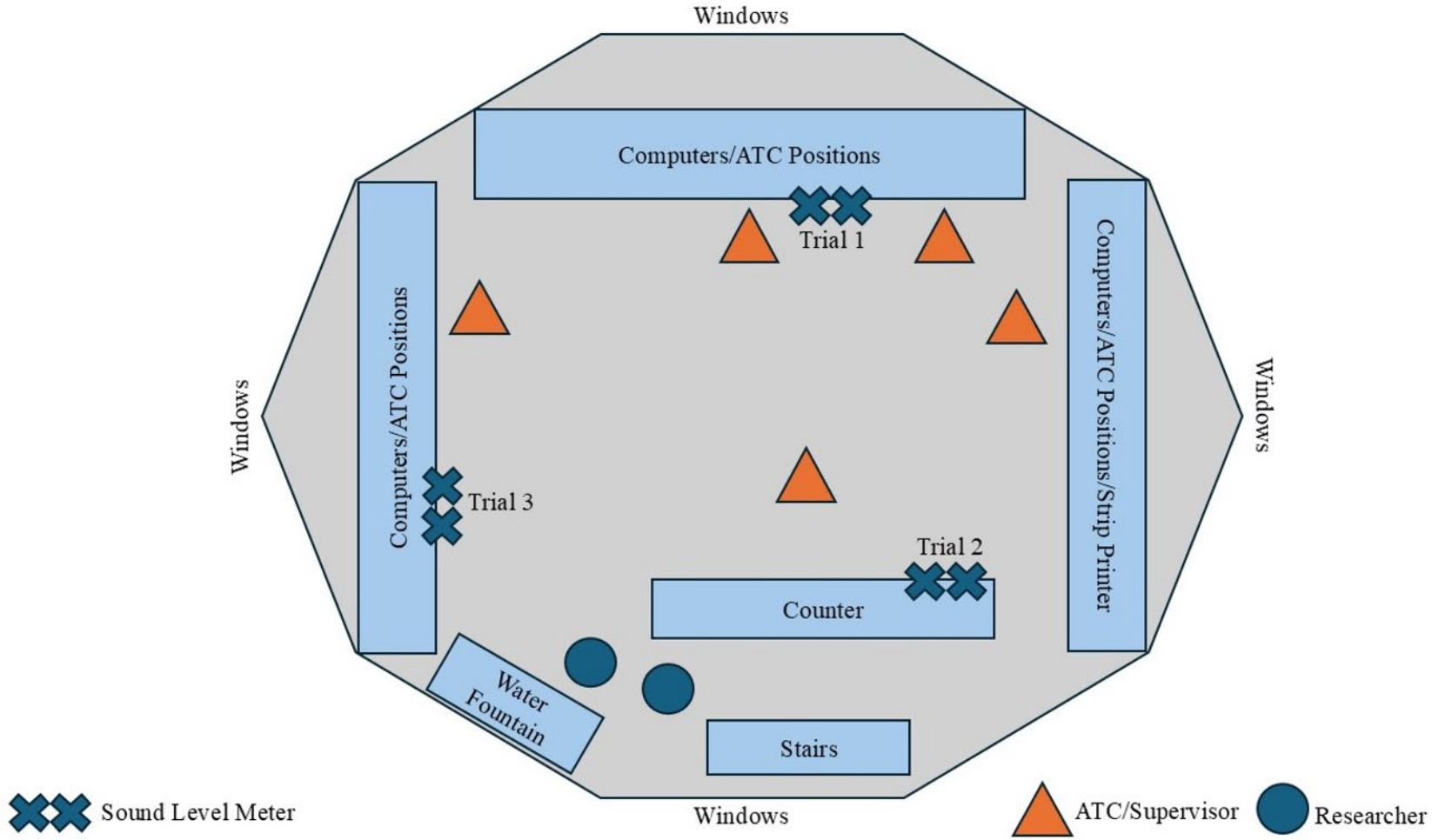



Figure I-12. TMB ambient sound measurement trial locations

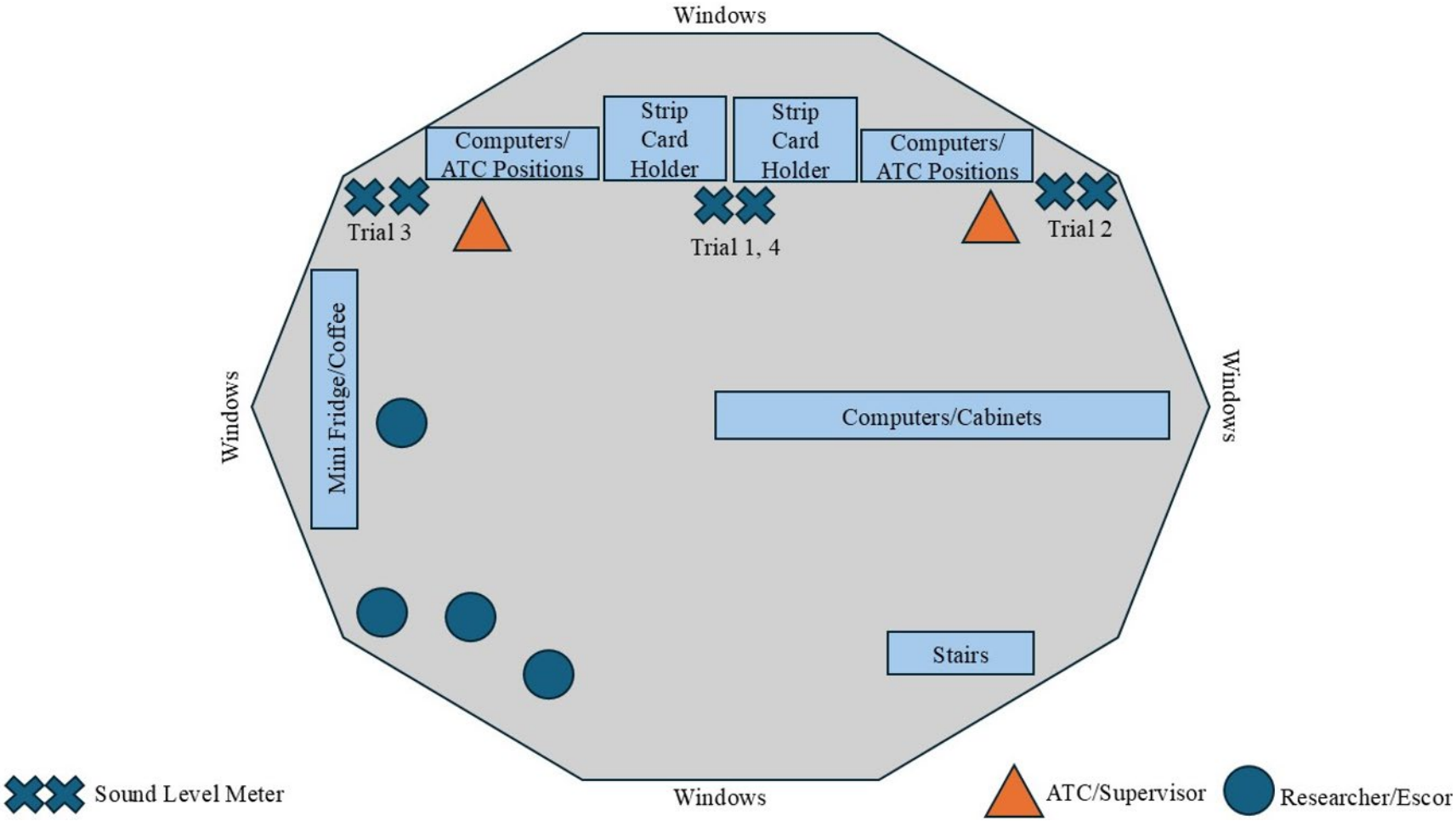



Figure I-13. TTN ambient sound measurement trial locations

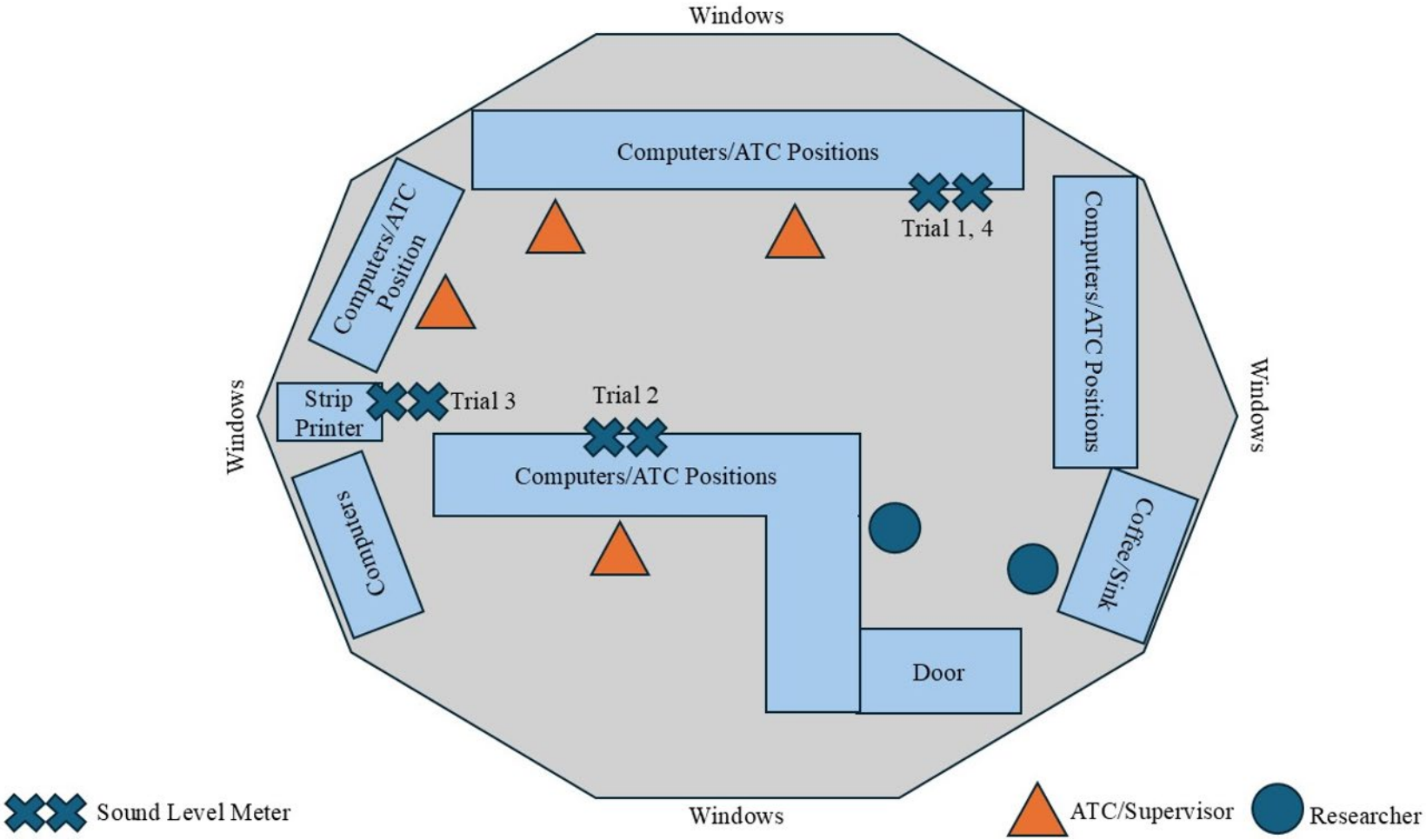



Figure I-14. TUS ambient sound measurement trial locations

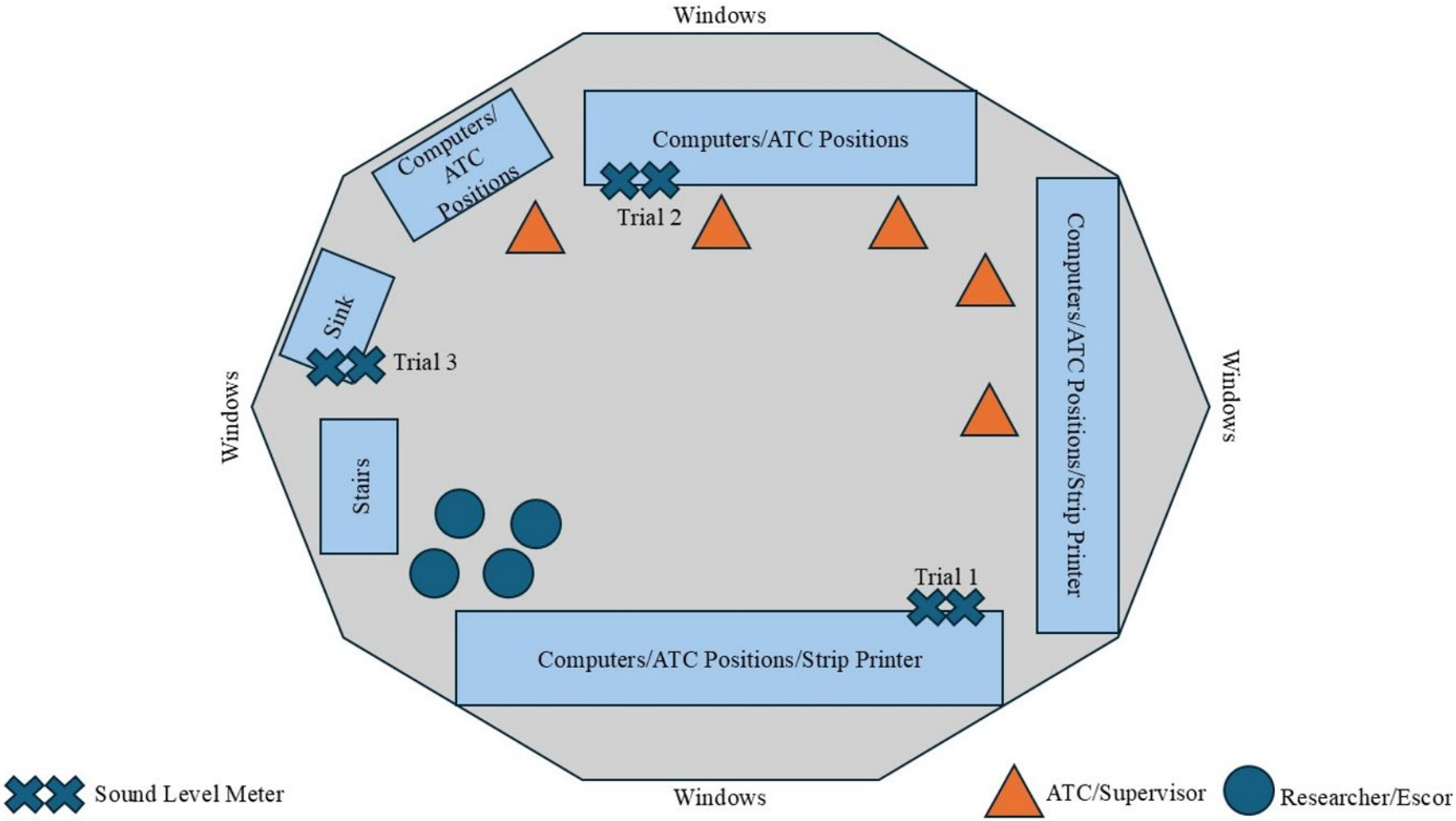



Figure I-15. VRB ambient sound measurement trial locations

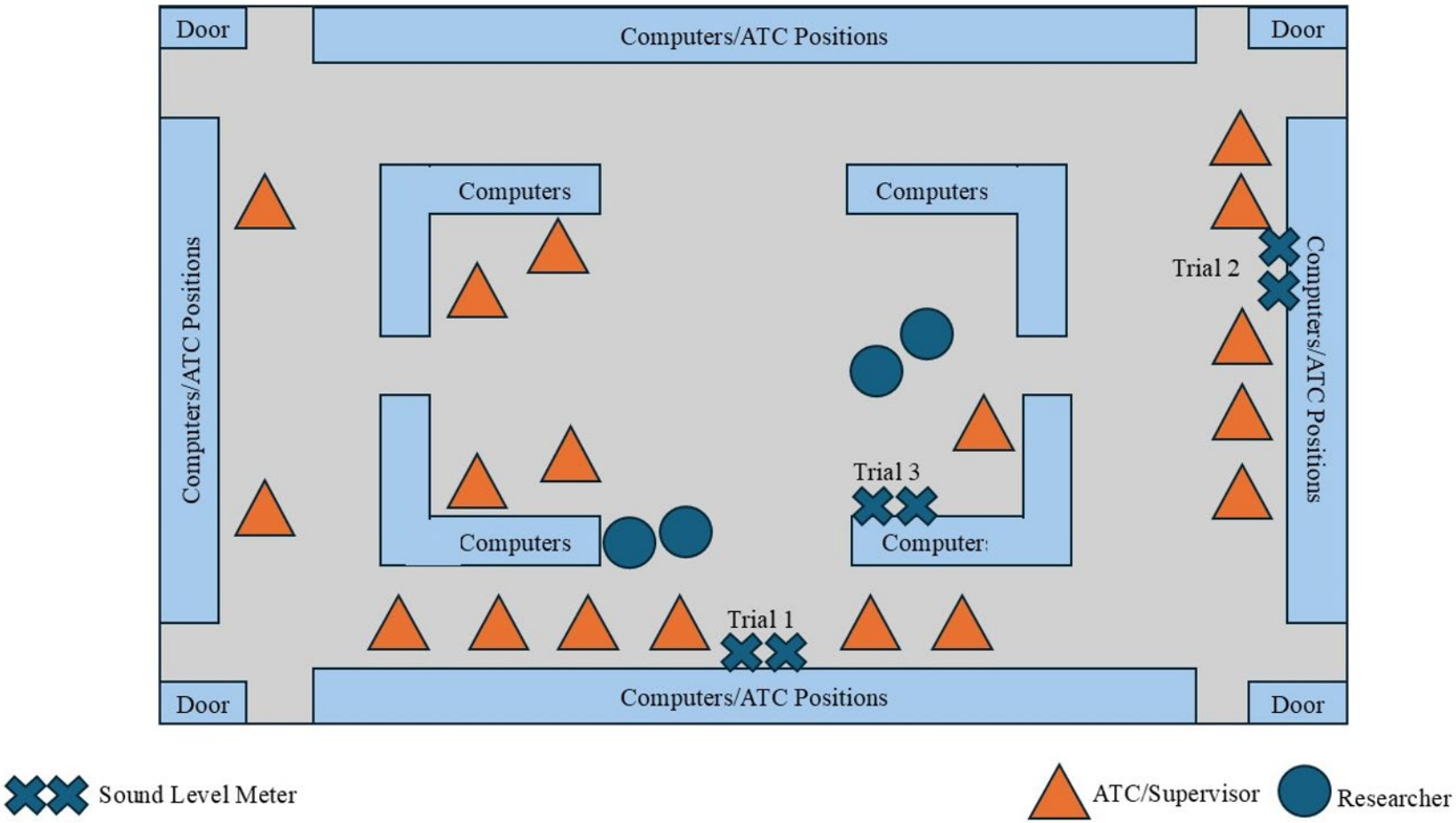



Figure I-16. I90 ambient sound measurement trial locations

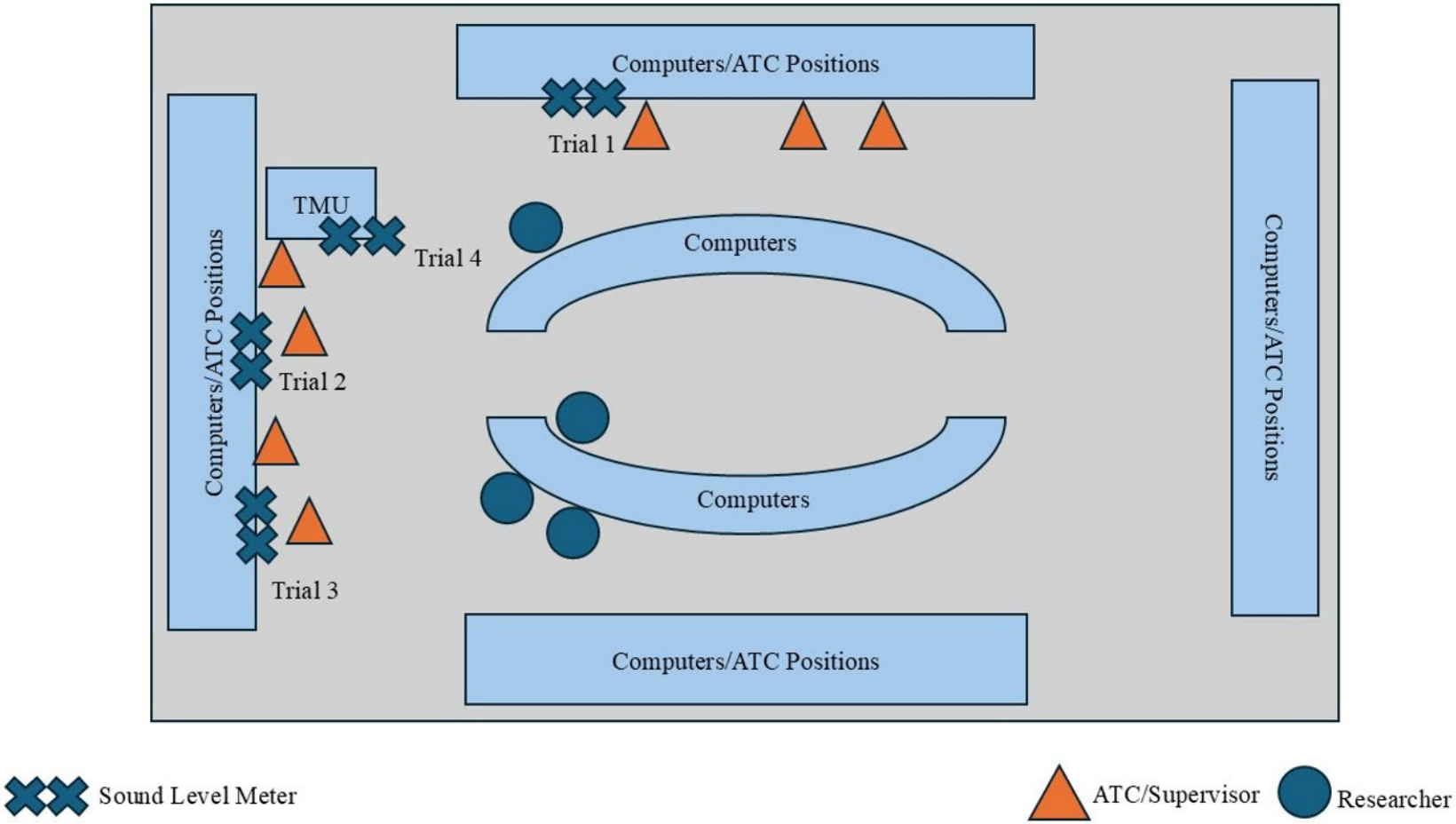



Figure I-17. P50 ambient sound measurement trial locations

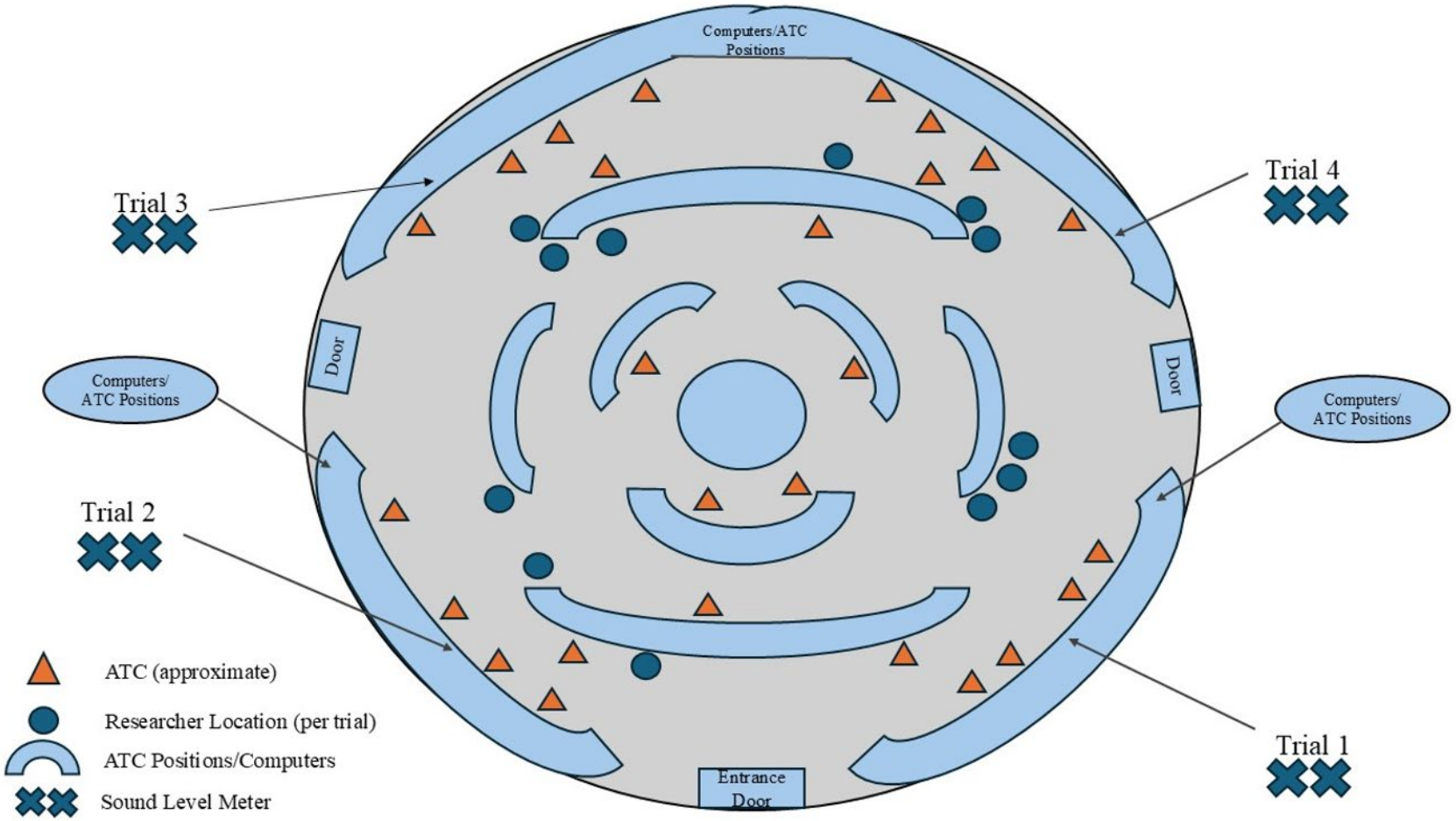



Figure I-18. PCT ambient sound measurement trial locations

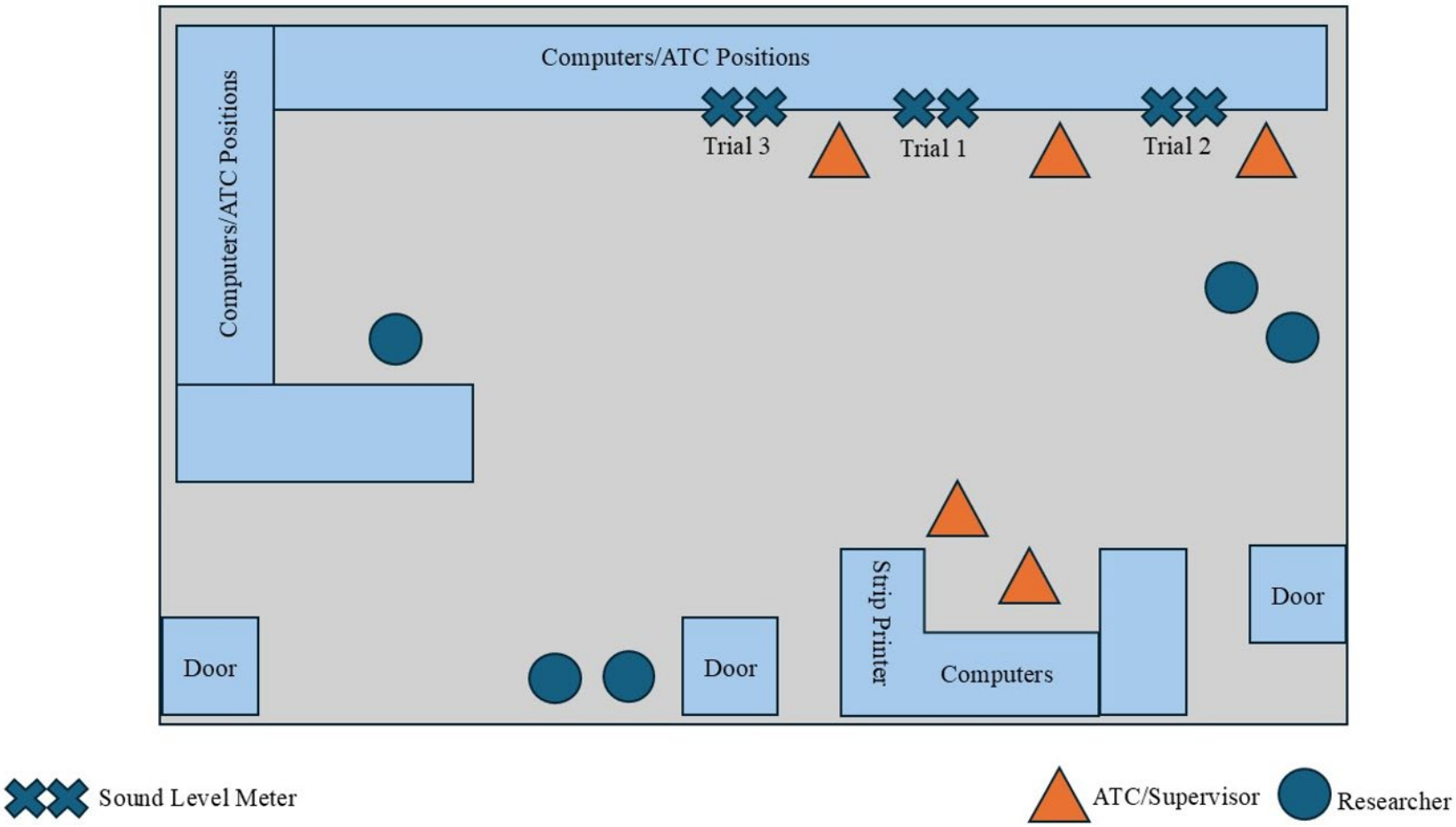



Figure I-19. U90 ambient sound measurement trial locations

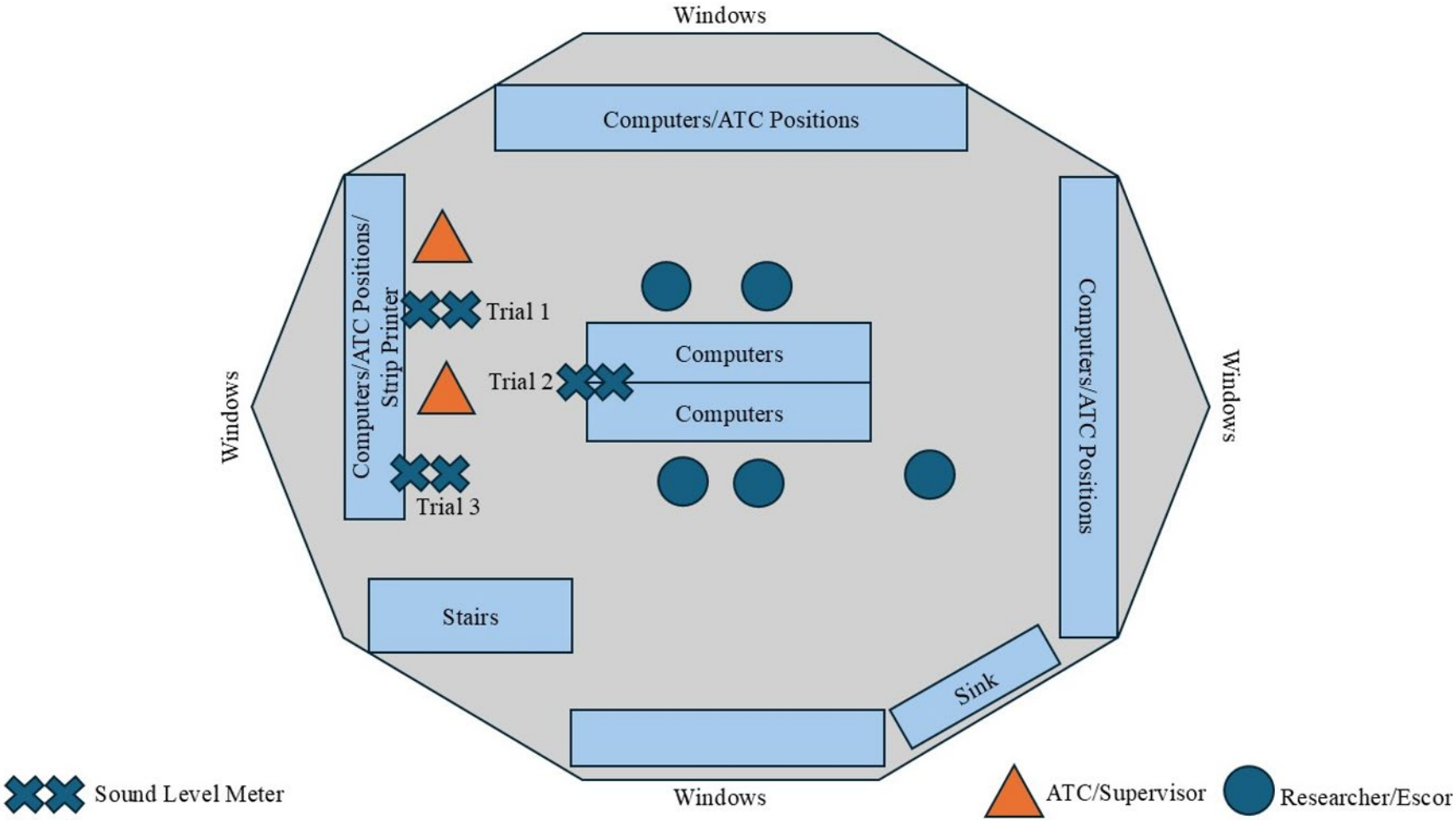



Figure I-20. ABE ATCT ambient sound measurement trial locations

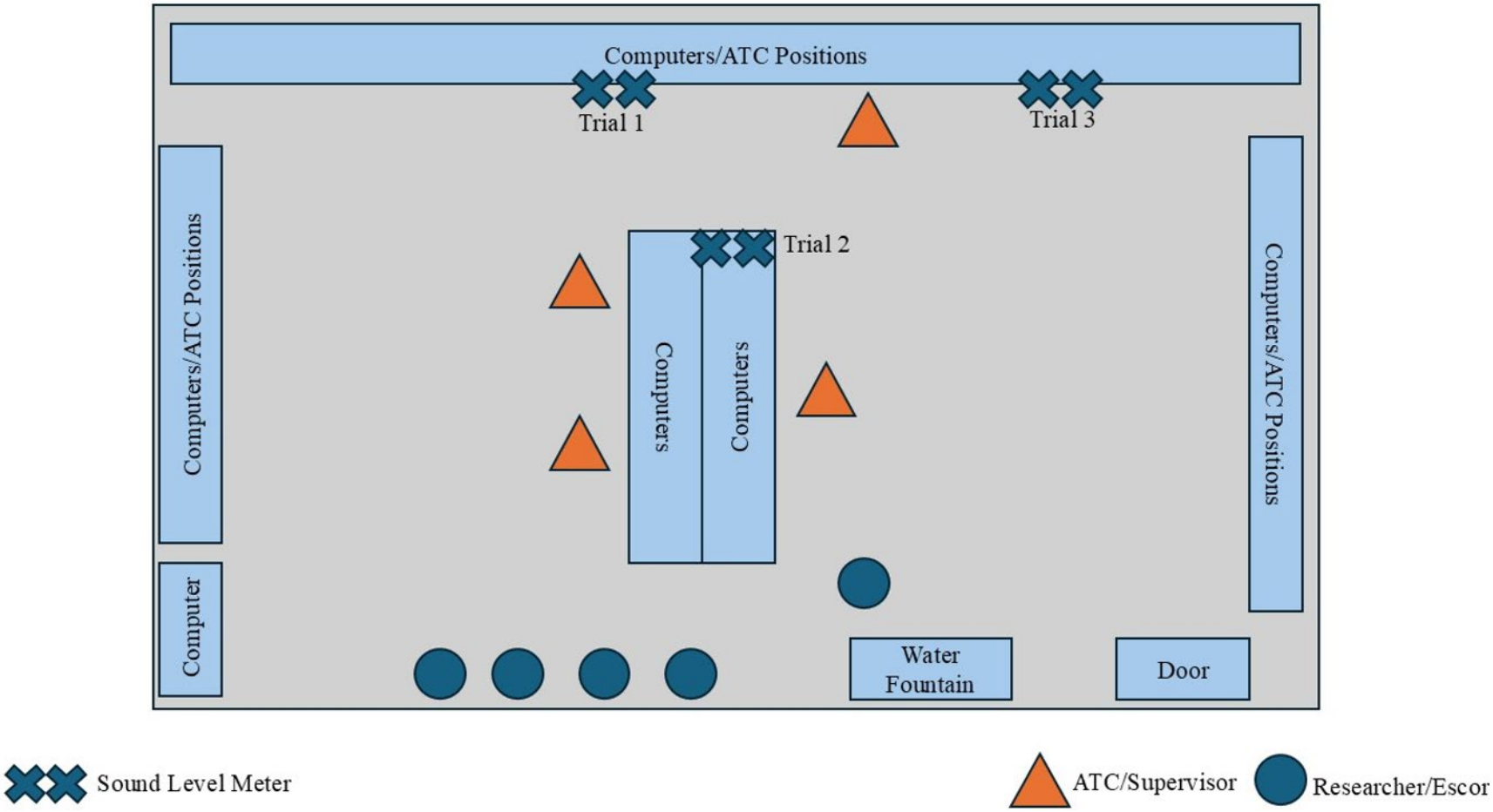



Figure I-21. ABE TRACON ambient sound measurement trial locations

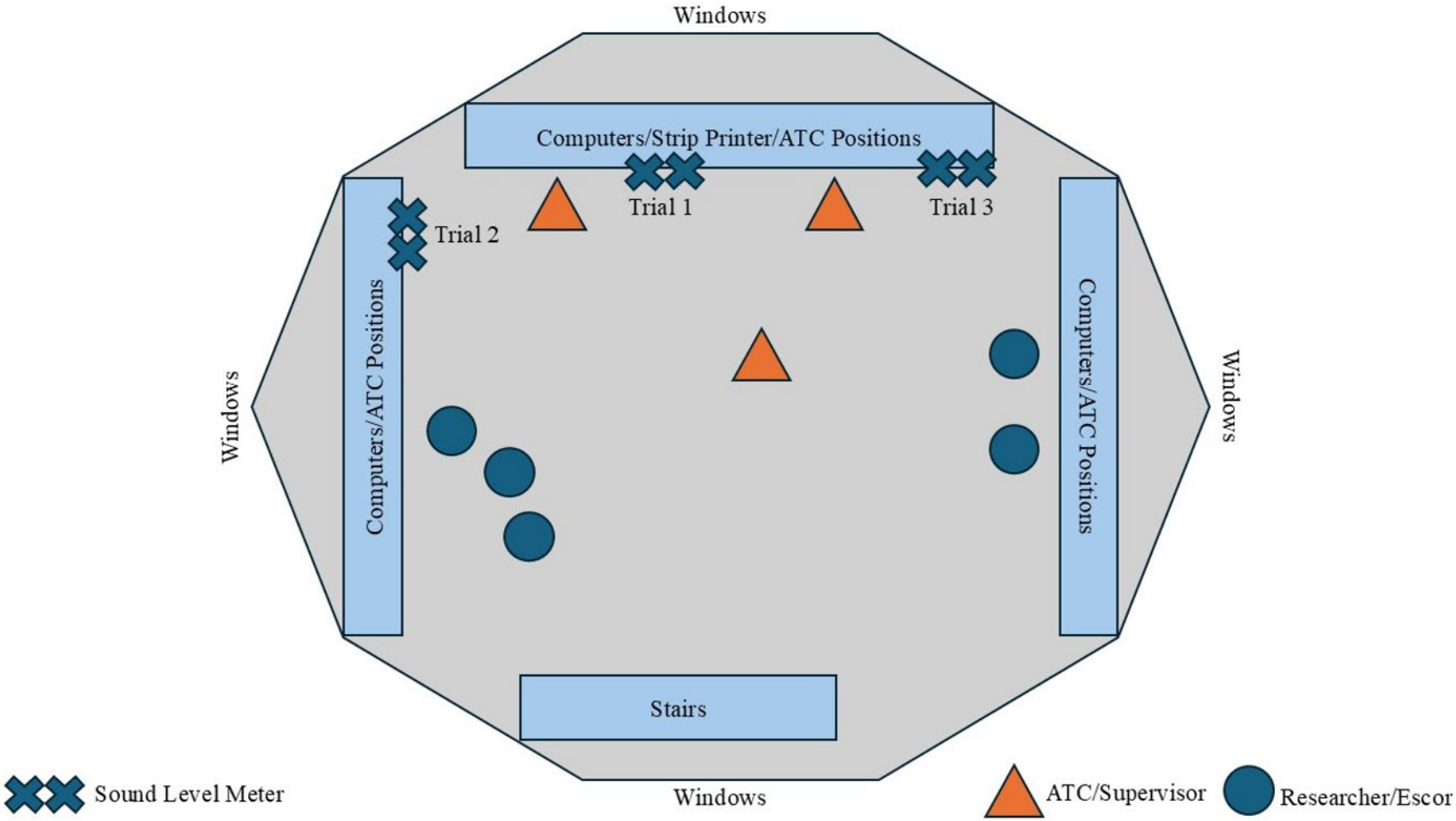



Figure I-22. MDT ATCT ambient sound measurement trial locations

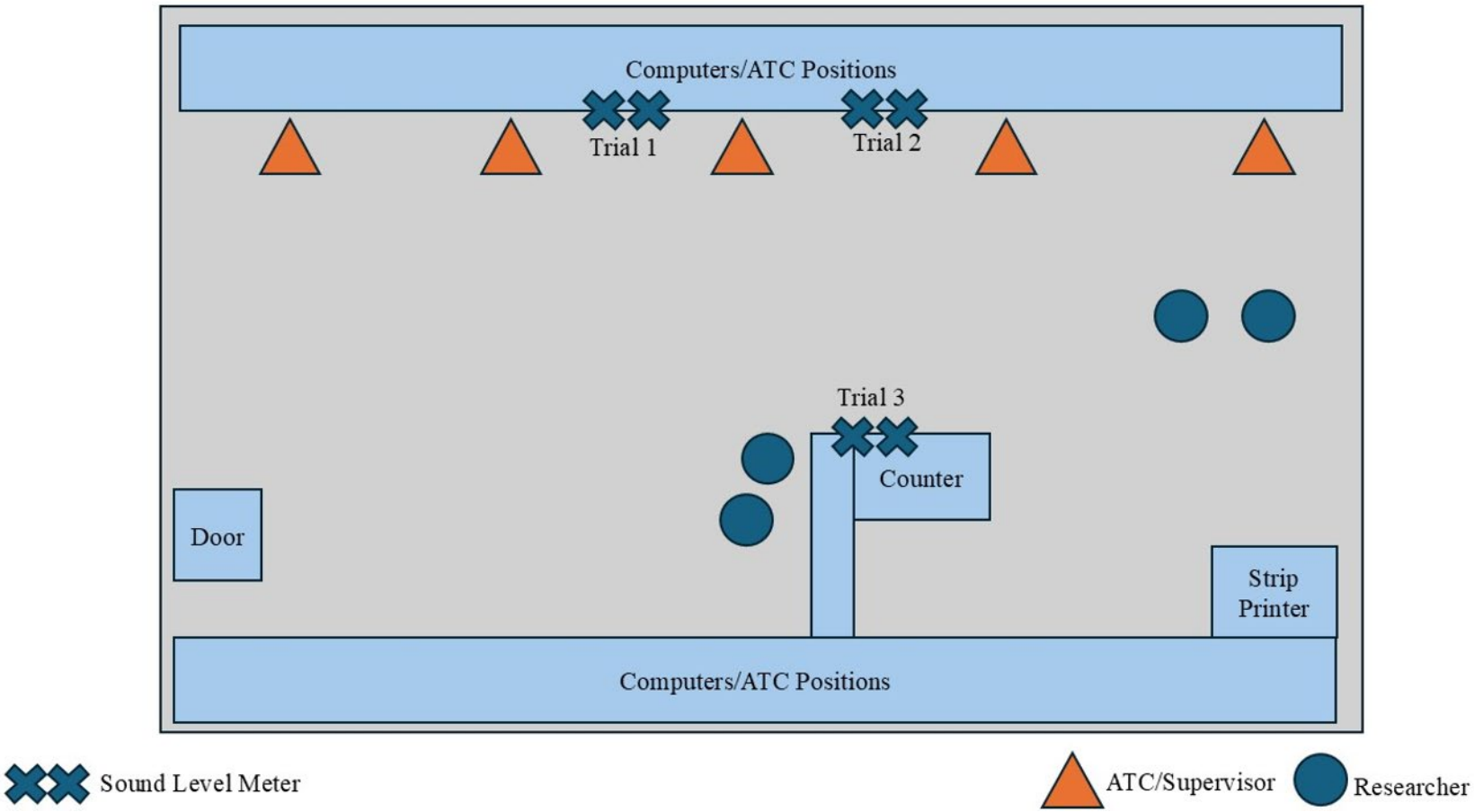



Figure I-23. MDT TRACON ambient sound measurement trial locations

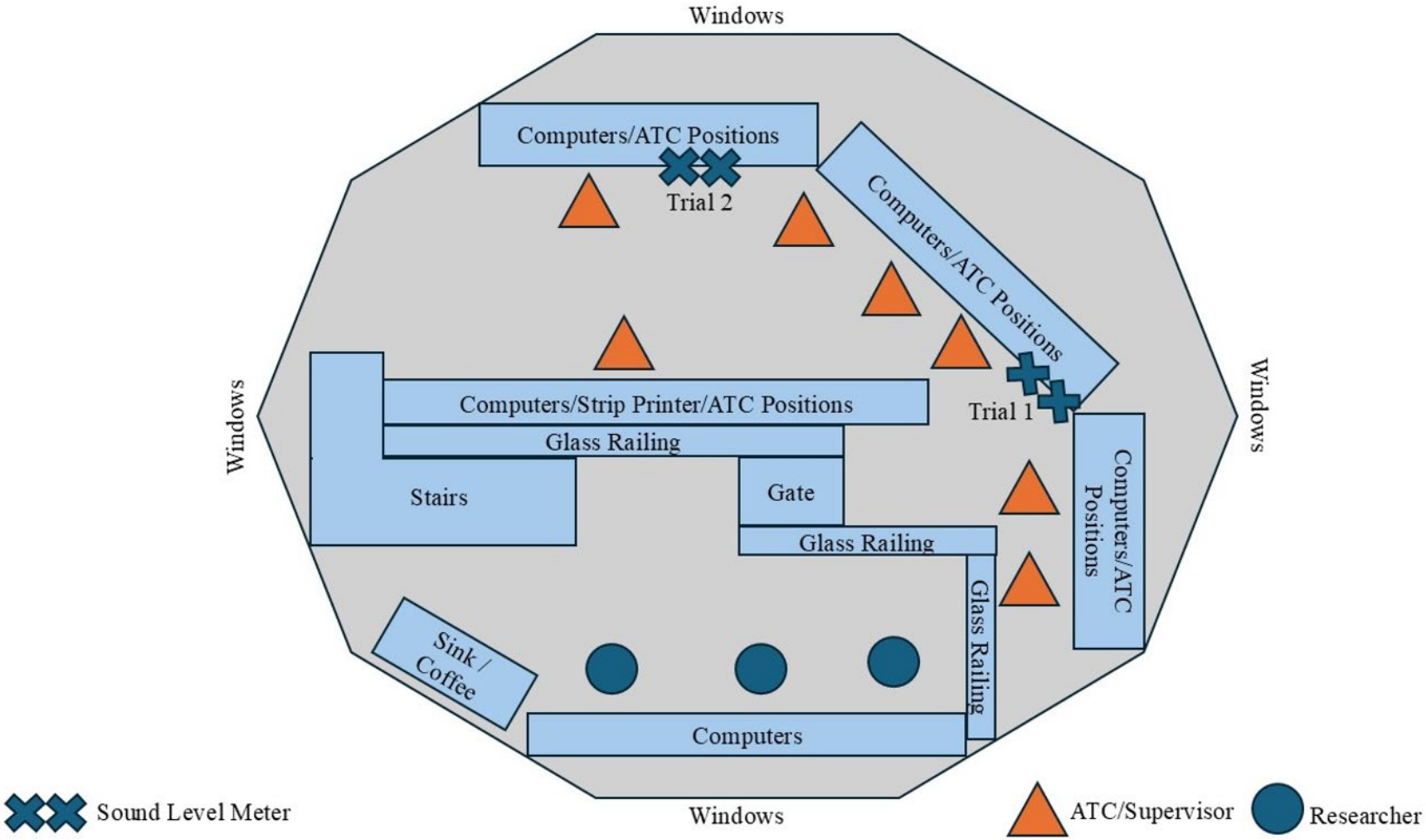



Figure I-24. MIA ATCT ambient sound measurement trial locations

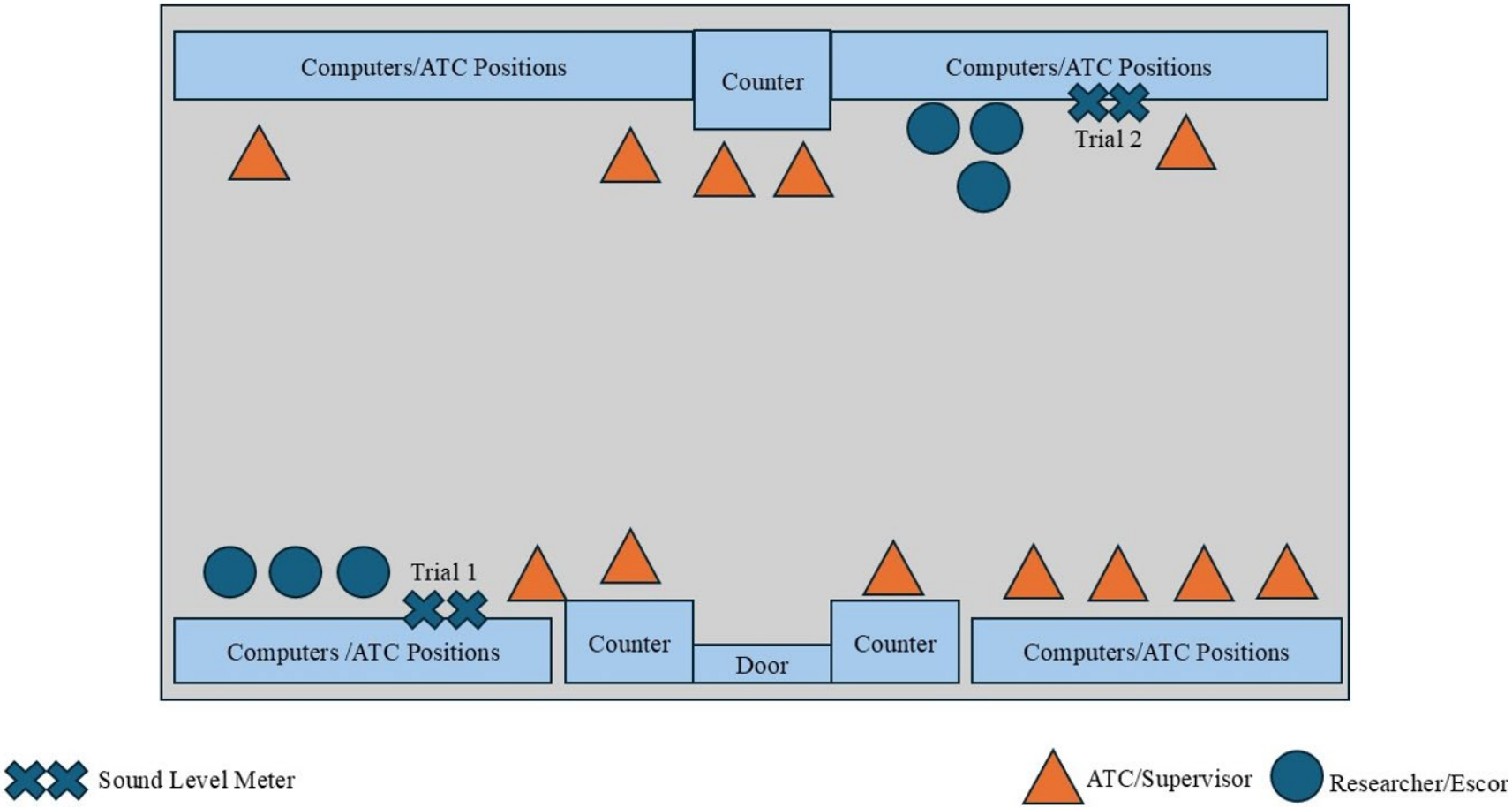



Figure I-25. MIA TRACON ambient sound measurement trial locations

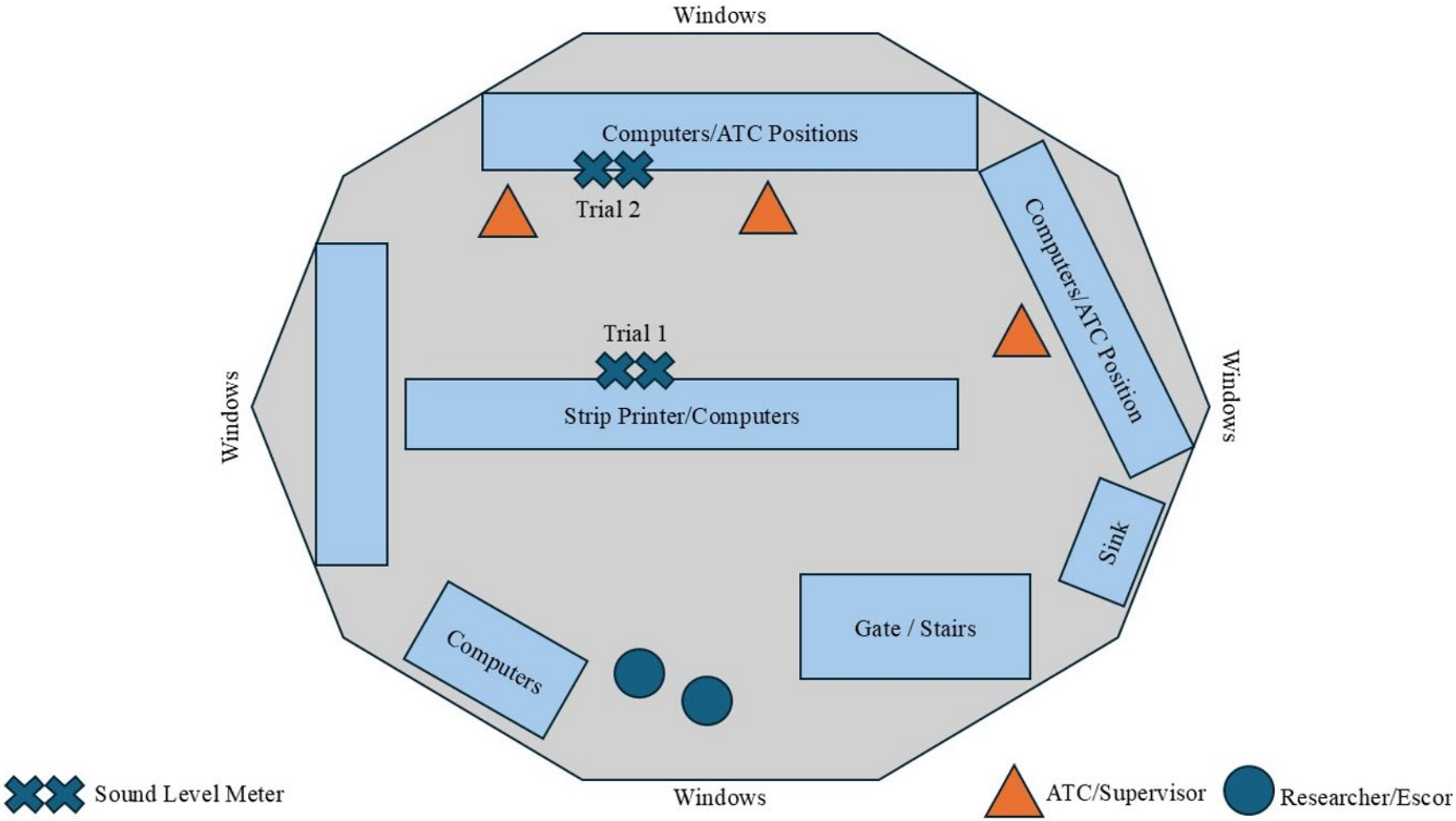



Figure I-26. PBI ATCT ambient sound measurement trial locations

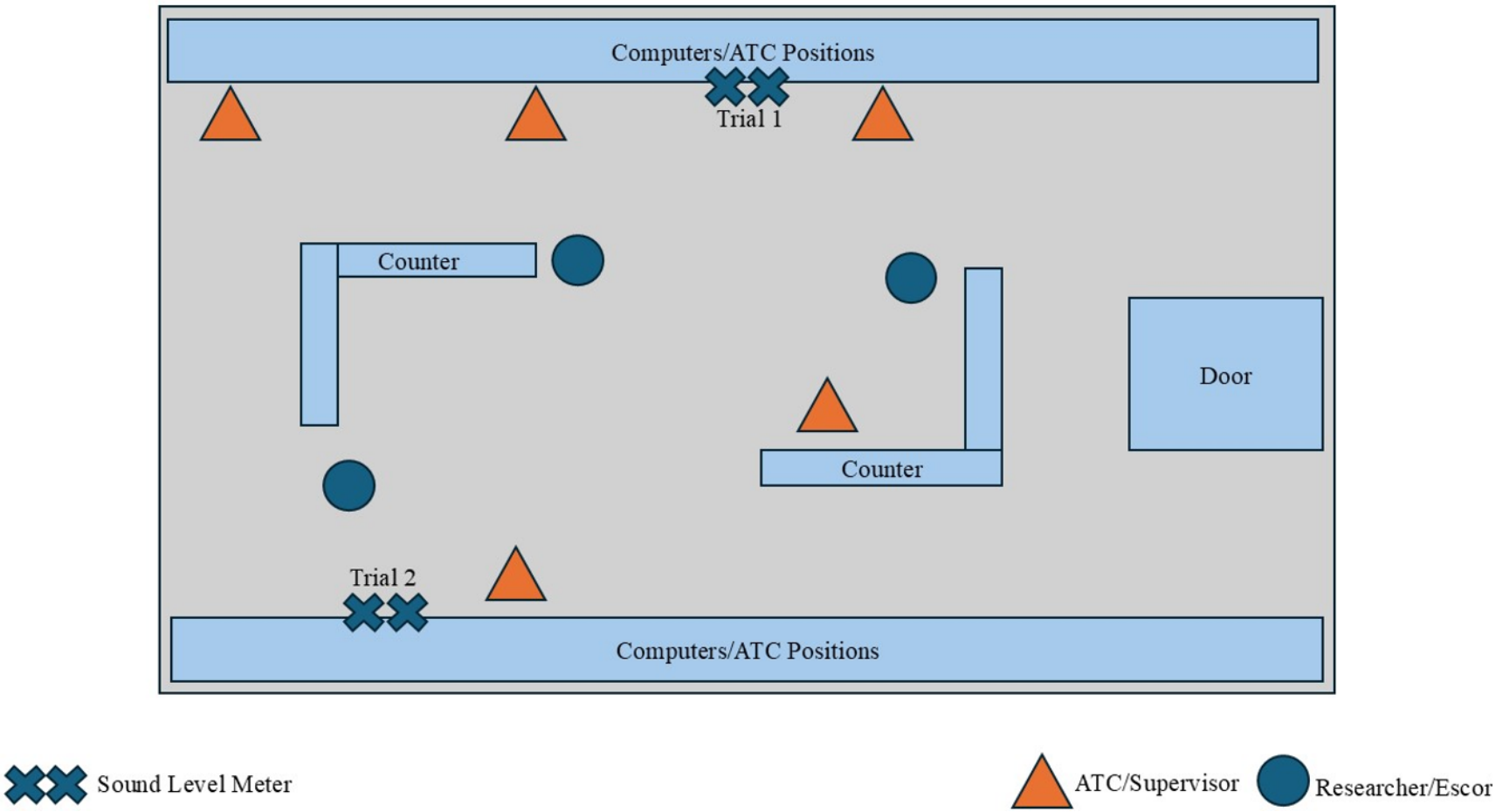



Figure I-27. PBI TRACON ambient sound measurement trial locations




Figure I-28. PHL ATCT ambient sound measurement trial locations

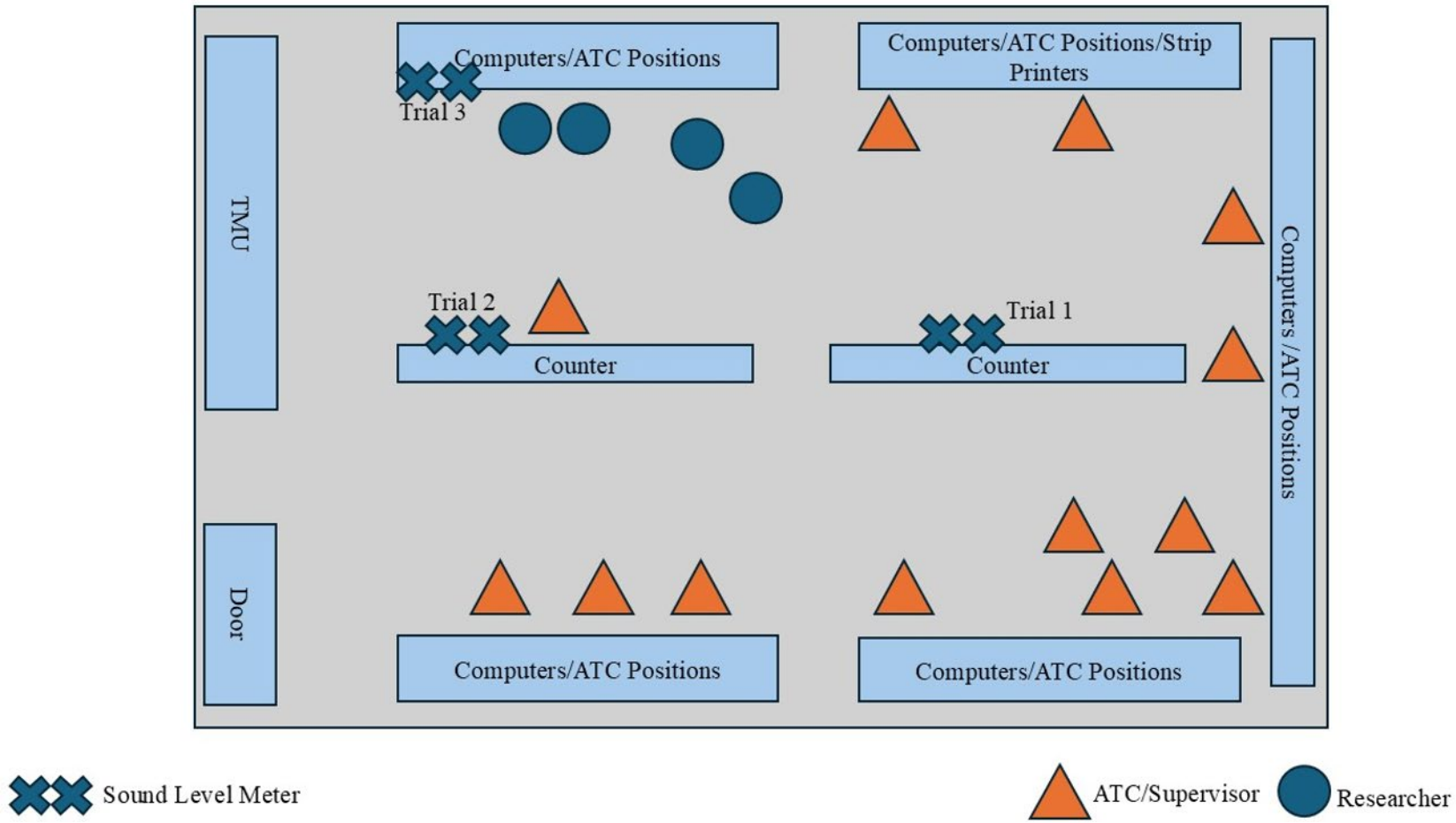



Figure I-29. PHL TRACON ambient sound measurement trial locations

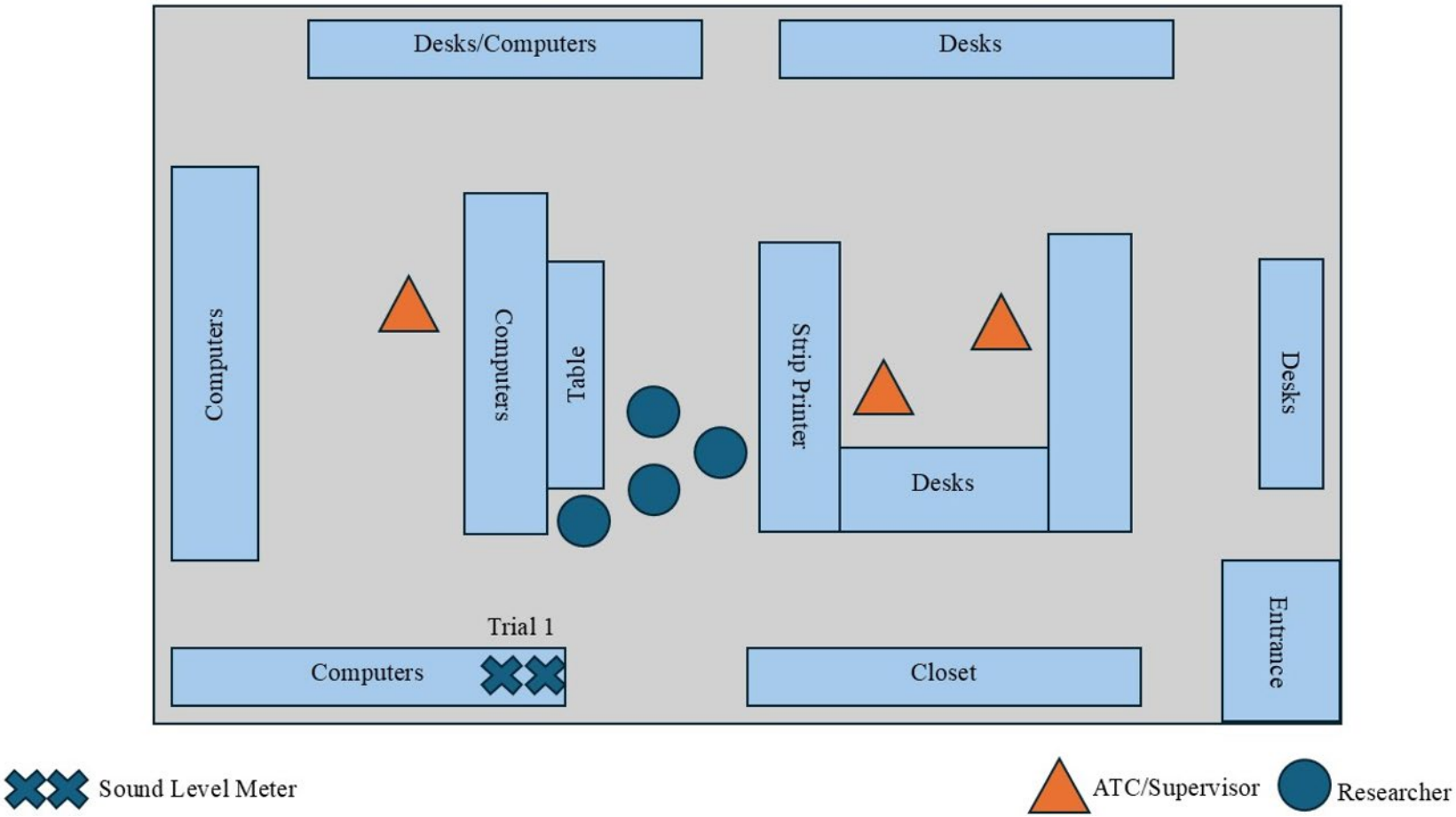



Figure I-30. ZDC TMU ambient sound measurement trial locations

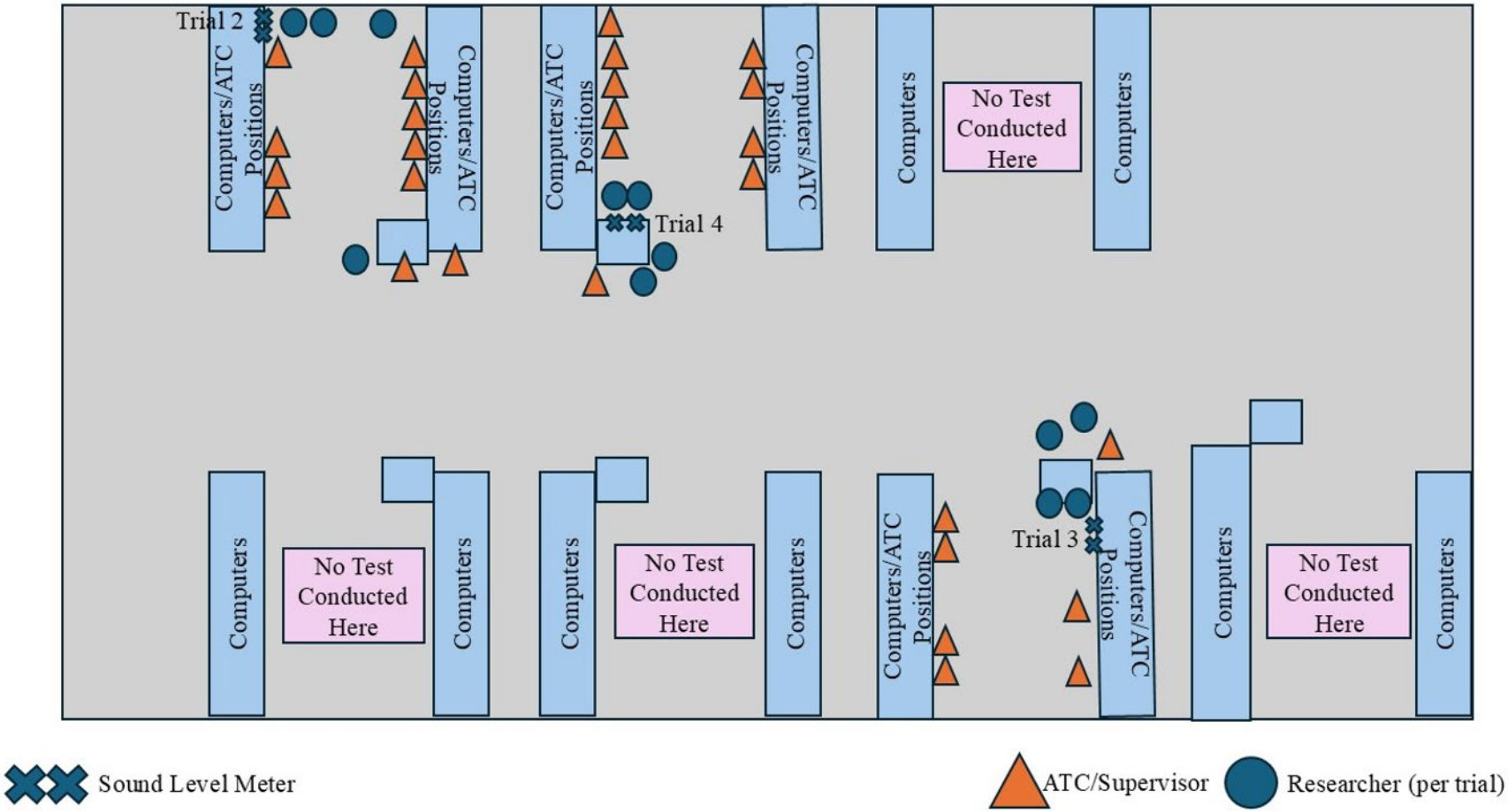



Figure I-31. ZDC operational area ambient sound measurement trial locations (TMU area not pictured)

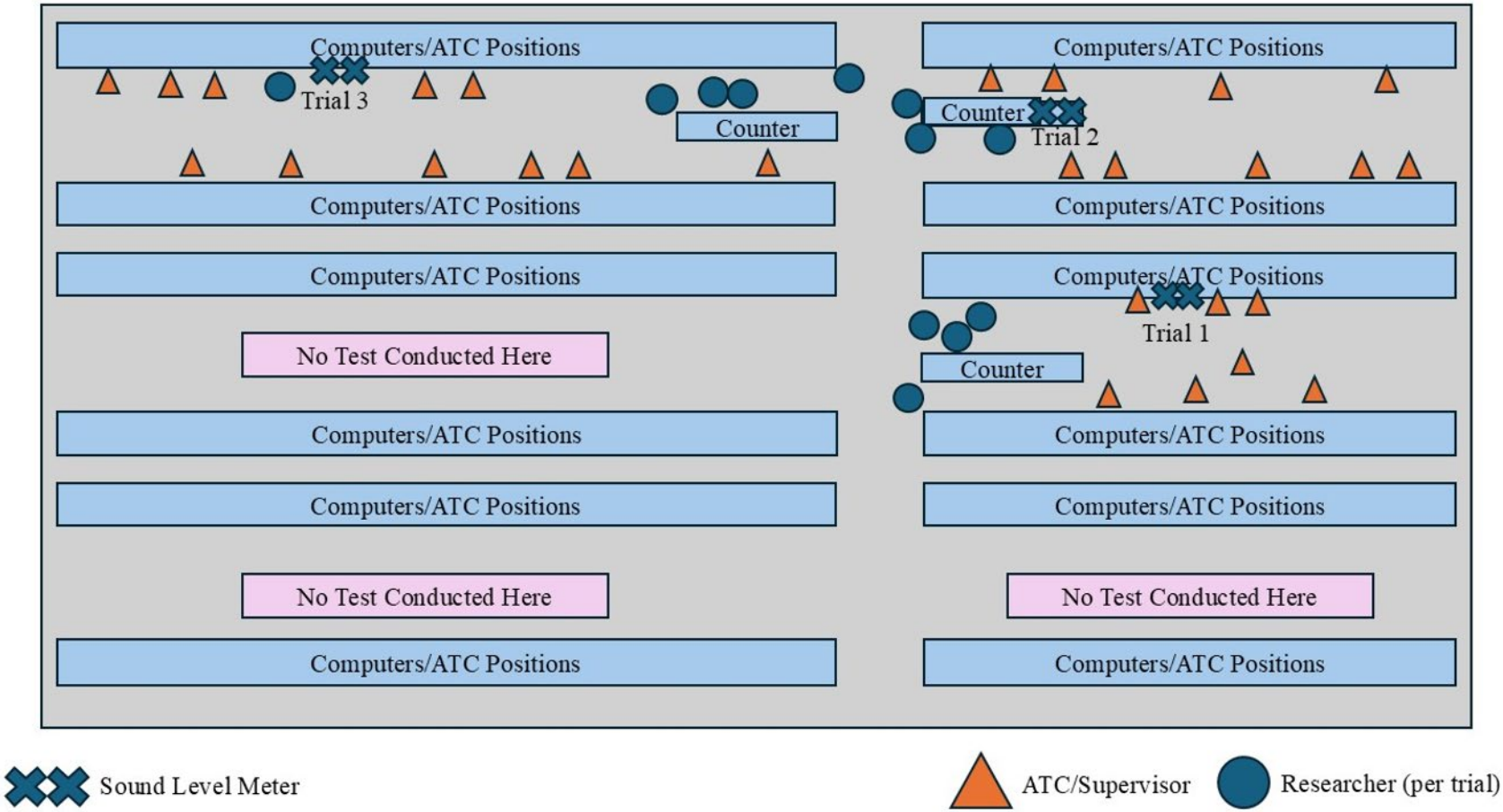



Figure I-32. ZHU ambient sound measurement trial locations (TMU area not pictured)




Figure I-33. ZMA operational area ambient sound measurement trial locations

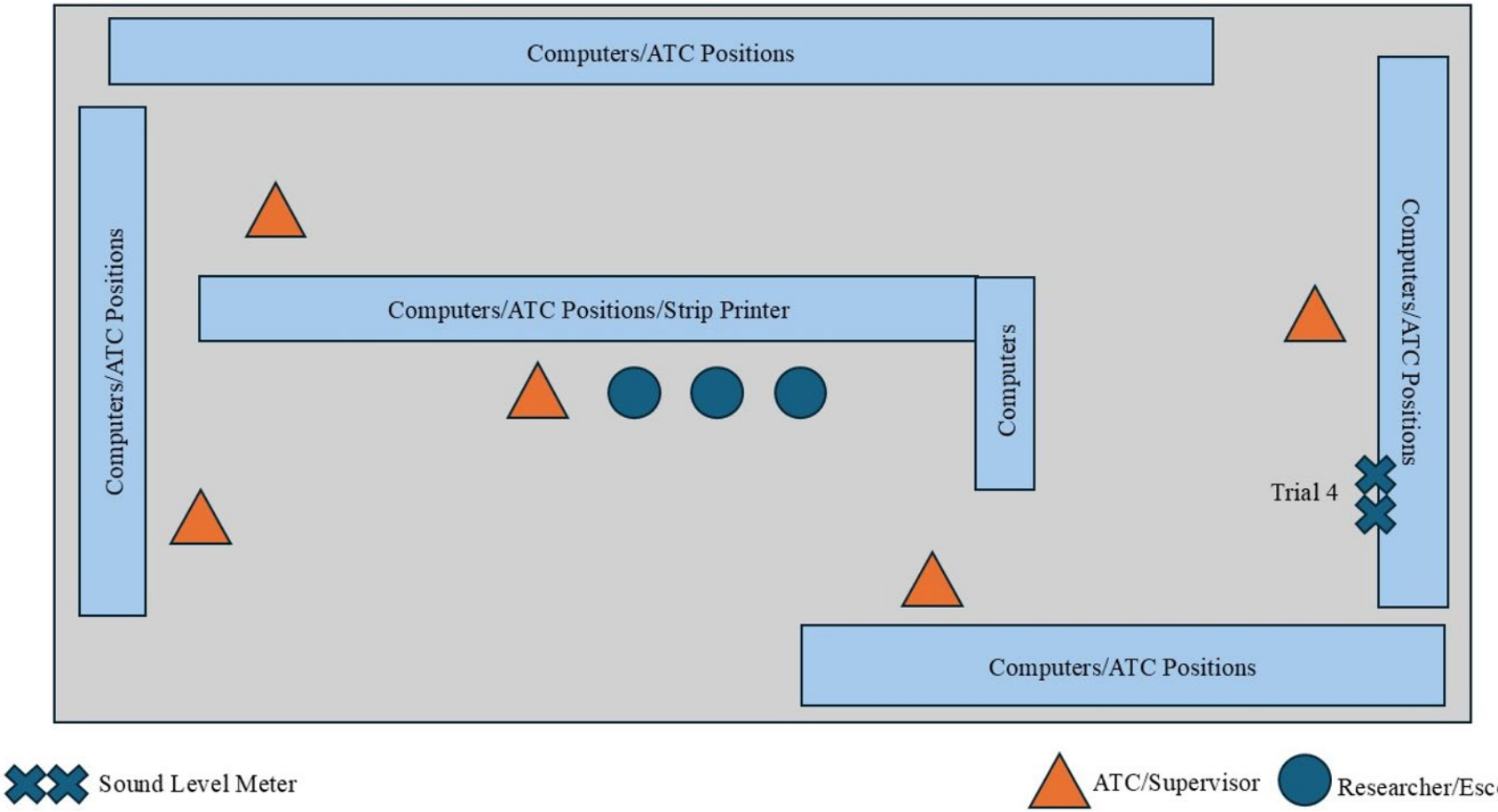



Figure I-34. ZMA TMU ambient sound measurement trial locations