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# An Exploration of Architectural Acoustics and Design in Commercial Recording Studios

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One hundred years after the original house was built, the Gramophone Company purchased the nine-bedroom, London residence known as Abbey Road ("The Origins Of The Gramophone Company"). An estimated 100,000 pounds sterling, equivalent today to roughly 2,000,000 US dollars, went into the purchase, redesign, equipment, and furnishing of the new Abbey Road Studios ("Abbey Road Studios"). Two years later in November 1931, the Gramophone Company merged with Columbia to become Electrical and Musical Industries (EMI) and opened Abbey Road Studios for the first time ("Our Story"). Upon the studio's grand opening, a performance of "Land of Hope & Glory," a British patriotic song, was conducted by Sir Edward Elgar in Abbey Road's Studio One. EMI's original three studios (Studio One, Studio Two, and Studio Three) are all still housed within Abbey Road Studios today ("Our Story"). An additional new studio, The Penthouse, was built in 1980, followed by two smaller studios, The Gatehouse and The Front Room, in 2017 ("Our Story").

Between 1962 and 1970, The Beatles recorded 190 of their 210 songs at Abbey Road Studios ("Our Story"). A famous photograph of the band walking across the Abbey Road marked crosswalk remains an iconic image, used for their 1969 album, *Abbey Road*, which was named in tribute to the studio in which they spent so much time. The Beatles, known to have had a significant impact on the studio culture, were only one of many other artists to record at Abbey Road Studios ("Our Story"). Aretha Franklin, Amy Winehouse, Frank Ocean, Pink Floyd, Adele, and Ed Sheeran are among a much longer list of artists to record at Abbey Road Studios. Film scores from the Lord of The Rings trilogy, *Black Panther*, and the Harry Potter series were also recorded at Abbey Road Studios ("About Us" [*Abbey Road]*).

In 2010 Abbey Road was declared an English Heritage Grade II listed site, identifying it for its architectural and historical significance. Architecturally, the design includes "[l]ate

Georgian frontage" and is significant for the "involvement of the noted inter-war architects Wallis, Gilbert & Partners…[and] despite extensive modification, special interest resides in the early fabric and layout of Studios One and Two" ("Abbey Road Studios"). As the pre-existing layout started to become outdated, the Abbey Roads team agreed upon several new design proposals.

To begin the studio design and remodel, they decided upon a Dolby Atmos equipped film mix stage, two new rock and pop recording spaces, two new isolation booths and a new lounge for Studio Two, and the development of the garage site into two production suites among other additions ("The Story Behind"). As new technology broadened the possibilities of recording, Abbey Road Studios was intent on staying contemporary. The Penthouse studio was built "fully accredited for Dolby Atmos Home Entertainment mixing projects" ("The Penthouse"). This new all-digital recording and mix suite catered to the modern trajectory of recording studios ("The Penthouse"). The Penthouse, along with The Gatehouse and The Front Room, are all significantly smaller studios, which also meant that they were more affordable ("The Story Behind").

Throughout the history of Abbey Roads' Studio Two, several remodels and the addition of new acoustic treatment helped transform the studio into what it is today. The early design of Studio Two was catered to stringed instruments. In the early recordings from Studio Two, the room sound was very reverberant, and in the 1950s, twenty years after its opening, the Abbey Road Studios team began to experiment with the studio's sound. This brought the addition of, arguably, one of the most recognized design features of Studio Two: the long hanging drapes located around the upper half of the room. To further "tone down" the room's acoustics, bass traps were added above the stairs ("Creative Cribs"). In 1961, swinging acoustic perforated panels were added to help divide up the room and were intended to provide more sound isolation. Later on, two additional isolation booths were added to Studio Two, one of which was the control room in the original studio's design. They moved the control room upstairs in the late 50s to accommodate these isolation booths and to support the increased demand for new gear ("Creative Cribs"). Both the redesign of Studio Two and the addition of three new studios since Abbey Road Studios' original construction suggest an evolution in the conventional acoustic design and demands of recording studios.

Abbey Road Studios' artistic and architectural significance models the fundamental designs and applications of key architectural features that other studios strive for. The design and construction of recording studios are largely built around a set of parameters that dictate the sound characteristics and functionality of any given room. These parameters begin with the architectural design and then give way to interior design and treatment. All of these should contribute to the clarity and quality of the sound in a room. In total, studio designers should focus on building a space that supports the needs of the artists, engineers, and producers all while maintaining quality acoustic characteristics. It is critical to develop an understanding of the design techniques and features that will dictate the quality and functionality of any given studio in order to begin designing a recording space. Architecturally this concerns environment/location, floors/foundation, walls, ceilings, doors, windows, and room-specific construction. Moving beyond architecture and into interior design and functionality involves gear, furnishings, acoustic treatment, and their respective placements.

The goal of this research is to present a series of industry standards and best practices that will dictate the design, construction, and material selection for commercial recording studios. In combining all of these tools and design principles, studio designers can work toward creating ideal sound conditions within a recording studio environment. These established industry standards and best practices will then be applied to a proposed recording studio design. The intention is to use this example as a platform to further the understanding and application of the described industry standards. Notice that the terms 'best practices' and 'industry standards’ will be used interchangeably within this research. In order to focus this investigation on recording studio design, the proposed studio will focus on architecture and acoustic treatment. Studio gear, equipment, location, and cost breakdown will all play a role in studio design. However, to limit the scope of this research, these factors will be excluded from this analysis.

There is an important disclaimer to make that is described by many studio designers – the idea that there is no perfect design for a studio. Commercial studios across the world look very different, which may be attributed to interior design and acoustic treatment selection, where personalized design choices can determine the look and feel of a space. However, the architectural design of recording studios is more commonly related to one another and will emphasize similarities and industry standards. Even so, there is no perfect studio design that can be replicated for optimal sound recording. Instead, acousticians and studio designers rely on these shared industry standards and best practices that can facilitate the direction of studio design. It is important to remember that every aspect of a studio's construction will contribute to the space's acoustical characteristics: walls, ceiling, furniture, lighting, mechanical systems, and the material used for each of these (Holmes). Additionally, the technology and fundamental understanding of sound are often changing and evolving. With this evolution will come new developments in the design, materials, and desired functionality of recording studios. Despite these changes, the objective remains the same: manufacture a space with ideal sound acoustics through architectural construction and implementation of acoustic treatment.

## What Is Architectural Acoustics (Sound Acoustics)?

Architectural acoustics is "the study of sound in…buildings and the design of those structures for optimal acoustic performance" (Holmes). Understanding the acoustics of architecture allows studio designers to have control over sound transmission, speech intelligibility, and sound isolation. Each of these factors can be broken down into more detailed categories, but all determine the listening experience within any given space (Holmes). Recording studios fall on the extreme side of these essential acoustic properties. Whether one person or a fifty-piece orchestra is being recorded, there is not only an expectation but a requirement for the studio's sound design to maximize sound isolation, absorption, and reflection control.

Acoustics help studio designers understand the structure, control, and perception of a space which includes loudness, reflections, absorption, diffusion, reverberation, phase, and clarity. These factors determine the sound quality; a key aspect of any studio and the driving force behind the high demand for many popular studios' sought-after sound characteristics. The acoustic design of any recording space will often be tailored to the needs and wants of the studio owner(s), however, unless specified otherwise, "the goal is to allow a natural spatial impression that does not colour the sound" (Perry). Understanding the ways that architecture and room design interact with the resulting sound characteristics requires a brief digression to define sound, its functions, and its interactions within enclosed spaces.

Holmes defines sound as "small and very rapid fluctuations in air pressure above and below atmospheric pressure." Acousticians use a measurement called decibels, or dB, that quantifies sound intensity. In any given space, two key measurements help to evaluate acoustical characteristics: acoustic absorption and sound transmission loss. Acoustic absorption describes a material's ability to absorb rather than reflect sound, while sound transmission loss refers to the ability to reduce sound transfer from one space to another (Holmes). Sound transmission loss can also be understood through something called STC or sound transmission class: "one of the standard metrics that quantifies an assembly's ability to decrease airborne sound transfer between rooms" (Holmes). Absorption and sound transmission loss are two important factors that describe the way that sound acts within a room and both have the ability to remove unwanted sounds.

Two other tools used to evaluate the quality of a room's acoustics are geometrical acoustics and statistical acoustics. Geometrical acoustics describes the relationship between the space, early reflections, and direct sound, which refers to sound traveling from the source to the receiver without reflections. Further, statistical acoustics explains the reverberation characteristics of a space by understanding the more extensive role of reflections (Borenstein 3). Another way that acousticians can talk about sound is by referring to time, frequency, and energy. Each of these helps describe an event, and each event is best understood by the length of time a sound occurs, what frequencies are involved, and the energy or intensity of that sound (Storyk, "Studio Architecture & Acoustics").

Software programs and models can aid in predicting how sound will interact in a room but a comprehension of the general functions of sound, knowing how to describe sound events, and understanding the way sound interacts with different materials are key aspects of recording studio design. To fully explore sound would require a much more extensive exploration into the intricacies of sound interaction than is possible within the scope of this paper. However, having a fundamental understanding of these tools used to evaluate sound will facilitate an ability to assess and treat rooms in order to achieve exemplary acoustic performance.

**Introduction to Recording Studio Design**

The architectural design of a studio will largely determine the layout and sound qualities of the space. However, the architectural structure is not the only factor that dictates a studio's sound characteristics. Interior design is critical in creating a functional studio. Treatment, furniture, lighting, and overall layout (gear/equipment) will all facilitate the energy of the studio. Steven Durr, an expert in acoustic design and consulting, observes that the number one most overlooked factor in studio design is the "vibe." Durr believes that, when creating a studio, designers should think about the people that will be working in that space and, as a designer, the goal should be to create a space that is inviting, emotional, and one that people would not want to leave. Creating music is a very emotional process for all of those involved. Artists want a space that will allow them to be confident and express themselves. Likewise, as a recording engineer or producer, having a space that invites creativity and is comfortable to work in is a priority.

The first step in the design process is to establish the wants and needs of the desired studio. This is known as pre-design (Tracy). Other studio designers refer to this as the assessment and requirements stages ("About Us" [*John H. Brandt Acoustic Designs*]) or client expectations ("Our Process"). Having realistic expectations and goals for finances, operations, technical performance, and the targeted market will help keep everyone on the same page throughout the design and build process (Berger). The next step is the design itself; both sketches and floor plans will emerge, and designers can work with studio owners to evaluate and review what is working and what is not. As a studio designer, this is a crucial step in establishing a system of trust with a client. A high level of trust will allow clients to feel confident in bringing up new ideas or expressing concerns (Durr and Schlachter).

Subsequently, the procurement stage in establishing a studio is extremely important as it will guide and determine what laws and regulations will affect the design including required permits, inspections, or other prerequisites for construction (Tracy). Not only is this stage important to understand as it pertains to building codes and regulations but also because it plays a significant role in the initial sound design. This topic should be discussed early in the design process to determine whether the studio will be built within a pre-existing structure or from the foundation up. From a financial standpoint and also from an acoustical one, this will determine what architectural elements are needed to address and prevent noise pollution and maximize sound isolation.

Finally, the construction and post-construction stages will occur including (Tracy) construction administration and performance verification with routine site visits, updated drawings, and a final test of all systems to ensure all aspects of the studio are working how they are supposed to ("Our Process"). Reviewing the plans and progress at each stage of the design process will help guarantee the success of the final product and eliminate the need for renovations and remodeling to fix sound quality issues later on, which can be very expensive.

**Environment/Location**

An important consideration when designing any studio is environmental noise and noise pollution. As previously mentioned, where a client wants a studio built will play an immense role in what kinds of environmental noise will be a factor. While it may be recommended to build a studio in a quiet location, studios have been built in many different places (apartment or office buildings, neighborhoods, next to busy city streets, etc). In a perfect world, studio owners and designers would have their pick of location but the reality is that people want studios to be built in all kinds of places. Knowing the kind of noise that will interact with the space will help studio designers and architects build and design accordingly. Environmental noises to consider here are public transportation, nightclubs, restaurants, live sporting events, neighbors, etc. (Holmes). Without taking these noises into consideration design and building shortcomings can happen and will likely lead to overpaying for studio designs that don't fully support a quiet and effective recording environment (Berger).

Constructing a studio within a pre-existing building may require a more precise examination of sound isolation due to the proximity of other unwanted noises. A design technique known as "room within a room construction" may be a useful tool in this case. This technique results in each room being "a closed container with an individually decoupled (or 'floating') floor, and each with individually decoupled walls and ceilings" (Noy). This design allows each room to be constructed to ensure maximum vibration isolation (Letang). Alternatively, building a studio away from large amounts of noise pollution offers more flexibility for material use and construction techniques.

For instance, a studio built within an apartment building with loud neighbors and on a busy street may require room within a room design, thicker wall construction, and added separation between floors and ceilings. Suppose instead that the studio is to be built in a quiet rural neighborhood. In this case, a room within a room design may not be needed. Instead, a thicker outer shell can be constructed and interior walls may be sufficiently built with two layers of drywall over a staggered stud construction to reduce noise transmission (Perry).

This is an area where it is difficult to describe specific design methods due to a substantial amount of variation presented in environmental and noise pollution. Most importantly, each studio location should be evaluated before any in-depth discussions of design take place. It may be the case that the desired location is unusable because of how much noise pollution occurs and the cost and design needed to establish quality sound isolation. Once a location can be established, the next step is to determine how the studio will be manufactured, from the ground up.

**Foundation/Floors**

In the case that a studio is being built within an established building, the chances are that a foundation has already been set. This leaves the floor design to be determined by what is below, above, or both. Alternatively, beginning with the foundation, concrete will create a strong base. It can be poured as a single base for the entire building or in separate slabs for each room. One design technique that uses concrete is known as a slab-on-grade foundation. This design is made up of concrete that is formed from a mold and set into the ground. Concrete will then get poured directly into the mold eliminating any air gaps between the ground and the concrete ("What Is A Slab-On Grade"). Jimi Hendrix's Electric Lady Studios was built on a slab-on-grade flooring system (Storyk, "Studio Architecture & Acoustics"). This design technique has pros and cons but like any aspect of the studio, design should be catered to the environment and structural expectations. Some of the benefits of the slab-on-grade flooring technique are that it creates a sturdy foundation, is relatively inexpensive, and is less vulnerable to infestations because there are no open spaces between the bottom of the foundation and the ground. However, this lack of space beneath the foundation can eliminate underneath access, increase the potential for flood damage and heat loss, and make it difficult for renovations ("What Is A Slab-On Grade").

A key term that will help support further examination of floor design is decoupling. The fundamental definition of decoupling is "to separate objects" ("Concept of Decoupling"). Sound vibrations will transfer through materials easier than through air, so decoupling them describes a design build that uses "resilient sound clips, resilient channel, or specialty framing like double stud or staggered stud walls." Interrupting the transfer of vibrations by minimizing the number of connection points will maximize the sound transmission loss ("Concept of Decoupling").

To take advantage of this technique, studio designers will create "floating" floors. This means that the floors will be separated from the rest of the studio and thus support more efficient decoupling ("Designing A Vocal Booth"). This is important because the floors of a studio will carry a large number of vibrations if not constructed properly. These vibrations will leak into recordings and produce higher levels of sound transmission. The sound isolation achieved by floating the floors in the studio will be especially effective for low frequencies such as drums and other environment noise (Perry).

For the interior studio floors, designers will often use wood, known for its sturdiness, ease of maintenance, and use in creating multi-purpose rooms. Acoustician John Storyk suggests that the exact wood used is not a significant variable (Storyk, Personal Interview) and instead describes a common approach to floor design as is seen in Jimi Hendrix's studio, where wood flooring is paired with area rugs to provide additional absorptive qualities to the room (Storyk, “Studio Architecture & Acoustics”). Fundamentally, the floor design and construction will facilitate the characteristics of the remaining studio. For this reason, it is crucial that the floor is built and formulated very carefully.

**Ceilings**

Although the dimensions from floor to ceiling can create some of the most undesired acoustic qualities of a room, this is also an area that offers more flexibility within the overall studio design. The largest consideration and discussion surrounding ceiling height will likely fall to establishing a minimum. Here, Perry suggests that the height should not fall under thirteen feet. Klein also states that the ceiling should not angle below twelve feet anywhere. Steve Durr refers to a minimum of ten feet and suggests up to twenty feet. In a preexisting space, this can become more difficult as the ceiling height will likely be predetermined. In 2019, the standard ceiling height for homes was listed as nine feet (Lefton and Vila). However, recording studios are built with different objectives from everyday homes, and, given the option, studio designers will rarely place a ceiling at this height and in the standard fashion, parallel to the floor. As this is usually the smallest dimension and is often left untreated, it can create large low-frequency issues (Foley, "What Is An Ideal Control Room?").

In recording studios, there are several features that can change the way studio designers determine ceiling height. It is important to note here that design concepts should be worked through in conjunction with all other aspects of the space. For example, the height of the ceiling will dictate the dimensions of width and length for the rest of the room (Durr and Schlachter). Within control rooms, the ceiling height may also be determined by the use of a type of acoustic treatment called a "cloud." This treatment option will often extend several inches from the ceiling so studio designers may build higher ceilings to accommodate this extra needed space.

How the ceiling is mounted is important, especially for decoupling. A popular technique for mounting the ceiling is to use springs, therefore separating the ceiling from the rest of the studio. This will help with vibrations and sound transmission (Storyk, "Studio Architecture &

Acoustics"). Additionally, the materials used and what is behind them will affect a room's acoustical performance. The incorporation of an air gap behind an acoustic ceiling can support better low frequency performance (Souza).

In the construction and build of Jimi Hendrix's Electric Lady Studios, a three-layer design used a layer of plywood in the middle of two layers of sheetrock. Studio designer John Storyk described the added benefit of a second material being used in the middle layer (in this case plywood). He states that it changes the coincidence dip (Storyk, "Studio Architecture & Acoustics"). The coincidence dip refers to an acoustical event in which "the wavelength of the sound in air is the same as the bending waves in the partition" ("Glossary"). Introducing a new layer of material, as in Electric Lady Studios, offers the opportunity to interrupt the sound waves and reduce their impact as they intersect with a barrier.

To reiterate, the most significant consideration in any room is parallel surfaces. Acoustic treatment options can help balance out the unwanted effects of these parallel surfaces but another technique that is commonly used to counteract parallel surfaces is to adjust the angles of the ceiling. Angling the ceiling will help redirect first-order reflections to the back of the room (Storyk, "Studio Architecture & Acoustics"). Perry also suggests a splayed ceiling concept that allows studio designers to avoid unwanted parallel surfaces. Disrupting the unwanted effects of parallel surfaces by changing the angles of the ceiling is an effective tool also applicable and effective in wall construction.

**Walls**

One of the most important measurements in a studio space is that between walls. Parallel walls, in particular, are a common discussion point for studio design. This is because parallel walls create standing waves and undesirable reflections. Standing waves are the natural frequencies (also called modes) that tend to be reinforced based on their position within a room. Storyk suggests that there is nothing wrong with standing waves: "if there are no standing waves in your room, it simply means you're not in a room or you're in a completely dead room, or you're outdoors. If you're in a natural-sounding room, you have to have standing waves" (Storyk, “Architectural Acoustics and Audio Systems Design: Understanding Room Modes"). Even so, standing waves are an important aspect of studio acoustics to consider.

By eliminating parallel walls and acoustically treating a room, the build-up of the associated frequencies can be reduced. Irregular angles can be used to avoid strange resonances (Demming). The term “strange” refers to unwanted and undesired frequency resonances. Studio designers may choose to build a room that is more of a trapezoid shape by angling side walls outwards towards the back of the room. This is especially common in control room designs as the goal is to maintain symmetry and send direct reflections away from the listening position. Acoustician Vangelis Koufoudakis stated, "In the world of acoustics, we love irregular shapes because they stop sound focusing or other unwanted acoustic artifacts" (qtd. in Demming).

Often the interior and exterior walls will look different. For the interior walls, changing the angles will help with standing waves by reinforcing diffusion (Durr and Schlachter). The characteristics of first-order reflections will also be determined by the design of the interior walls (Ermann). For example, first-order reflections in wide rectangular rooms will come back later in time and therefore have less of an effect on the listening position. Another option is to use a curved back wall and additional acoustic treatment (Storyk, "Studio Architecture & Acoustics"). On the exterior, the same kind of angled walls might not suit the polished look that studio owners want (Durr and Schlachter). In this case, a similar idea to the room-within-a-room design is achieved. In a room-within-a-room design, the goal is to maximize sound isolation, however, in this case, the design is meant predominantly for visual appeal.

The materials used for walls will also play a large role in the sound transmission loss, vibrations, and isolation. Exterior walls may be constructed with thicker materials such as concrete that supports good sound transmission loss (Holmes). Interior walls can be constructed with any kind of material but will often be framed with gypsum board (also known as drywall). Within the wall, a common design is the double stud partition. While a single stud partition can be used, the double stud design allows for an air gap to be created between the two sides of the wall. This has the benefit of improving the overall sound transmission class rating and enhancing low-frequency performance. Sound transmission class, also referred to as an STC rating is "one of the standard metrics that quantifies an assembly's ability to decrease airborne sound transfer between rooms" (Holmes). A mass-airspace-mass arrangement offers the best use of materials and space (Souza).

This is another area in studio design that will benefit from some clarification. When assembling the walls within a studio, a common misunderstanding can occur. This is the idea that adding additional layers of material to the walls will increase the sound isolation. Richard Schrag, project manager for Russ Berger Design Group, suggests otherwise. On a double stud partition, a single layer of drywall with cavity insulation will result in an STC rating of 56. By adding two additional layers of drywall to the inner face of one stud, the STC rating drops to 53. By adding two more layers on the inner face of the other stud, the STC rating will continue to drop to 48. This is due to the relationship between the mass of the surface's material and the thickness of the air gap between them. Adding more layers of material to the inside faces of the studs divides the air gap into smaller sections. This affects the sound transmission loss, specifically relating to low frequencies, which are largely responsible for determining the STC rating (Schrag).

Since each room within a studio will likely be constructed from different materials and parts, "how the materials are put together is often more important than what materials are selected" (Schrag). This means that flanking is another potential issue and one that must be properly addressed. Flanking, or flanking transmission, is "a term used by acoustical engineers wherein the sound passes around, over the top or under the primary partition separating two spaces" ("Flanking Transmission"). There are several design practices that can result in flanking: partitions that extend above the ceiling, points where the floor meets the wall (wood construction), back-to-back openings on either side of a wall, or barriers (outlets, cabinets, etc.), unsealed openings through walls and floors (ducts, pipes, conduits), connecting ducts from one room to another (especially with short and or straight runs), and doors and windows. Use of non-hardening caulk and packing (or firestop putty for larger holes), conducting preliminary tests for effectiveness (visual and auditory), and locating electrical outlets, phone jacks, cable wall jacks, and recessed cabinets on one side of a wall so they do not occupy the same inter-stud cavity as similar penetrations on the other side are ways to reduce the effects of flanking. Similarly, using plastic vapor-barrier electrical outlet boxes, designing for building control joints where needed (these minimize cracking of walls and offers vibration isolation), and resiliently (non rigidly) connecting room surfaces to the structure (this helps break the "weak link" sound path) will all help reduce the impact of flanking (Ermann). Due to the expansiveness of studio design possibilities, often it is only a matter of finding the right solution to any given problem.

The doors and windows of a recording studio are the final aspect of wall construction that should be carefully considered. As these create openings and gaps in the structural design of a studio, they are important to get right and can be quite expensive to remedy if not built and constructed correctly. Most likely, studio designers will partner with a team that specializes in acoustic and soundproof doors and windows. These teams will have the knowledge of door and window design as well as materials to be able to build them into the studio design.

Sound-rated doors are the first step in the selection process. These are doors where all aspects of the door are manufactured as an integral unit (Shrag). When it comes to studio doors there are several things to keep in mind. The first is the material used for the doors themselves, often wood, steel, fiberglass, or glass. Steel and fiberglass doors have the benefit of being constructed from a combination of materials that also acts to maximize sound isolation.

Generally, the denser the material, the better job of blocking and reducing noise transmission it will do. A door's core material is another consideration. Commonly this will be most effective as a high-density, polyurethane foam core. Other considerations are installation, placement, seal, use of glass, and STC rating ("Choosing the Best Soundproof Door"). “[K]eeping the door opening separated from the noise sources will help obtain appropriate sound isolation” (Schrag). For example, placing a door at the exact point of a first reflection is not the best choice given that the sound waves will be at their strongest and more likely to produce flanking.

Glass is another material that can be and is often used but should be carefully considered. This is not to say that it is impossible to include glass in a well-designed studio; on the contrary, many studios are adapting to an increase in glass presence, from doors to large windows. Establishing a partnership with a manufacturer and expert in acoustic glass will be an excellent resource for studio designers wanting to incorporate large amounts of glass into their studio design. As windows will be the largest concentration of glass within a studio, these are also important to design carefully.

Once again, the window design in a recording studio may be best suited for a specialist in acoustics and glass. However, a good studio designer will have the knowledge and frame of reference to understand what to look for and how to apply window design techniques. The first of these is window shape. Square windows should be avoided (Gilby). The next key aspect of the window is the frame because it will dictate the seal of the window panels to the surrounding walls. This is where flanking can occur if the seals are not treated properly (a very expensive problem to have after the studio has been completed). If the frame is made from wood, it is best for the window to be "hardwood," meaning that it has already been dried to match the studio environment. This is critical for reducing warping, which can lead to malfunctions in the window integrity (Gilby). Wood is not the only viable material for framing a window, yet it is a common one. The design of the windows should also include a strong seal. This begins with the use of rubber, set into the frame, so as to eliminate vibrations from transferring off the glass (Durr and Schlachter). Paul White suggests a material known as neoprene gasket, a common tool for door and window sealing.

It is rare to see a single pane of glass used for a studio window. Instead, windows will use two or three sheets of glass. The difference between using two and three sheets is based on the level of attenuation, or how much the sound will be decreased. Supposing two sheets of glass with two hundred millimeters of air between each, designers can expect a forty decibel level of attenuation. By adding a third sheet of glass, also with two hundred millimeters of air between each, the attenuation level is expected to increase to its maximum amount at fifty-five decibels (Gilby). This research suggests that there is no situation in which multiple sheets of glass should be the same thickness. This will cause one to resonate at the same frequency as the other(s) (Storyk, Personal Interview).

The last key point for window design is the angles of the glass, which will play a significant role in the window's functionality. Like with walls and floor-to-ceiling dimensions, window panes mounted parallel to each other will risk problems with standing waves. A simple solution here is to adjust the angle of the glass. Schlachter and Durr suggest that a three-degree angle on one side and a five-degree angle on the other is sufficient enough to eliminate standing wave problems. The V shape this creates (wider at the top, closer at the bottom) will reduce the number of resonant frequencies that can pass through the window (Durr and Schlachter). That would be the case with two sheets of glass. In a window of three sheets of glass, the middle pane should be angled to span the distance between both rooms' respective walls (Gilby). Storyk also points out that while angling the glass outwards is common, another way to think of this is the direction that the designers want reflections to go. This will relate to first-order reflections making it an important decision. Angling the glass can also affect light reflections. In a control room, this is especially important because studio owners don't want to be trying to look through a window that is reflecting all the light of their room back into their eyes.

As recording studios evolve, the use of glass has also evolved. There has always been some level of glass in studios because of the visual connection supported between recording rooms and control rooms. Still, some people remained wary of windows, which may be due to their inferior sound isolation characteristics (Gilby). Storyk and Durr both emphasize the larger role that glass plays in studios today. Many studio owners want to take advantage of views and natural lighting.

The chief considerations of wall design and construction are the materials, preventing parallel surfaces, interior design details that will affect a studio's acoustic sound quality, and the material, placement, and design of doors and windows. Any place that will create holes in the structure needs to be correspondingly remedied. This includes lighting, HVAC, electrical (outlets), equipment/gear, doors, and windows (and their frames). While the framework of the studio should be designed to support minimal sound transmission, there are areas like these that will require more in-depth assembly to maintain sound isolation. Left untreated these unwanted noises will have a major impact on the effectiveness and efficiency of your studio.

**Heating, Ventilation, and Air Conditioning (HVAC)**

Studio designers and engineers Steve Durr and Matt Schlachter suggest that every studio design should begin with the air conditioning. This is because air conditioning, one of the three categories described as HVAC (heating, ventilation, and air conditioning), can have a large impact on the sound quality of a studio if not designed and built thoughtfully. Three key points of consideration in building and installing an HVAC system in a recording studio are the desired air temperatures within each room, the noise that the HVAC system will create, and the effects of air movement on sound waves.

Due to the natural design of many studios, the air temperature will likely remain the same and not need to be changed dramatically over time. If the temperature does fluctuate, the change will likely only be a few degrees per hour (Durr and Schlachter). Durr says that often manufacturers will look at a studio and design a system that is far more complex than it needs to be because they misunderstand what is needed within a recording studio. The noise that the

HVAC system makes is another factor that can be mitigated by reducing the overall system size and only applying the necessary pieces of the system's design.

There are several techniques that can be used to reduce the unwanted noise produced by any HVAC system. Mounting the system on springs is the first step because "[s]prings are the only thing that isolates low-frequency energy" (Durr). The amount of air that travels through the system can also be a factor. By reducing the overall size, even by half, Durr suggests that part of this noise will be reduced. The last key point here is the grills. As the air passes through them they can begin to cause rattling or whistling sounds. Many of the grills sold by HVAC contractors will have an NC number attached to them. This is the noise criteria number and paired with the amount of air traveling through the vents will describe the amount of noise generated by each grill. Importantly, because air is traveling through both parts of the system, the air conditioner and the grills should be designed together to maximize their sound performance (Durr). Durr also suggests that sometimes the best countermeasure is to simply take the grills off.

Lastly, the path of air traveling through a studio will have an additional effect on the sound waves traveling from source to receiver. As Durr explains, "the convection of that air, like how the air is introduced into that room is very critical." Air temperature can drastically change the movements of sound waves. Another way to think about this is similar to heat waves that affect our perceived visual image. These temperature gradients create perceived shifts in the acoustical stereo image. HVAC systems that are poorly placed can have these effects (Schrag). One tactic for preventing these effects is to build the supplies into the ceiling, above an acoustic cloud treatment. This will allow the cold air to fall out and around the listening space where returns in the floor can begin cycling the air out of the room (Durr and Schlachter).

The heating and cooling of a studio may not seem like it would take precedence over other aspects of the architectural design and surely all of the aspects discussed here should be integrated as a whole, but, like the others, it can dictate a lot about the final sound quality of the studio space. Largely this is due to the fact that having an HVAC system requires there to be holes in the architectural design. These can be treated and built into the larger studio design smoothly, however, awareness of the recommended design plans will allow studio designers to maximize the space, money, and efficiency of their studio through the heating, ventilation, and air conditioning system.

**Acoustic Treatment**

Within any recording or listening environment, the goal is to maximize isolation while minimizing noise pollution and sound transmission. These fundamental acoustic characteristics of a room are determined fundamentally by a studio's architectural design. Once the superstructure and enclosure are completed, studio designers will be faced with a new set of sound characteristics (Tracy). The rudimentary factor in recording studio design is the clarity and quality of the sound produced and received. Within a control room, live room, or isolation booth there are tools that will help studio designers achieve optimal performance through the treatment of first-order reflections, standing waves, frequency absorption, and diffusion, among others. This is where a new kind of design option comes into play that is called acoustic treatment.

Acoustic treatment will look and perform in a variety of different ways. The key concept behind acoustic treatment is to facilitate "better sound" (Souza). This can be done by applying materials to a room to help control the interactions of sound within an enclosed space. These interactions create patterns that acousticians and studio designers can assume and predict.

Predictions that are made will help determine the kind, size, and requirements of the desired treatment options. Correspondingly to architectural design, acoustic treatment for a recording studio is another area of the design process that involves personal preference, depending entirely on the sound characteristics studio designers are looking for in a room. Several points can be made regarding common practices for placement but fundamentally this will depend on what the sound design objectives are.

One common misconception when it comes to acoustic treatment is that it will help with soundproofing. This is where the architectural design of your space needs to be meticulous so that soundproofing and sound transmission are taken care of before moving on to treatment options. Soundproofing focuses on minimizing the levels of sound that enter and exit a room, while treatment is better used to help control sound within a space ("How to PROPERLY Install Acoustic Clouds."). Different treatment options will help control sounds in different ways and therefore support the desired sound qualities within a recording studio.

Diffusers are one kind of acoustic treatment, whose function is to break up larger reflections into a multitude of smaller ones (Foley, "DIY Sound Diffusers"). Diffusers work to spread direct sound waves around the room creating a more complete and full sound ("How Sound Diffusers Work"). Commonly, diffusers will be made of wood, due to the material's reflective properties. The design of diffusers incorporates varying heights, depths, and angles (also referred to as troughs and wells) that determine the way sound is reflected and the range of frequencies that a given diffuser is able to affect ("Best Types Of Sound Diffusers"). There are several different kinds of diffusers: one-dimensional, two-dimensional, skyline, quadratic, and convex. One-dimensional diffusers, when mounted vertically, work by dispersing sound waves from left to right, while two-dimensional diffusers work both left and right as well as up and down. The dispersion of the sound waves right and left develops from vertical wood slats that are angled outwards at varying degrees. The difference with two-dimensional diffusers is that these wood slats will sit in both vertical and horizontal positions, therefore adding a new dimension of sound reflection up and down. Often these are recognizable as a checkered pattern with alternating horizontal and vertical panels. Skyline diffusers, given the name because they look like a city skyline when viewed from the side, gather sound waves at varying points in time and reflect them back into the room in the same way. Quadratic diffusers are considered one of the truest types of diffusion given the criteria of "true diffused sound": smooth frequency response, no spatial irregularities, uniform decay, reverberation, and diffusion throughout the entire room (Foley, "DIY Sound Diffusers"). Convex shapes (curved outward) are another natural kind of diffuser (Storyk, "Studio Architecture & Acoustics"). These curved panels are a good option for ceilings and walls due to their ability to uniformly spread out flat wall reflections and establish a sense of spaciousness in your studio (Souza). Variations of each of these diffuser types can also be found and applied in similar ways.

Absorbers are another kind of acoustic treatment that helps control sound within a room. Unlike diffusers, absorbers are used to quiet a noisy space, reduce reverberation for speech intelligibility, and prevent acoustic defects (echo from distant surfaces) (Ermann). As sound waves hit the diffuser, the fibers and particles of the material will begin to vibrate. These vibrations, creating friction, will generate heat from a sound's energy waves. This is what creates sound absorption (Souza). The materials that are used will determine the sound absorption characteristics of any given treatment option. Similarly, the density and thickness of that material will help identify it for specific frequency ranges (Souza).

Absorbers also have a variety of specific designs, each built from different materials and functioning differently. Four of the larger categories that define absorbers are dissipative, panel, cavity (also called Helmholtz), and porous (Borenstein 7). Mounting them one-quarter the length of the targeted frequency wavelength from a reflective surface will cause them to function well for high and mid frequencies due to their ability to reduce the energy from a sound wave viscously. Panel absorbers are good for controlling bass reverberation and are made from a stretched cloth membrane. Panel absorbers have a narrow affected frequency band, resulting in their use for specialized applications. They may be tuned to peak effectiveness at unwanted frequencies (Ermann). The Helmholtz absorbers are made up of cavities, constructed of wood or concrete which are open to the air at a narrow neck and resonate at particular frequencies. Additional absorption will occur at certain frequencies if the interior is dampened with an absorptive material, usually fiberglass. Helmholtz absorbers function through broad-spectrum low-frequency absorption. In a recording studio, they can be used to dampen out low-order standing waves (Borenstein 8). Another kind of absorber is a porous absorber, often referred to as "fuzz." It can be made from any of the following: glass fiber, mineral fiber, fiberboard, acoustical ceiling tile, cotton, pressed wood shavings, velour, felt, and open-celled foams (Ermann). The materials used for absorbers will determine the acoustic properties and characteristics; the more fibrous material, the better the absorption, and denser materials are usually less absorbent (Souza). Additionally, low frequencies can contribute to some of the greatest sound design faults in a recording studio, and they are harder to absorb because of their longer wavelengths (Souza). Targeted low frequency (200-200 Hz) absorption is a useful tool in this case (Storyk, "Architectural Acoustics & Audio Systems Design: Low-Frequency Control"). The buildup of sound at the back of a room can also be treated with sound-absorbing material placed at the end of the room (opposite to sound sources) to improve clarity and alleviate echoes (Ermann).

Lastly, for low-frequency control studio designers can use a treatment option called bass traps. Bass traps are a derivative of the Helmholz resonator and are made up of pits, recesses, or cavities (Borenstein 9). They may be constructed from a variety of materials, including foam, rock wool (mineral fiber insulation), and fiberglass (McAllister et al.). As sound fills a room there is a natural tendency for it to build up in the room's corners. Bass traps will intercept these sound waves to reduce the harmful effects of targeted low-frequency build-up. The design of bass traps will include varying thicknesses of material and airspace. These two factors will determine each bass trap's effectiveness towards the targeted frequencies, and "[m]aximum sound absorption occurs when the resonator depth represents a quarter wavelength of the incident bass note frequency" (Borenstein 9).

Several treatment options offer multiple benefits to your space. Curtains are a popular point of discussion here because they can be used to transform hard surfaces into soft surfaces (Demming). Additionally, carpets will give any reflective floor absorptive qualities. Storyk describes the use of carpet covering the hardwood floor allowing for a multi-purpose system to be both reflective (hardwood) at 2kHz and absorptive (carpet) at 40 Hz (Storyk, "Studio Architecture & Acoustics"). Many studio designers reiterate the idea that building hard or reflective surfaces and relying on adjustable treatment options to absorb sound will be the most beneficial use of material and space. Similarly, the addition of an air gap behind treatment panels can give them more impact on frequencies across the spectrum, including additional support for low-frequency absorption (Souza).

While acoustic treatment is very useful in creating the desired sound space there is an argument to be made against using too much. With too much we begin to lose all reflections, lower the reverberance, and remove sound energy from the space (Ermann). Storyk says that it is important to find the points of reflection and place treatment accordingly. This design technique referred to as focused acoustic treatment placement is equally effective as mounting treatment throughout the entire room (Storyk, "Studio Architecture & Acoustics"). However, as with many recording studio design techniques, acoustic treatment placement is entirely up to the discretion of the designer and studio owner(s). Beginning with focused treatment placement may be a good starting point and allow the design to evolve as desired. Another benefit to focused treatment is the cost breakdown. Acoustic treatment options are often sold by larger companies and built to have special acoustic and frequency-specific characteristics, making them more expensive. Room-specific sound design will also play a role in the desired treatment functionality and placement. This will be further addressed in the prospective studio design.

**Prospective Recording Studio Design**

To reiterate, recording studio design is a complex and largely varying process. Attention to detail, preliminary planning, and a skilled team will all facilitate the construction of a successful studio space. However, while studio designers are unable to describe any one specific studio model that is better than the rest, they can aid in the discovery of a set of industry standards and best practices that will assist with any studio design. In an attempt to explore these techniques further, a prospective studio design will be laid out here. Additional material including room drawings and floor plans are attached in an appendix and intended to provide a visual aid to the descriptions given here.

Firstly, each studio will vary based on how many rooms the studio owner would like to have. In a commercial setting, recording studios are built to house three main rooms: a control room, a live room, and isolation booths. Each of these rooms will share design standards, although the function of each room will likely change. This proposed studio design will center around an eight-room studio (see figure 1). The first and arguably the most important of these rooms is the control room. As this is the center of the listening and mixing stages, it is important that this space is accurate, to begin with. There should be no learning curve within the control room's acoustic listening environment (Durr and Schlachter). To effectively create this kind of room, the proposed studio will be designed as follows:

**The Control Room (see figures 2 &3)**

The control room will have six walls. The back wall will measure twenty feet in length. The connecting sidewalls will measure nine feet and sit at a ninety-five-degree angle off of the back wall. The second angle in the sidewalls will be one hundred and fifty degrees and the wall will be seven feet long. These sidewalls will connect to the front-facing wall of sixteen feet via a one hundred and fifteen-degree angle. A three-and-a-half by eleven-foot window on the front wall will overlook the live room. Angling the sidewalls and keeping the dimensions from being the same will help eliminate any unwanted issues with standing waves. All of the walls will be a double stud build with an air gap between them. The air gap will have benefits for soundproofing and decoupling. A double layer of drywall for the interior walls will be used to increase the wall's STC rating (Dominic). Acoustic treatment will cover the walls as needed.

Additionally, two sound-rated doors will lead out of the control room and into their respective sound locks. These doors will be symmetrical in placement, two-and-a-half feet from the intersection of the front-facing wall. All the doors within this studio will be three-feet-wide by eight-feet-tall wood doors with high-density, polyurethane foam for the core. Each door will host an additional window, one by six feet. Schrag suggests that doors are the weakest link in sound isolation and therefore sound rated doors are the "only reliable means of getting acoustical performance." Where the doors are mounted will also play a role in a room's sound quality. By placing them on the sidewalls, they will not be in a direct path from the sound source, which further helps to "obtain appropriate sound isolation" (Schrag).

A sloped ceiling, reaching twelve feet at its lowest point over the front wall, will have additional benefits for redirecting first-order reflections. Three different angles of the ceiling will help redistribute sound waves as they move around the room. This height will also allow for the installation of an acoustic cloud over the listening position. The cloud will be made up of a four-piece set of absorbers, mounted several inches from the ceiling on the first angle of the ceiling with two larger panels above them on the second angle of the ceiling. The first angle will be approximately five and a half feet in length and sit at a one hundred degree angle from the front wall. The second angle will be an additional ten degrees and three and a half feet in length. To prevent the back of the room from having any parallel surfaces, the last six feet of the ceiling will sit at a gradual two-degree incline to the back wall.

The floor will be a combination of hardwood and carpet offering options for both reflective and absorptive surfaces. The carpet will surround the listening position and lie closer to the back of the room. At the back of the room will also be a ten-foot couch, surrounded on both sides by two eight feet tall and five feet wide and one foot deep bookshelves. These will be mounted to the floor and walls as permanent structures within the room. The addition of books, magazines, artwork, and shelf cavities will function as a natural diffuser. Between them will be a skyline diffuser. Each of these diffusers will work to redistribute and prevent sound waves from building up at the back of the room.

Three other treatment options will be added throughout the room to reduce harmful reflections and increase overall sound quality. This will include absorbers, perforated panels, and bass traps. Two six feet tall and two feet wide absorbers, one on each side, will be placed two feet from the floor on the adjacent walls to the ones hosting the right and left symmetrical doors. These will be used to target first-order reflections coming straight from the speakers. Above each door, on the front side walls, there will be two more panels of perforated absorbers. These will be mounted further from the wall than the room's other treatment options in order to have a larger impact on low frequencies and prevent them from building up, unnaturally at the front of the control room. An additional selection of seven custom-shaped absorbers will sit at the top of the back wall above the bookshelves and act as a contrasting treatment to the angled ceiling and diffused sound waves as they reflect around the room. Another grid of diffusers will be mounted between the front wall window and the projector screen above it. The projector screen is available for use in post-production audio work, where a larger screen may be preferred. The rear sidewalls will use acoustic perforated panels, mounted in groups of four. Their ability to disperse sound waves, therefore lowering their volume will contrast the room's diffusive properties ("Advantages of Perforated Acoustic Panels"). Over the top of the bookshelves will be bass traps mounted into the upper corners of the back wall. Likewise, in the front of the room, floor-to-ceiling bass traps will be placed at the front wall and side wall corners to help with low-frequency build-up. Each of these treatment types, unless otherwise specified, will be placed relative to the speakers' positions. For the purpose of this research, as the speaker location is an aspect of the studio equipment, the exact location and reasoning will be excluded from this proposed studio design. However, given the direction that sound travels after leaving the speakers (or sound source), the acoustic treatment placement is intended to interact with the most direct sound waves as they travel from the front to the back of the room. Placing focused treatment at the target points for the largest and most undesired reflections will reduce the unwanted effects of these waves.

As previously mentioned, one of the key elements in any control room is symmetry. Designing and building a symmetrical room will help with maintaining an equal distribution of sound and frequencies and is also critical in establishing an accurate stereo image. Equally as important are the sound qualities of the room. At any given place in the room, the sound quality and characteristics should be the same (Durr). For the listening position, this is critical and will have the added benefit of allowing other listeners and musicians to have the same, accurate listening experience no matter where they are in the room. Putnam suggests several design aspects control rooms may suffer from including insufficient floor space and overall size, non-symmetrical room geometry, unsatisfactory acoustics, poor monitoring conditions and quality, limited space and positioning for producers, and insufficient electronic facilities. The proposed studio design will work to prevent all of these problems through all of the above-mentioned design plans.

**The Live Room (see figures 4 & 5)**

The next room within this studio is the live room. This room will be larger than the control room and approximately five hundred and sixty square feet. This room will function as the main recording space for large groups and ensembles. The live room will be a seven-walled, wood-floor space. The room will have three doors, two leading into the studios two sound locks and the third to an isolation booth at the side of the live room. Each wall will be a double stud wall with an additional layer of drywall on all walls shared with other studio rooms to maximize sound isolation. The long back wall and the adjacent wall on the left (assuming a position at the front of the room looking to the back) will each be supported by an outer layer of concrete and increased insulation as both walls will also be exterior building walls. Three windows will match the location of the other three rooms housed within this studio: both isolation booths and the control room. Although much of the discussion surrounding these studio rooms implies that parallel walls should be avoided, this live room will make an exception. Although it is not recommended, in this case, the parallelism will be disrupted by the use of four nearly floor-to-ceiling one-dimensional diffusers mounted on the back wall.

The ceiling will be angled downward from the back of the room to the front where it will be its lowest at fourteen feet. Beginning at the back wall with a height of eighteen feet, this will leave a four-foot rise from front to back over a nearly nineteen-foot room depth, approximately a twelve-degree angle of increase. The sloped angle of the ceiling will benefit the space by further reducing the negative results of a parallel floor and ceiling while also providing the space for room length tiers to be incorporated into the ceiling design.

Alternatively to the focused treatment placement of the control room, the live room will have a more expansive use of treatment options since “live rooms are most likely to benefit from treatment that focuses on the whole of the room instead of specific points" (Vinnie). The tiered system in the ceiling is inspired by recording and mixing engineer TC Zhou's Studio 21A, designed by the Walter-Storyk Design Group. There will be five tiers that alternate in thickness and help disperse sound back throughout the room at different times. As mentioned before, the back wall will support four sixteen-an-a-quarter by six-foot, one-dimensional diffusers. This will be combined with eight custom-shaped absorbers on the left-hand side wall (standing at the front of the room looking to the back), designed to match those on the back wall of the control room. Four acoustic perforated panels will be mounted above the doors and windows and the remaining four walls. A large six-foot by five-foot bass trap will be mounted above the window on the back right-hand wall. These will help lessen the amount of noise build-up and improve the overall sound quality of the room.

Lastly, the live room will have the option of adding a large carpet over the original wood floor to assist in creating a more absorptive surface. Commonly this will benefit drum recording, however, carpet is also beneficial in preventing any drums from sliding on the wood floor during a performance. The live room, separate from the studio's two isolation rooms, will be the central location for a large percentage of the recording process. Due to this, it is essential that the live room enables the artists, engineers, and producers to get the very best possible sound in their recordings. While the production stage may be used to counter any unwanted noises or effects, the ideal recording will be as close to the desired final product as possible.

**Isolation Rooms (see figures 6, 7 & 8)**

In addition to the control and live rooms, the proposed studio will host two separate isolation booths. The smaller of the two will be roughly thirty-five square feet and designed for individual and vocal tracking. The door will connect to the control room via one of the studio's two sound locks. This room, intended to produce the clearest recordings (particularly important for vocal tracking) will use a double stud wall design, with added insulation and drywall on both the interior and exterior of the walls. Continuing on from the live room, a cement exterior wall will also increase isolation and reduce any unwanted noise pollution. The ceiling will sit twelve feet above a fully carpeted floor. Sidewalls will measure five by eight by seven by four and three quarters. These dimensions will eliminate parallel walls and orient the room to match the angled front wall (looking to the front of the room) of the live room. Here there will be a four-and-a-half by six-foot window allowing anyone in either room to benefit from a clear line of sight. An additional window will be mounted into the door, allowing for a line of sight connection to the control room.

The three main windows of this studio will be three sheets of plate glass, with an air gap between each. All three sheets will vary in thickness, therefore, reducing resonance. The thickness and angle of the glass will also determine the effects of standing waves. Angling each sheet of glass helps reduce these factors by eliminating parallel surfaces (White). The addition of an absorptive material (Rockwool for this studio design), mounted into the frame and between the glass sheets, will function to capture any sound energy that does transfer into the air gap. A neoprene gasket will be used to fill in the space between the glass and the frame so that the glass is isolated from the surrounding wood frame (White).

The second isolation booth will be larger, roughly eighty-five square feet. One longer, twelve-foot wall will be the backdrop of this room. On the opposite side will be a door and window. The door will sit on the far left-hand wall (looking ahead from the back wall). This second angled wall will have a full six-foot by eight-foot-tall window looking out to the back of the live room. Additionally, as this window and that of the first isolation booth will look over the live room from opposite corners, it will have the advantage of being able to establish a line of sight connection from one isolation room, through the live room, and to the other. The larger size of this isolation booth is intended to support larger instruments (drums, percussion, piano, etc.) or small groups that may be suited to be isolated from the live room.

The ceiling will be twelve feet high with acoustic perforated panels mounted six inches below. These will help absorb and redistribute sound throughout the room. This room, like the other isolation booth, will be fully carpeted. This way the floor and ceiling surfaces will counteract each other and soften the overall room sound. Additional absorbers will be mounted on the back wall with floor to ceiling bass traps mounted in both corners of the back wall. The door leading to this room will not have a window, given that the space itself already has one. The wall design will match the first iso booth.

**Equipment Room (see figure 1)**

This studio will also have two additional non-recording-based rooms, one for storing gear and a second will be used as a machine room. The first of these will be located adjacent to the control room on the right-hand side (looking forward to the control room). Access to this room will come through the sound lock into the hallway and have a door on the right-hand side. With a fully carpeted floor and a nine-foot-high ceiling, this space will function strictly as a storage space for gear (microphones, stands, instruments, amps, cables, etc.). A standard single stud wall with insulation and a single layer of gypsum board on either side will be sufficient to frame this room.

The second of these rooms will connect to the other side of the control room, through the sound lock. Even though this room will also not be used for recording, thicker walls will be needed as this is the space where all of the machinery needed to operate the studio will be located. Often this will include fans and systems running with some amount of noise. Isolating these within this room will best support a fully functioning and quality sound space for the control room. To do so the room will be fully carpeted and keep a double stud partition between it, the control room, and the isolation booth adjacent to it.

**Sound Locks (see figure 1)**

Another space that has been mentioned often and will often be found in recording studios is called a sound lock. These are small spaces that connect one room to another. This proposed studio will have two sound locks that connect the control room to the live room, iso booths, machine room, and entryway. The sound lock on the right-hand side of the control room (assuming a position looking forwards) will have four doors. One to the control room, one to the smaller of the two iso booths, a third to the machine room, and the fourth out to the live room.

The added benefit of these spaces is that they function as an extra barrier between rooms (iso booth and control room, control room and live room, and the machine room) to further increase sound isolation ("Sound Lock Framing"). Similar to the double stud partition wall design, the air gap created by separating rooms from each other will function as an additional insulator. Sound locks are great for sound design, but also because they can be incorporated into the studio design as functional spaces without taking up unnecessary space. With the walls of a studio standing at different angles, this creates locations between rooms that may otherwise go unused and as unneeded, but usable square footage. Like other elements in studio design, they are a way to maximize space and efficiency by serving a multipurpose.

**Conclusion**

The proposed studio design is intended to demonstrate an understanding and application of the research presented. To complete a full design and plan a commercial recording studio space, however, additional time and research would be needed. Studio features such as gear, additional rooms, electrical, and lighting were omitted due to the focus of this research on architectural acoustics and treatment design.

While designing a recording studio, it is important to think about whom the space is being designed for. This varies from studio to studio based on what the intended use of each room will be (this includes people, gear, and sound characteristics). All in all, it is important to remember that the design should reflect a space built for everyone involved. This includes the engineers, producers, and artists. As acoustician Steve Durr remarks, the "vibe" in any recording studio is critical to its success. People want to play and record in a space that is welcoming and inspires creativity.

Finally, to reiterate a key point of recording studio design, there is no one right way or perfect plan that will formulate the ideal studio space. When it comes to designing and constructing a studio, the goal for any studio designer should be to create a space that sounds good. Noise pollution, sound transmission, sound isolation, reverberation, and reflection control are some of the leading components that will determine the acoustic characteristics of a room. Fundamentally these will all boil down to one important factor: clarity. Each step in the recording process (the recording itself, mixing, editing, and mastering) will all depend on a space that accurately presents clear and controlled sound. Without this, every step in the creative process becomes subjective to that specific space and will not translate accurately outside of the studio environment.

This research is an attempt to answer a much larger and very complex question: what does it take to design, plan and construct a commercial recording studio? The gathered research and proposed studio design are intended to function as a representation of a series of industry standards and best practices that will guide the design, construction, and material selection for commercial recording studios. By no means does this research claim to identify every single shared studio design technique, nor present an all-encompassing studio design plan. Instead, the goal is to begin this exploration and provide a research-based, example-supported look into architectural acoustics and design in commercial recording studios.

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