A Case Study on the Design Process of a Panelized Control Room

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The sound studio industry is shifting from commercial to residential, and audio engineers are in need of a home workspace. These audio engineers work in an environment called a control room, and they use technology to creatively produce sounds that can be used in film, music, video games, presentations, or any other situation requiring professionally adjusted sound. New technology is giving audio engineers the ability to turn laptops into personal music producing platforms, but they are still lacking the acoustical environment that commercial control rooms provide. This case study covers the journey through the design of a panelized control room fit to solve this issue. It is a structure that can be built nearly entirely off-site in a controlled factory environment, and then assembled on-site with little or no additional framing material. This paper describes how this structure integrated classic acoustical design concepts with the modern acoustical assemblies found in Playstation's new audio edit rooms currently being built in Los Angeles.

Key Words: Panelized Control Room, Acoustical Design, Music Industry, Sound Studio, Home Office

Introduction

An audio engineer uses technology to creatively produce sounds that can be used in film, music, video games, presentations, or any other situation that requires professionally adjusted sound. Most of their projects involve creating music, and many audio engineers work in an environment called a sound studio. The term sound studio, however, is broad in that it encompasses many different work environments (Everest, 2013). The panelized sound studio is geared to be a control room, thus it has been named a panelized control room, or PCR for short. This room can be used to do the following: create music using software instruments, listen to music, mix music, refine and master music, evaluate music, edit videos, and operate as a home office. It is versatile and therefore it is in demand in the music industry.

From a macro point of view, the industry is shifting from commercial to residential. "Although nobody officially tracks the number of recording studios, the consensus among industry experts is that the big commercial facilities have taken a major hit. They estimate that as many as half of the L.A. area's commercial studios have closed or been sold to artists for private use" (Oliverez-Giles, 2009, p.1). This is not to say that commercial sound studios are becoming obsolete, nor is it saying that none are being built any more. There is something happening though: more music is being created in residential workspaces. There are a few reasons for this, but there is one big one in particular; new technology.

New technology is giving audio engineers the ability to create music in places outside the big commercial sound studios. "A key reason is that recording software emulates what old studio consoles and tape recorders used to do, at a fraction of the price" (Oliverez-Giles, 2009, p.1). Avid's Protools and Apple's LogicPro are examples of applications that can turn most new laptops into professional music producing platforms. This software is amazing, for it is opening up new doors for audio engineers. They can more easily start their own companies and work as contractors. They no longer need to get hired by big commercial sound studios, though they certainly still have that option. There is a problem though, and that is that as they move away from commercial studios, they lose access to well-designed control rooms.

Audio engineers may have the equipment to work outside the commercial atmosphere, but they still run into problems without nice sounding control rooms. This is because the control room has a very big impact on how the music sounds when it is finished. If the control room is not designed properly, then the audio engineer may consistently put out music that has deficient or excessive decibel ranges in certain frequency bands (Everest, 2013).

This poses a big problem when music is played back in other rooms, as it can make listeners feel uncomfortable with how loud or quiet certain parts of the song are. This is why the perfect circumstance for an audio engineer is created by having access to nice equipment and nice control rooms. Unfortunately, audio engineers cannot afford professional control rooms at their house.

According to the (Bureau of Labor statistics, 2013), audio engineers made around $62,000 per year on average. A professionally designed and constructed residential control room can cost hundreds of thousands of dollars, or even worse yet, millions of dollars. So it is time to create a solution to this issue so audio engineers can gain access to a personal work space that is affordable. There is already a company attempting to do this. Delta H. Design Inc. has begun to turn forty foot shipping containers into control rooms for the public. This, however, does not solve the problem for the average audio engineer living in an urban environment, because shipping containers will not easily fit on their property. The music industry is going to need something that can make it into an average sized backyard without using a crane.

This paper is a case study on the journey through the design of a control room fit to solve the issues presented above. It is a panelized structure that takes a big step in the direction of reducing control room costs, and increasing control room portability. The design is intended to give every audio engineer the capability of becoming completely self-sufficient.

General Background

Before going any further, it is important to define what a panelized system is. "A panelized wall or roof system is a system in which wall or roof assemblies are built partly or entirely off-site in a controlled factory environment, and then assembled on site with little or no additional framing material" (Barrows, 2005, p.4-19). This control room will be completely panelized from floor to roof.

Sustainability

In the very beginning, upon creation of the idea, there was an internal debate as to whether this control room should be built off site in a warehouse, or on site at the audio engineer's house. The final choice was in a warehouse. This allows for controlled weather, mass production, convenience to the audio engineer, but most importantly, it is more sustainable. "Because panelized systems are built using exacting designs, material waste is kept to a minimum" (Barrows, 2005, p.4-19). The National Association of Home Builders recognizes these structures as a great way of helping to conserve nature. "Construction waste is generated at the rate of about 0.5 tons per person each year in the U.S. or about 5-10 lbs per square foot of new construction. Waste from renovation occurs at the level of 70-100 lbs per square foot" (Kibert, 2005, p.1). Based on these industry numbers, it is very important to utilize any green building application when possible.

Quietness Acoustics vs. Internal Room Acoustics

While keeping the design green was very important, the control room acoustics were even more important. No one wants a control room that does not sound wonderful. John Storyk, owner of Walters-Storyk Design Group, is a high end sound studio designer. He has been building sound studios since the Jimmy Hendrix days, and he has broken down the core issues of sound studio design into two classifications. The first is quietness acoustics, and the second is internal room acoustics (Storyk, 2004). When Mr. Storyk mentions quietness acoustics, he is speaking about keeping sounds created outside the control room from getting in. This is also known as sound isolation. This first issue is challenging to solve, so much attention must be directed its way. The second issue, internal room acoustics, addresses sounds being created from inside the control room; here, creating an optimal listening condition is the goal. Though this second issue raises much concern as well, it is usually less costly to solve.

Sound Isolation

Sound isolation that creates an appropriate noise criteria (NC) rating will be critical for the urban environment this PCR plans to operate in. A NC rating says how quiet certain frequencies must be inside a room. They are based on balanced noise criteria contours. "These criteria curves plot octave sound pressure levels with respect to frequency and show levels of maximum permissible noise" (Everest, 2013, P.185). The PCR will be shooting for a NC 20 rating; this is preferred for control rooms (Storyk, 2004).

This is a very quiet rating. Here is a small list of measurements found in a structure built to a NC 20 rating: 16dB at 8000 Hz, 22 dB at 1000 Hz, and 33 dB at 250 Hz, just to name a few (Noise Criterion, 2014). To really understand how quiet this is, it is important to examine the ambient noise levels of an urban neighborhood. It is estimated that the majority of people living in urban neighborhoods are exposed to around 55 or 60 decibels (Office of the Scientific Assistant). This study does not give decibel levels at different frequencies, because they are always changing, but it does show why good sound isolation is important.

The most effective way to isolate sound, which gets measured using transmission loss (TL) values, is to use dense materials for the floor, wall, and ceiling barriers. "TL is the reduction in sound energy caused by a barrier," and "it is measured in decibels" (Everest, 2013, p.97). The TL values for materials also vary with frequency. Dense materials provide high TL values, so it will be advantageous to incorporate them into the shell of the PCR. Aside from using dense materials, floating the control room is another design feature that helps achieve high TL values. To float a room, a floor is built on top of another floor with neoprene isolation pads and insulation on the underside, then walls and a ceiling are built using the new floor as a base (Construction Isolation, 2014). This technique gives a high TL value, because the new room is not mechanically connected to the main structure. When used in combination, dense materials and floating systems create very good TL values. Integrating these concepts into the PCR will be a big help in reaching a NC 20 rating.

Room Shape

The first step in addressing internal room acoustics is figuring out the shape of the room. The shape of the room can have the biggest impact on how sound will get reflected. There are three main types of reflections that cause issues for the audio engineer: repetitive reflections, early reflections, and standing waves. The shape of the room can be adjusted to help control all of these issues.

Repetitive reflections, also called flutter echoes, typically occur at parallel walls. Sound reflects back and forth between the two parallel walls until the sound decays to an inaudible level (Everest, 2013). An audio engineer will hear sharp pulses of sound as these flutter echoes pass by their ears each period. This interferes with the direct sound coming from the speakers. This issue can be avoided by designing the room with few parallel walls.

The next type of reflection, called an early reflection, is created when sound reflects from a wall near to the speaker and interferes with the direct sound coming from the speaker. This indirect sound interfering with the direct sound causes impurities at the listening position, the location where the audio engineer works. To solve this issue, the designer can change the angle in the near speaker walls to redirect these early reflections away from the listening position.

Lastly, standing waves can cause issues for the listener. Standing waves are formed when certain frequencies resonate, and cause sound pressures to build-up and drop in different areas of the room (Everest, 2013). When a build-up or drop appears at the listening position, the audio engineer will not hear the frequencies properly. They will hear them either as too loud or too quiet. The best way to control standing waves is through the shape of the room, because it affects the natural distribution (Storyk, 2014). When the room is shaped and dimensioned accurately, standing waves can be tuned or diverted in a way that is advantageous to the audio engineer. Taking the time to do this in the design process can save a lot of trouble later on once the room is built.

Location of Speakers

The next step in the design process is to decide on the location of the speakers and listening position. The PCR will have two speakers and one listening position. There is no absolute way of positioning these. John Storyk said that "there is still no definitive stereo playback listening position standard other than everybody seems to be in agreement that the left and right speakers are symmetrical around a listening/acoustical centerline" (Storyk, 2004, P.22). He further went on to illustrate that the most commonly used layout is an equilateral triangle having dimensions between eight and twelve feet.

The audio engineer sits in the middle of the room with the two speakers in the front. The speakers are angled so their centerlines intersect at a point that is about two feet behind the audio engineer's head. This is done so the centerlines pass directly through the ears (Everest, 2013). The speakers are lifted to be at roughly the same height, or a bit higher than the audio engineer's head. If higher, they are tilted down to keep the centerlines pointed towards the ears. This layout fits nicely into the PCR's floor plan.

Materials

Different types of materials are strategically placed throughout control rooms to tailor their overall sound, which is characterized in many ways. This paper does not have room to cover all those ways, so it will focus on one of the most common characterizations; whether the room sounds "live", "dead", or somewhere in between. To understand where a room falls on this spectrum, reverberation time needs to be defined.

Reverberation is found in every room, and it is characterized "as the decay of a body of sound energy contained in architectural space; the decay [is] the result of energy being absorbed by the material surfaces [binding] the space" (Thompson, 1997, P.599). Reverberation is examined over a period of time, and that is the time it takes for the body of sound energy to drop 60 dB (Everest, 2013). When it drops below 60 dB quickly, the room is considered "dead". When the sound lingers and envelops the space for a while, it is considered "live." Reverberation time is dependent on all the materials in the room and their respective absorption coefficients.

The absorption coefficient, as the name implies, describes the absorptivity of specific materials. "This coefficient can be viewed as a percentage of sound being absorbed, where 1.00 is complete absorption (100%) and 0.01 is minimal (1%)" (Schwind, 1997, p. 1). Materials with coefficients less than .2 are considered reflective, and materials with coefficients greater than .5 are considered absorptive. A control room needs to have a good balance of reflective and absorptive materials. Just using these two types of materials can solve a lot of acoustical issues, but not all of them.

There are times when absorption could solve a problem of reflection, but if added it would result in a decrease of sound energy that is undesirable (Everest, 2013). In this case, diffusers could be added because they keep the desired sound energy while solving the reflection issues. Diffusers come in all shapes and sizes, but they all work in similar ways. Sound waves hit the diffuser and get scattered throughout the room in all directions. The room begins to feel enveloped and full of sound when these diffusers are placed in the correct position. While diffusers are not critical to have in small rooms like the PCR, they can be used strategically to give the room a bit more energy.

Live End-Dead End

Many control rooms are configured in a live end-dead end fashion. In this configuration, the side of the room with the speakers set up contains absorptive materials, while the opposite end is set up to be more reflective and diffusive. So the front end with the speakers becomes "dead," and the back end becomes "live." This concept is also integrated into the PCR.

Base Traps

The last part of this section is devoted to the low frequency issues that arise in small controls rooms such as the PCR being discussed in this paper. Low frequencies cannot fully propagate in small rooms, because they have wavelengths longer than the room itself. For example, 20 Hz has a wavelength of 56.5 ft. The front end of this wavelength will reflect off the back wall of the control room, and interfere with itself on the way back. This issue leads to undesired standing waves, but it can be addressed.

"[Low] frequencies tend to build up in the corners of a room, so an absorptive apparatus called a bass trap can be positioned in these areas to minimize low-end woes" (Pedersen, 1997, p.1). In simple terms, bass traps are box like structures with built in insulation. Low frequencies enter into the structures and get trapped inside. The base trap depth determines how low of a frequency will be absorbed. The trap needs to be at least a quarter-wavelength of the frequency. For example, a 3 ft. deep trap would peak at 94 Hz, because that has a wavelength of about 12 ft. (Everest, 2013). Since space is limited in small rooms, big base traps are not always feasible. This means issues at real low frequencies can still show up; nonetheless, they are still mitigated using a strategic combination of base traps and the other design principles discussed above.

Objectives

The journey through the design began by first deciding upon three objective criteria that would make the PCR appealing for audio engineers that want to work from their house. These criteria were based on sound quality and convenience to the audio engineer.

The first objective criteria was formed on the basis that the PCR must be a professional sounding control room capable of meeting a NC 20 rating. To achieve this rating and professionalism, ideas need to be drawn from both literature and other professional control rooms. Therefore, the PCR will have a design that incorporates ideas from the design of Sony Playstation's audio edit rooms. These audio edit rooms are currently being built in Los Angeles, and they will achieve a NC 20 rating.

The second objective criteria addresses the speed of which the PCR will be up and running after it leaves the warehouse. This design criteria requires that the PCR must have the ability to be shipped on-site, and become operational within a few days of procurement. This way, the audio engineer can begin working the very week it is ordered.

The final objective criteria requires the PCR to be designed so it may be constructed on-site with only a few construction workers. Keeping the quantity of labor low will make this design more affordable for the audio engineer, because labor is an expensive variable in construction cost. These three objective criteria create a foundation and help guide the design into a smooth progression.

Methodology

Before any designing could be done, a deep understanding of acoustics needed to be obtained. This is why becoming more educated on acoustics was integral to the design. Studying acoustics displayed a new realm of concepts that could be integrated into the PCR. Therefore, it is important to note that studying literature was an ongoing process that followed through the design process.

Working with Sony Playstation's Design

It is also important to note that the PCR is still in the process of being designed, so this paper only covers the beginning of the story. It starts out with a trip down to Los Angeles, where an interview took place with a superintendent. This superintendent worked for the general contractor in charge of building Sony Playstation's audio edit rooms. These rooms are very similar to control rooms. They are used to produce music for video games, and they are designed to seat one audio engineer.

The superintendent was very well versed on the details, materials, and assemblies being used throughout all the audio edit rooms, so he started to discuss some of the techniques used in the rooms. The floor plan he described uses a technique that is commonly used in professional control rooms. It is a technique that utilizes what is called a reflection free zone around the listening position.

Reflection free zones angle the side walls of the control room so the sound reflects around the perimeter of the room, leaving the listening position free from any early reflections. In other words, it creates a "sweet spot" at the listening position that gives a spatial impression of being enveloped by sound. To help induce this reflection free zone, the audio edit rooms had creatively placed angled base traps in the back center of the room. With these in place, the sound would leave the front speakers, bounce around the perimeter of the room, hit the back centered base traps, and do two things: First, low frequencies would be absorbed by the base traps. Second, the angle in the trap would push any sound that was not absorbed back along the perimeter of the room.

In light of seeing this technique both in literature and at Sony Playstation, it was made clear that the PCR should take on a room shape and base trap configuration that creates a reflection free zone at the listening position. Gaining this information propelled the design forward because room shape plays a large role in the movement of sound within a control room.

The design process was going very smooth with the help of the superintendent, but a big issue of portability was unraveling as he discussed the complex features that were framed into the audio edit rooms. The back centered base traps, just mentioned, exemplify the first part of the issue, because there was a question as to how these could get shipped on-site and installed in the PCR.

Another part of the issue came with the base traps and speaker frames that were located in the corners of the audio edit rooms. Even though back corner base traps were discovered in the literature review, there was still no answer to as of how these were going to find their way into the PCR. The audio edit rooms also had framed speakers in the front end of the room with thoroughly insulated baffles. This also required a need for on-site framing, but this is not an option. It would require too much time on-site. There were now three components that needed to be made portable: the angled base traps in the back center of the room, the back corner base traps, and the front wall speaker frames.

Results

This is the part of the story where AutoCAD started to come into play. The basic idea of the structure was set, and it was now time to start drawing it out to resolve the issues. AutoCAD was a great help in doing that. It inspired creative solutions, because design tweaks could be made effortlessly. While drawing in AutoCAD, it was made clear that the solution to the portability issue did not involve anything along the lines of adding more intricate panels to the system or creating framing attachments. Instead, each component could be broken down into stackable modular pieces.

Designing in AutoCAD

These pieces are small enough to be handled by two people, and they can combine to make both base traps and speaker stands with insulated baffles. They can also be placed around the room to create any geometric shape desired. They also provide good places to attach diffusors. Figure 1 shows the first conceptual floor plan of the PCR, along with the base trap and speaker frame modules stacked inside. There are seven sets of modules. The three sets in the front of the room offer both vibration control and housing locations for the speakers and television. The four sets in the back of the room stack to become base traps. These four sets will both absorb low frequencies and help create a reflection free zone.

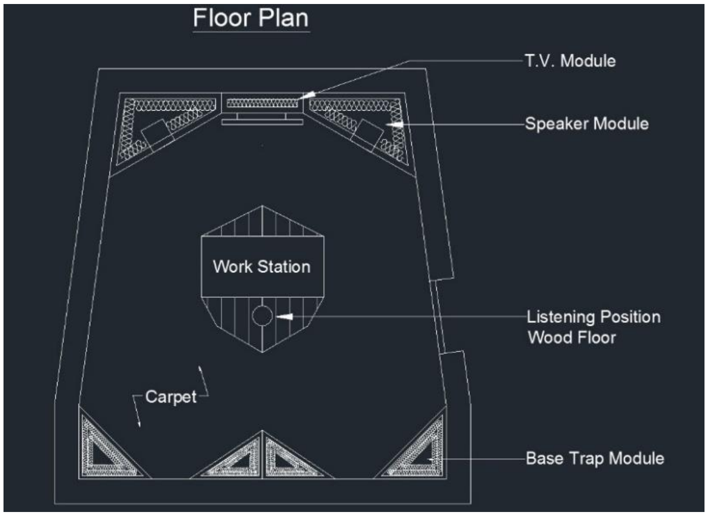

Figure 1. Panelized Control Room Floor Plan Showing Room shape and Module Placement

Designing and placing these modules was another big thrust in the design, because now every part of the PCR was portable. Without these modules, the design might have come to a halt, because the PCR would not have been able to meet the objective convenience criteria. With this criteria now met, a new door in the design was opening.

The next stage involved figuring out a way to integrate the structural system with the acoustics. Good sound isolation is one of the primary goals when trying to achieve a NC 20 rating, and good sound isolation comes with dense materials and floating systems. Therefore, a lot of researched needed to be done to figure out what materials would be best, as well as how a floating system could fit into the design. Once these were better understood, there needed to be cohesion between them and the structural system.

The first and most realistic way of meshing the acoustics and structural system came to mind in the form of having the structural system act as a scaffold. It can be made from steel and pieced together quickly on-site. Once together, panel pieces with pegs can attach to the scaffold and be held in place. This keeps the structure sturdy, but it also holds the desired acoustical integrity. Good sound isolation is provided by using this technique.

With this pegged connection now in mind, the first panels could start being design. The floor panels were the first, because they provide the best opportunity to integrate a floating system. The floor panel design uses a system very similar to the floor system used in the audio edit rooms at Sony Playstation. The main difference is that the PCR will be using it on a raised floor, while Sony Playstation was working with a concrete slab.

Figure 2 shows an AutoCAD drawing of a typical floor panel and how it will connect to the scafforld. The bottom side of the floor panel uses aluminum framing with acoustical insulation, and is then sealed with a product called Quietwood. This is a proprietary material that provides a high transmission loss value, and it can take the place of normal sheathing. Above the Quietwood lies an isolator system. This isolator system uses polymeric pads every sixteen inches on center to float the floor above it. Then, multiple layers of dense flooring material can rest on top for better isolation.

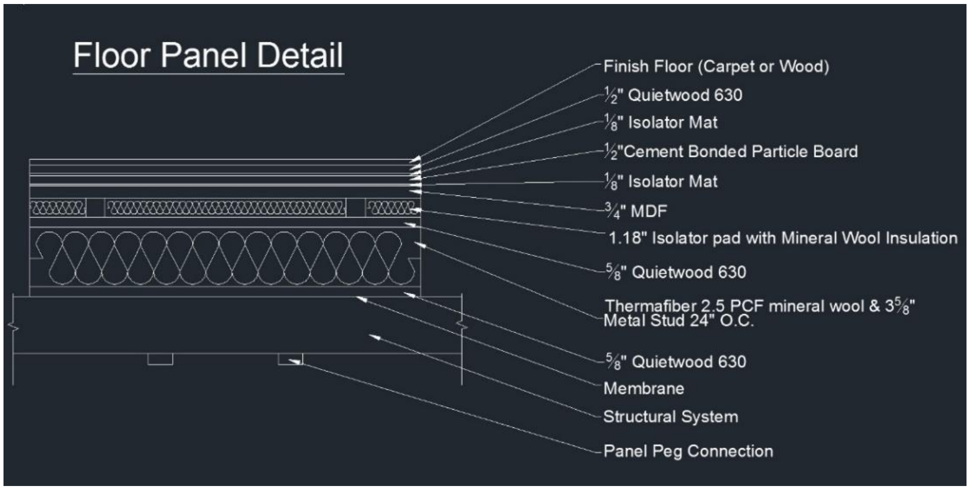

Figure 2. Panelized Control Room Floor Panel and Connection

The next stage involved deciding how big a typical panel should be so two workers can easily pick it up. As mentioned above, these materials are very dense and will be heavy to lift when layered the way they are. So the panels need to be small; roughly two feet by four feet. This size can be used for floor, wall, and ceiling panels.

The wall panels were designed next and Figure 3 shows the result. These panels also connect to the scaffold system using pegs. This panel does not use the polymeric isolator system. The figure also shows siding connections.

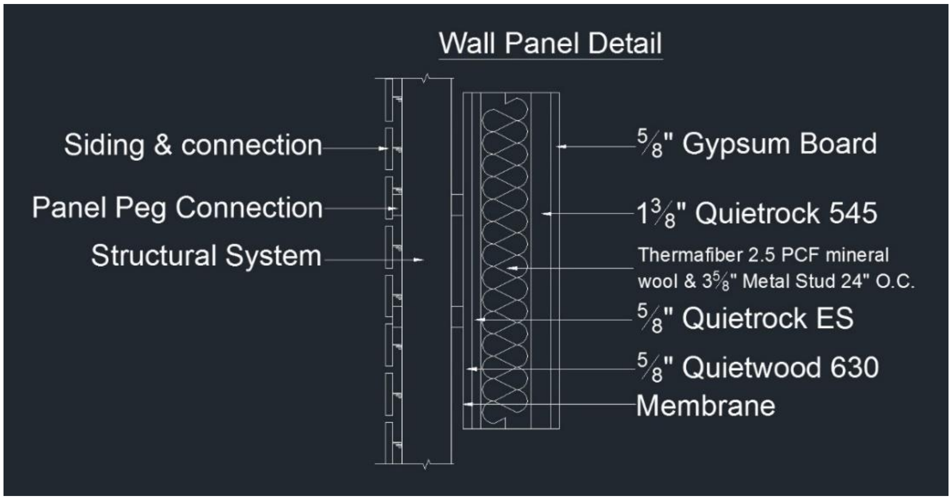

Figure 2. Panelized Control Room Floor Panel and Connection

As it is possible to imagine the ceiling system will be similar to this, and it was the next step in designing the PCR. Many of the acoustical details have been designed at this point, but there are still hurdles to leap before the PCR can be brought to the public.

Future Research

These hurdles all involve future research and designing. The HVAC design has been started, but it is still in the beginning stages. Future research and design should continue from this point. There are many acoustical techniques that get integrated into this area of the design, and it is an interesting topic. Control room designs find some of their most challenging issues presented during the design of the HVAC system. This is because HVAC units produce low vibrations that find their way into the control room and interfere with sounds coming from the speakers. This can be managed by treating the ductwork. Aside from the HVAC system, the electrical system also needs to be designed. This should not be too intricate, because there isn't an astounding amount of electrical devices that need powering.

Once the major components of the design have been completed, it would be good to run a model of the PCR through aural imaging software to simulate how sound will move around inside. This software accurately predicts how well the PCR will function as a control room. After adjustments are made, a physical mock-up will need to be built and assembled to iron out any kinks. Mock-ups catch sound impurities in the design, help confirm it only takes a few workers to assemble, and can bring forth any other problems that were not discovered during the design process. The PCR is small, so it should at least be done once.

From a business standpoint, there is also much work to be done. A cost analysis and market study needs to be conducted. The market study will be used to figure out the best places to sell the PCR. There are a few very important cities in the music industry, so finding those cities and the target market within them will be very important.

Finally, when everything above is settled, a business plan can be brought forth. The horizon is still far away, but it is visible. The work that needs to get done from here is very interesting, and it will surely produce a deeper understanding of what the acoustical world has to offer.

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