CONTROL ROOM DESIGN: THE MONITORING ENVIRONMENT

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Introduction

The term "control room" originated in radio broadcasting and was later adopted by the music recording industry. In the early days of disk recording, the control room was little more than a booth, and it is still called a "cabina" in Latin-American countries. Today, the room is much larger, perhaps 18 by 25 feet. It is used both to control the actual recording process ("tracking") and to assemble the multiple tracks into a final 2-channel or surround sound product ("mixing"). In a large music recording facility, mixing may be performed in a separate, dedicated room. If the product is to be released as a music album it will be sent to a mastering facility for a final check. The mastering engineer usually adds minor electronic processing, but may recommend re-mixing certain portions before the recording is released. A third type of monitoring environment is a production studio (or "composer's room") in which music is both created and edited.

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Historical Perspective

Before the introduction of audio tape recording in the late 1940s, commercial music was recorded direct-to-disk. In the U.S., the control booth was usually a small, utilitarian space adjacent to the recording studio. A window, perhaps 3 feet high by 5 feet wide, provided visual contact between the two rooms. The cutting lathe and a small audio control panel were located close to the window, giving the operator a good view of the studio. An ordinary radio-quality loudspeaker in a box was mounted on the wall above or beside the window. The only acoustic treatment consisted of perforated fiber tiles on the ceiling and upper wall areas.

The Capitol Records Tower in Hollywood, containing two state-of-the-art recording studios, was constructed in 1956. Each control room was a triangular structure built across one corner of the studio. At that time most recordings at Capitol were made on 3-channel tape, with one or two microphones routed to each channel. Three-channel master tapes made it easy to release albums as mono or (after 1958) stereo LP disks. The audio control board was placed against a wide studio window, and three loudspeakers (one for each channel) were set in an alcove above the window. Recording engineers had access to a patch bay and a fair amount of audio processing gear—mostly equalizers and limiters. Tape machines were located in the rear corner. Although a great deal of attention was given to the acoustics of the studios, the control rooms were not intended to be critical listening spaces.

The idea that the control room should function as a reference listening environment dates from about 1966. By then, 8-track recording was common, but the process of combining all 8 tracks into a 2-channel stereo master was still in the experimental stage. RCA Records had opened large, new studios in several U.S. cities. These were designed by John Volkman to meet the special requirements of multitrack recording, and he established acoustical goals for the control rooms as well as the studio spaces.

Also in 1966, the British Broadcasting Corporation standardized basic acoustical requirements for broadcast control rooms, based on the belief that: "listening rooms and control rooms should not be very dissimilar from the average conditions encountered in private houses." BBC control rooms were therefore designed to have reverberation times of 0.4 second up to 250 Hz, gradually decreasing to 0.3 second at 8 kHz.[1]

By 1969 the number of tracks for music recording had increased to 16 and it became apparent that monitor loudspeakers should serve as a reference for the final 2-channel product rather than providing dedicated sound sources for individual tracks. Instead of the BBC's simulated living room, the mixing environment became a kind of acoustical magnifying glass. As an example, the Los Angeles Record Plant opened in 1969 as one of the world's first 16-track recording facilities. Control rooms, designed by Tom Hidley, looked more like space ship cockpits than conventional listening rooms.

Each control room had a pair of high-power, custom-designed monitor loudspeakers flushed into a tilted wall above the studio window. The speakers abutted a hard, sloping ceiling that descended to a height of about 7 feet above the work area. In the rear third of the room the ceiling leveled off and was covered with absorptive treatment. The large 16-track console was located near the center of the room, providing a fairly wide area in which stereo playback could be judged. Hidley's goal was to provide an accurate stereo image in the console working area and not worry about the remainder of the room. As a bonus, the "compression ceiling" delivered powerful, gut-punching bass that was a new experience for recording engineers.

The next ten years saw a further increase in the number of recording channels from 16 to 32. It also saw a proliferation of new control room design philosophies, each characterized by its own technical jargon, such as compression ceiling, live-end-dead-end, Haas fushion process, bass trap, quadratic residue diffusor, and reflection-free zone. F. Alton

Everest gave a well-researched comparison of several design approaches in the 1987 *Handbook for Sound Engineers.* [2] One of them generated enough interest and controversy to deserve a brief discussion here.

In 1980, Don Davis and Chips Davis (the two authors are not related) published a paper titled, "The LEDE Concept for the Control of Acoustic and Psychoacoustic Parameters in Recording Control Rooms."[3] The LEDE (live-end-dead-end) concept suppresses first-order reflections in the range from 0 to at least 5 milliseconds. Later reflections are made as dense and diffuse as possible. To achieve this goal in a control room of practical dimensions, the front half of the room must be almost completely absorptive, and the rear half must consist of reflective scattering surfaces. The design was said to provide two important advantages. First, it tried to avoid comb filtering generated by early reflections. Second, the dense, later arriving reflections were intended to create the subjective effect of a much larger room.

Regardless of the pros and cons of LEDE theory, it is difficult to implement in practice because the "dead" surfaces should be fully effective down into the 200 Hz region. A number of very small LEDE rooms were built, and they sounded just as bad as other too-small control rooms. In any case, although LEDE control rooms were actively promoted for several years, they disappeared almost overnight, as did other radical designs. In the following 30 years, much additional research was done regarding the role of early reflections and other aspects of listening room acoustics. The subject is fully covered in Toole's *Sound Reproduction*, first published in 2008.[4]

In the 1980s and 1990s the music recording industry grew rapidly, stimulated by the introduction of the digital CD as a universal playback medium. At the same time there was a steady shift away from large, multi-studio facilities owned by the major record labels. More and more albums were recorded in smaller independent studios. It became common practice to cut individual tracks in various venues, and then assemble the final product in a dedicated mix room. During that period the independent mastering engineer became an important figure in the production process, serving as a final retouch artist before an album was released.

After an unfortunate detour for quadraphonic monitoring, new control rooms in the U.S. gradually began to fit a common template, one that emphasized 2-channel playback but allowed for surround sound mixing as well. At the turn of the century the recording industry mistakenly assumed that consumers would rush to buy surround sound albums of their favorite artists. Things didn't work out that way.

In the 2002 edition of the *Handbook of Recording Engineering*[5] Eargle gives a description of a generic, high-quality control room. Its design will be taken up a little later, but one feature should be noted here. Eargle explains, "A center loudspeaker is often soffit mounted in the front along with the traditional large stereo loudspeakers, and this is to facilitate film work." In other words, only three years after Sony's introduction of the Super Audio Compact Disc, surround sound was not considered to be a successful format for music recordings.

After 1990 or so, although professional recording engineers had reached a consensus regarding the characteristics of a good mixing room, fewer and fewer such rooms were being built. The Pro Tools digital work station had become the accepted standard for tracking, processing, and mixing recorded music. Almost every music composer and producer acquired a Pro Tools setup and proceeded to use it in the nearest convenient location. A spare bedroom became a professional music production room. If we include music composed for television and movies, the bulk of music produced in the U.S. today probably comes from residential studios. A major challenge for studio designers is how to make a small room acoustically acceptable for stereo monitoring and mixing.

Control/Mix Rooms

As noted above, there is substantial agreement as to what constitutes a good mix room. It is a fairly large room because it must accomodate production personnel (or keyboard players) in addition to the recording engineer. Two or three large loudspeakers are usually flushed into the front wall. The edge of the mixing console is about 7 feet from the wall, such that the distance from the engineer's ears to the speakers is around 8 feet. A low cabinet behind the engineer's chair holds a variety of electronic processing gear and also serves as a producer's desk, with space for chairs at the rear. All these functional requirements add up to a room length of about 24 feet.

The room will be used at very high sound levels, and leakage into adjoining spaces is difficult to control, especially at low frequencies. Background noise should be held to NC-25 or less, which may require placing computers and other noisy equipment in an adjacent closet or machine room.

The generic mix room shown by Eargle[5] is 17 feet wide at the front, 22 feet wide at the rear, and 24 feet front-to-back. The ceiling height rises from 9 feet at the front to 11 or 12 feet at the rear. The room is acoustically neutral, with a scattered mix of absorptive and reflective surfaces. Eargle does not specify a preferred reverberation time, but expects the engineer to hear an equal mix of direct and reflected sound from the main loudspeakers. Working backward from that requirement, the corresponding reverberation time is about 0.3 second, and roughly half of the interior surface area must be absorptive. Dolby and THX standards for mixing cinema or TV sound in a room of this volume require a reverberation time of 0.25 to 0.3 second, so it seems that a room optimized for 2-channel stereo mixing should also be acceptable for surround sound mixing. An informal survey of West Coast recording engineers supports that conclusion.

In fact, bilateral symmetry and the control of early lateral reflections are more important for 2-channel stereo than surround sound. Good stereo imaging requires a pair of well-behaved, closely matched loudspeakers, but if early reflections are suppressed then the listener must be exactly centered between the two speakers. Moreover, because each ear

Fig. 1. Interscope Records control room, showing flush-mounted loudspeakers, sloping ceiling, and side soffits.

hears both speakers (interaural crosstalk), a phantom center image is not the same as that heard on headphones. The direct path length from either loudspeaker to one ear is different from that to the other, producing a comb filter with its first dip around 2 kHz. In contrast, a good ensemble of symmetrical lateral reflections spreads out the sweet spot, adds depth to the stereo image, and helps fill in the 2 kHz dip.

Loudspeaker/listener geometry is controlled to some extent by the need for visual contact with the recording studio. If the main loudspeakers are located above a wide window then they are a little too high for optimum mixdown. In some control rooms, especially those designed for surround sound mixing, the studio window may be located to one side, allowing the front wall to be used for loudspeakers and a viewing screen. Another common alternative omits the center speaker and places two stereo speakers on either side of a fairly narrow studio window.

For the past ten years or so, mixing engineers have relied more on small, nearfield loudspeakers than the main monitors. The big speakers are still important, but they are used for periodic checks and for playback to the producer's area. Therefore, the room must provide good stereo listening under three conditions: (1) main speakers to console, (2) nearfield speakers to console, and (3) main speakers to producer's desk. Good correspondence between the two sets of speakers is important, and the main monitors are sometimes equalized to match a particular pair of console-top speakers.

Achieving acceptable low frequency response is much easier in a comfortably large mix room than a small production room, but audible peaks and dips below 100 Hz or so can be expected, and this is true for the nearfield speakers as well as the large monitors.[6] Because of the requirement for good sound isolation, room boundaries do not dissipate very much low frequency energy. As a result, a substantial amount of interior volume must be used for broadband low frequency absorption.

The most common broadband absorber is a cavity loosely filled with fibrous absorptive material and faced with porous fabric. It is called a "trap" or "bass trap" by studio designers. The cavity must be more than two feet deep to be effective down to the 50 Hz region. Since the main goal is to absorb low frequencies, a substantial reduction in depth can be realized by facing the cavity with wood slats or pegboard, making it a low-Q Helmholtz resonator. A pegboard-faced wainscot, perhaps two inches deep, was a familiar feature of many older recording studios and control rooms. The writer favors somewhat deeper "bunker traps" that can be conveniently located under windows or behind seating. The same basic construction can be built from floor to ceiling to create an effective corner trap.

Deep soffits on the side and rear walls can serve as bass traps. These may be augmented by vertical traps in the rear corners. In older rooms it was common to create a two-foot deep broadband trap across the entire rear wall, effectively placing the seating area in an acoustical black hole. Some designers later replaced the rear trap with very deep diffusers, hoping to scramble low frequencies rather than absorbing them, but the subjective results were equally unsatisfactory. As with the side walls, a reasonable mixture of reflective and absorptive surfaces seems to work best.

The mixing console itself is an important but often overlooked element in optimizing low frequency reproduction. The console is the biggest piece of furniture in the room, and its exact location can have a surprising effect on audible bass response. Even though the console position is specified as part of the original room design, a six-inch shift forward or back will sometimes result in worthwhile subjective improvement.

Figure 1 is a control/mix room designed by Vincent Van Haaf for Interscope Records. The photo clearly shows the

Fig. 2. Marcussen Mastering, Hollywood, California.

spatial relationships between the loudspeakers, the sloping ceiling, the console, and the outboard equipment cabinet. The studio window affords full visibility between the loudspeakers, but the glass dips down and extends under the loudspeakers as well. The rear ceiling and the undersides of the soffits are fully trapped.

Mastering Rooms

Music was played on disc recordings from the very first phonograph records until the late 1980s. In recording studios, "mastering" was the process of cutting a master disc from a master tape. The procedure could be tricky, and involved additional audio processing to keep from overcutting the spiral groove. Some engineers became known for their ability to turn out high quality masters, and their prestige matched that of top-ranking recording engineers.

One might have expected the mastering room to disappear during the changeover to digital audio playback, but the opposite occurred. The mastering engineer became a digital guru who made sure that a digital master tape took full advantage of the medium and met all formatting standards before it was sent to a CD production facility. The mastering room became larger, quieter, and was fitted with expensive playback loudspeakers.

By 2005 most of the large U.S. recording studios had closed. Mastering engineers began to set up their own practices, following the lead of successful independent mastering facilities such as The Mastering Lab in Hollywood and Sterling Sound in New York. In today's world of digital audio files, the location of a mastering room is not all that important, and many mastering engineers prefer to work at home. Residential mastering rooms usually require some compromises, but building a mastering facility in a rented commercial space may be equally difficult.

Today, a mastering room is used as a critical listening space in which the smallest details must be audible. Mastering is done at relatively low sound levels, and sometimes at very low levels, so background noise should preferably be no higher than NC-20. The geometry of the room should be favorable for 2-channel stereo listening and also for 5.1 monitoring since the final product may be released in a variety of formats. The room requires very little furniture—a control desk, a client couch, and a few storage cabinets. Computers and other noisy electronic equipment can be located in an adjoining closet.

Acoustical goals are usually quite similar to those for a mix room, and the design of a mastering room may also be similar to a good mix room, but not always. Unlike a commercial recording studio, a mastering room is required to meet the desires of only one person, and the design may deviate substantially from the norm. A few mastering engineers like to work in an acoustically dead environment. A few prefer fairly lively acoustics, something closer to a good home listening room. In most cases, high quality freestanding loudspeakers will be used, but some engineers prefer flush-mounted monitors.

In residential mastering rooms size is usually the biggest limitation. The smallest mastering room encountered by the writer was about 11 by 13 feet, and the ceiling height was a little less than 8 feet. Fortunately, the client was aware of the room's shortcomings and was satisfied to make it merely workable.

Most mastering engineers would like to work in a large room, perhaps 20 by 28 feet, but a somewhat smaller space is considered acceptable. A good example of current design practice is Marcussen Mastering in Hollywood. Figure 2 shows Stephen Marcussen's original mastering room, which was closely duplicated at a new location in 2009. The new room is a fully isolated structure inside a concrete block commercial building. Interior dimensions of the rectangular shell are about 18 by 26 by 10 feet. Stephen originally requested a 12-foot ceiling, but it would have been too costly to modify the existing structure. (The theoretical distribution of room modes is actually a little better with the lower ceiling.)

The room's distinctive appearance was designed by architect Frank Glynn. The horizontal wood slats on the side walls are quite narrow and the gaps are relatively large, so the screens become acoustically transparent below 2 kHz or so. Varied "checkerboard" acoustic treatment is hidden behind the screens and on the end walls. Wall treatment is augmented by 5-inch deep bunker traps below the wood screens. The floor is carpeted except for a central hardwood work area. Five large B&W loudspeaker systems are arranged in a standard 5.1 configuration. The final locations of the loudspeakers and the work station were established subjectively through extensive listening tests.

Music Production Rooms

Commercial recording facilities often include include small production spaces rented to independent producers or music composers. It is even more common for composers of film and television music to set up work spaces in their homes. These tend to be fairly small rooms - perhaps 12 by 15 feet—designed primarily for efficient work flow. In almost all cases, the room will be set up for 2-channel stereo monitoring using small, nearfield speakers.

If possible, such a production room should be laid out symmetrically as if it were a smallish mix room, with a separate computer closet and possibly a small vocal booth. In many cases however, there is barely enough space for the equipment, which includes a digital audio workstation, a computer, loudspeakers, outboard processing gear, and keyboards. Existing doors and windows are additional constraints. Acoustic treatment may be limited to plant-on absorptive panels and perhaps a bookcase or a few throw pillows.

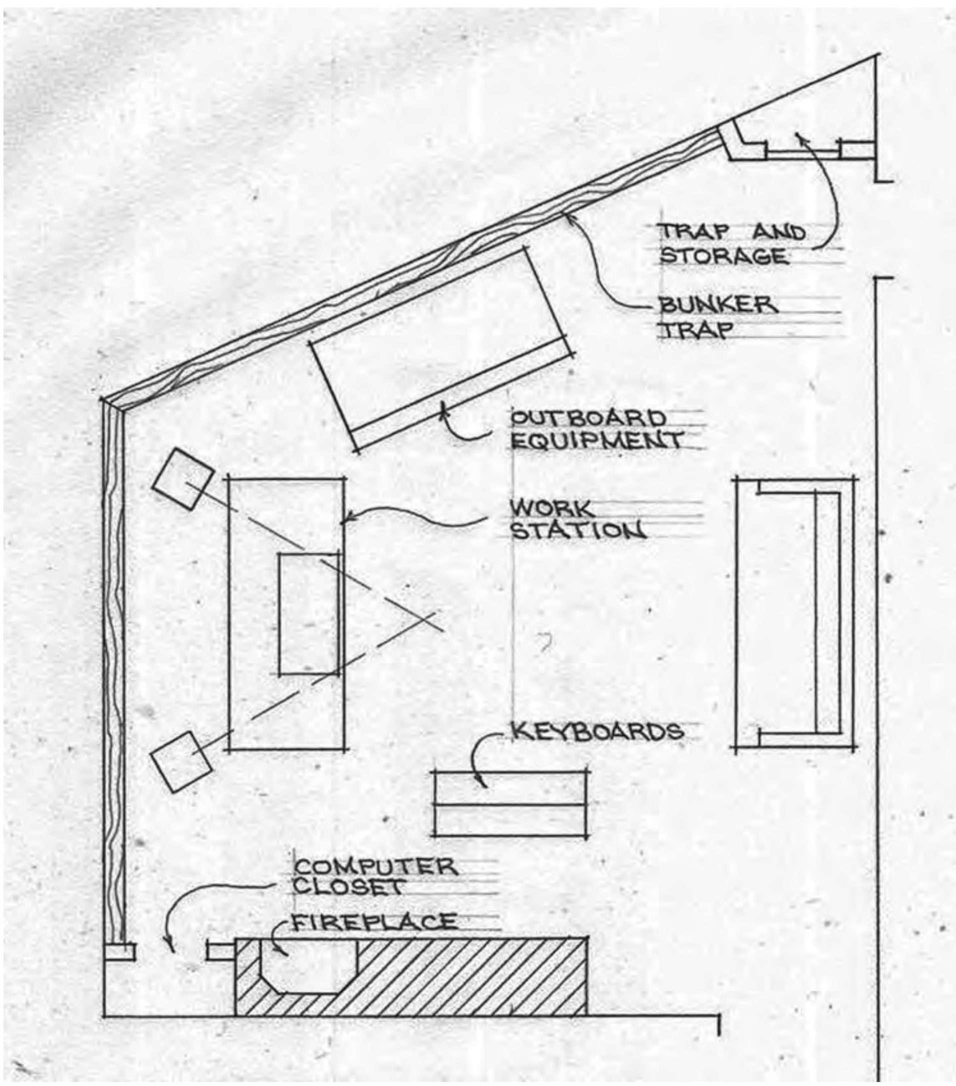

Fig. 3. Concept floor plan for residential production room.

In such a situation, it is a big mistake to jam the work station and loudspeakers against one wall. The only practical method of low frequency "tuning" is to experiment with the placement of the work station and loudspeakers, even if it requires two or three different arrangements of equipment and furniture. If the best sounding arrangement turns out to be awkward, the client can compare the trade-offs and make an informed decision.

A conceptual floor plan for a home production room is shown in Figure 3. (Two additional layouts were presented to the client.) The proposed design includes a new corner trap that doubles as a storage area. A 26-inch high bunker trap extends along two walls. The remaining acoustic treatment consists of plant-on wall panels and a large, suspended panel made of fabric over pegboard—an "acoustic cloud".

Conclusion

Even though a few Super Audio Compact Disc albums are released every month, surround sound has failed as a medium for home music listening. Rooms designed for music composing, mixing, and mastering must be optimized for 2-channel stereo playback.

For the next few years at least, the trend is expected to continue, and 2-channel stereo will remain the standard format for music production. Most popular music producers and recording engineers hate working with a center channel in spite of its obvious advantages. They have learned how to transform deficiencies into benefits, and the situation is not likely to change soon. Films, TV, and computer games all benefit from surround sound, but so far as music is concerned, the only viable consumer market seems to be luxury automobiles.**AT**

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