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ABSTRACT At the dawn of sound recording, recordists were mechanical engineers whose only training was on the job. As the recording industry grew more sophisticated, so did the technology used to make records, yet the need for recording engineers to use craft skill and tacit knowledge in their work did not diminish. This paper explores the resistance to formalized training of recording engineers and the persistence of tacit knowledge as an indispensable part of the recording engineer's work. In particular, the concept of 'microphoning' – the ability to choose and use microphones to best effect in the recording situation – is discussed as an example of tacit knowledge in action. The recording studio also becomes the site of collaboration between technologists and artists, and this collaboration is at its best a symbiotic working relationship, requiring skills above and beyond either technical or artistic, which could account for one level of 'performance' required of the recording engineer. Described by one studio manager as 'a technician and a diplomat', the recording engineer performs a number of roles – technical, artistic, socially mediating – that render the concept of formal training problematic, yet necessary for the operation of technically complex equipment.

Keywords audio engineering, aural thinking, 'microphoning', sound recording, tacit knowledge

Engineering the Performance:

Recording Engineers, Tacit Knowledge and the Art of Controlling Sound

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Listening to recorded music can be a deeply personal experience, whether through headphones to a portable compact disk (CD) player or to 'muzak' intruding on (or enhancing) our retail shopping experience (DeNora, 2002); whether seated in an automobile (Bull, 2001, 2002), at a computer, or in the precisely positioned audiophile listening chair (Perlman, 2004). Each of these listening landscapes helps to shape and color the listening experience, but regardless of the music we listen to, the media we use or the location we choose, what we hear has been tempered first and foremost by the technology used to record it and the technical and aesthetic decisions made in the studio. Since the advent of electronic instruments and multi-track recording, we tend to think of music as being technologically mediated both on stage and in the recording studio, but long before the sampler, the Moog synthesizer, or the electric guitar, recorded performances were subject to engineering of one form or another.

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Ever since the earliest recordings, capturing a live performance on cylinder or disk required subtle manipulation of the recording equipment by the operator, even when there were few possibilities for manipulation. In fact, one can say there has never been a recording that did not require some intervention, although the degree of intervention varied widely, from a touch of 'echo' to assembling a recording from multiple edited performances. Until the middle of the last century, when recording technology had surmounted most of the problems with quality in the early years – the tinny sound of acoustical recording, scratchy shellac records, limited frequency response – the goal in making records had been to capture the live performance. But, with the advent of magnetic tape recording, electronic musical instruments, increasingly sophisticated methods of signal processing and multi-track recording, capturing a live performance ceased to be the prime objective in the recording studio. Even so-called 'live' recordings were – and are – the product of manipulation, judicious editing and myriad other enhancements. During the 1960s, the studio became an instrument in its own right, which musicians and producer–engineering teams exploited to create new sounds, rather than simply trying to capture them. This is often seen as the beginning of 'engineered performances', that is, musical events that existed first as recordings, only later to be recreated by mimicking the record in concert.

This may come as no surprise to readers of this special issue devoted to sound studies, or to other readers who are avid and eclectic music fans. What may be less apparent is the extent to which recorded performances have always been engineered, even before the people operating the controls were referred to as 'engineers'. Also surprising is the degree to which the field has retained elements of art and tacit knowledge that were essential to the work of early recordists, even as recording technology has been developed to rationalize and systematize that work. This paper explores the evolution of the technique and practice of music recording from the acoustical era until roughly the present, focusing on the work of the recording engineer and describing how that work has both influenced and responded to technological innovation and changing musical styles. It will show how recording practice has retained craft skills and informal knowledge systems despite the steady growth of, and increasing dependence upon, complex technological systems.

In this effort to explore the use of the recording studio over time, this paper draws on oral interviews with recording engineers, record producers, musicians, and others associated with the recording industry in the USA. Some of them were associated with the industry as far back as the 1930s, and all were actively involved during the post-World War II period. It also uses amateur and hobbyist periodicals, trade and technical papers, memoirs, and other documentary evidence to trace the evolution of the oldest technical profession associated with sound recording. Even on the amateur level, making a recording once required enough mechanical and electronic proficiency to assemble or build equipment, but with the advent of computer-based recording programs anyone with the basic computer skills and the money to afford a 'studio-in-a-box' can make recordings of reasonable quality (Hawkins, 2002). Yet while it is truer than ever that 'anyone' can make records of reasonable quality, would-be recording engineers now must have extensive training and experience even to work as an intern in a professional studio. There is much more than technical proficiency required of the recording engineer; as it was in the acoustical era (1877–1925), the value placed on tacit knowledge, experience, and human interaction in professional recording has not diminished. In order to understand the work of recording engineers and how it has involved both change and continuity, both in terms of skills and the importance of the engineer for the 'sound' of records, this paper will begin with a glimpse into the world of the acoustical recordist, focusing on the required skills and how these can be considered a form of tacit knowledge. I then briefly trace the professionalization of audio engineering and the emergence of new skills associated with new technology, specifically microphones and stereo recording, both of which involved new ways of listening and 'envisioning' sound. Finally, I look at the role of formal education and the persistence of on the job training, and give examples of how changing technologies alter, but do not replace, tacit knowledge.

What the Acoustical Recordist Knew and How He Knew It[1]

In 1900, the National Phonograph Company instructed consumers in the fundamentals of recording with the Edison Recording Phonograph: 'The secret of making good Phonograph records is summed up as follows: – experience and knowledge of the Art. The two go together. One is useless without the other' (National Phonograph Company, 1900: 152). Although this advice was directed toward amateur recordists, a group of users the company hoped to cultivate, it neatly summed up the most important principles of professional recording practice.[2] The only way one gained knowledge was through experience, but the booklet offered amateurs valuable pointers based on the experience of the 'practical Phonograph men' who learned by trial and error. Eighteen years later, in his treatise on the recording and reproduction of sound, UK recording aficionado Henry Seymour described the 'recording expert' as:

> above all things, a man of resource, and if he have an intelligent appreciation of the fitness of things he will quickly discover what to do and what not to do in any emergency, after some little experience. Experience, to be sure, is the only real teacher in the art of recording. There are so many subtleties to comprehend, so much mechanical finesse to grasp, that no written instructions could ever amount to more than a rough and ready guide. (Seymour, 1918: 94)

Grasping 'subtleties', possessing 'mechanical finesse', and working without written instructions figured prominently in the early recordist's job description, and not everyone fits the bill. In the beginning of the era of sound recording, those who operated the acoustical recording devices were called 'recording experts', 'recordists', or, equating the operator with his machine, 'recorders'. In the acoustical method, the sounds to be recorded – instrumental and vocal – had to be projected (sung or played) into and 'collected' by a large recording horn, or several horns of varying sizes, connected to a sound box which housed a diaphragm. The sound waves vibrated the diaphragm, usually made of glass or mica, which in turn vibrated the cutting stylus attached to it either directly at its center or by a lever. This stylus, moving in a spiral groove pattern, engraved the sound waves on a wax blank cylinder or disk rotating on a turntable controlled by gravity weight and mounted on a heavy steel base. The recordist's work involved a range of skills, including selecting the correct thickness of diaphragm, the best means of damping the diaphragm's edges in the sound box, the appropriate size and shape of recording horn, the proper design and polishing of the cutting stylus, the proper composition and conditioning of wax, and perhaps most importantly, placement of instruments and voices before the recording horn (Read & Welch, 1976: 75). Judgment about where to position the instruments and voices, as well as knowing how to 'read' the grooves of the record (since playing the wax master ruined it, the recordist had to visually inspect the grooves to make sure no instrument was too loud, indicated by groove spacing), were critical skills learned only by trial and error. Yet as one early expert noted, not all possessed the necessary skills, and some could never learn 'the necessary knack of recording'.[3]

One of the most important skills was knowing where to place voices and instruments in front of the recording horn, and being able to convince artists who were accustomed to freedom of movement to stand where they were told. Because of the weak acoustical power of stringed instruments, they had to be played directly into the horn, sometimes placed on risers to achieve this. Some musicians would get carried away in the performance and forget the recordist's instructions. Raymond Sooy tells of one Hungarian violinist who insisted on walking around the studio while playing, despite repeated instruction to stand still, claiming that 'it was his artistic temperament' and that the recordist should not interfere. Finally Sooy asserted both his authority and his own artistic sensibility, 'I told him I had one of those "damn things" myself, and if he didn't stand where I placed him, there would be no records made. I had no more trouble with his artistic temperament after this – he stood exactly where he was placed'.[4] Vocalists, on the other hand, had to move according to the recordist's instructions. Fred Gaisberg, an early talent scout and recordist who became a leader in the record industry, recalled a session in which a German recorder named Max Hampe was so determined to make sure that singer Frieda Hempel moved to the right spot that he brusquely shoved her forward and pushed her away from the horn during her recording session. Her manager complained that this rough treatment undermined her dignity in front of the orchestra, but Mr Hampe claimed to be conscious only of the fact, as Gaisberg put it, 'that the lady was being paid 100 pounds a song and that it was up to him to produce results. ...

Successful records meant glory for the manager, but failures the sack for the recorder'.[5] Indeed, Henry Seymour noted that the recording expert 'holds the fortunes of the [record-making] establishment in his hands. Much depends on others, in the allied process, but they are as nothing in comparison to him. It is preeminently *his* work which is judged in the final analysis by the public' (Seymour, 1918: 94). Yet often the public did not know it. As the Hampe incident illustrates, a disparity existed between the recordist's relatively low place in recording hierarchy and the high level of dependence on him working his 'magic' in the studio, a disparity that would persist long into the future. Like workers in technical fields who serve as brokers between technology and society, early recordists had power incommensurate with their status.[6]

The recordist had to have experience with all the mechanical, acoustical, and chemical elements involved in the recording process. No operations manual provided guidance, and the hard-won methods remained highly individual and closely guarded secrets of each recordist. They considered the recording room to be a 'sanctum sanctorum' that few were permitted to enter (Mitchell, 1922: 66). Although recordists maintained secrecy about their techniques as well as their technology, knowledge was shared within recording departments much as it was within the apprenticeship system and 'shop culture' of early mechanical engineering firms.[7] Victor Talking Machine recordist Harry Sooy passed on the 'mysteries' of the cutting lathe to his younger brothers, Raymond and Charles, who joined him in the Victor Recording Department and continued to work there after his death in 1927. Bandleader Paul Whiteman recalled how the three brothers would stash their cutting heads (the tools that engraved the sound in the record) 'in little leather boxes which never left their possession, day or night' and that each 'worked out his own improvements' to recording as he went along (Whiteman, 1948: 4). One experienced recording expert admitted, 'I know practically nothing about sound. Every day I come across some new peculiarity; and it is only by constantly watching out for the tricks of sound waves and meeting them with counter-tricks that we make good records!'[8] Indeed, few early recordists had formal scientific or engineering training; rather, they were 'clever mechanics' whose success depended on experimentation, trial and error, and innovative thinking (Inglis, 1990: 21).

Tacit Knowledge

The concept that best describes the skills of recording engineers is tacit knowledge – the unarticulated, implicit knowledge gained from practical experience.[9] If one could 'disassemble the intuition' of the early recordists, as did sociologist Douglas Harper of the garage mechanic, Willie, in *Working Knowledge* (Harper, 1987) one might find interesting similarities, especially a deep understanding of materials and an ability to fix things by unconventional means. Just as mechanics use a working knowledge of materials and machines, so recording engineers deploy a working knowledge of the behavior of sound and the machinery of its propagation. In the acoustical recording era, this meant familiarity with every aspect of the recording apparatus, as well as with sound. This was their working knowledge, gained from experience. After the introduction of electrical recording in the mid-1920s, recordists had to acquire some understanding of electronics and electrical systems, and this had to be learned on the job as well. When he began his career with Parlophone Records in London in 1926, Cyril Francis recalled that acoustic recording engineers were middle-aged and had no knowledge of electronics. Techniques were still being developed by trial and error, and there was little acoustical control in the studio beyond positioning large movable padded screens.[10]

Robert E. McGinn has argued that electrical recording transformed recording 'from a predominantly craft-based enterprise relying on cut-and-try methods to a mature profession grounded increasingly in scientific, mathematical, and systems engineering methods and knowledge' (McGinn, 1983: 68–69). While it is true that the microphone, control panel, and speaker now gave the recordist greater control over sound and the ability to monitor it during recording, such expertise was not acquired overnight, and experimentation and trial and error continued to be essential in the studio. Now the recording engineer's work involved discovering the various electro-acoustical parameters: current flow, frequency response, and the action of the electromagnetic cutterhead, which had replaced the diaphragm–stylus–sound box arrangement of the acoustical recorder. Moreover, the recordist could only learn how to compensate for the inherent noise of microphones and their different response patterns by experimenting with them. The wider spectrum of sound that could now be recorded meant that studio acoustics took on greater significance because the new system was sensitive enough to record the 'atmosphere', the natural acoustics of the room in which the musical performance was recorded (Maxfield & Harrison, 1926; Burkowitz, 1977).

All of these improvements in the quality of recording and reproduction were made possible by the increasing amount of control attained by the recordist, who by the late 1930s was becoming known as the 'recording engineer', largely because of the closer ties between recording and radio forged by electrical transcriptions.[11] But while the recordist could now adjust the signal being recorded through a mixer, the greater sensitivity of microphones meant that microphone placement – positioning voices and instruments in front of the microphones to get the best sound – still depended, as it did when the sound collection device was a horn, on 'guesswork and experience' (Burkowitz, 1977: 875).

Professionalization, and the Sound-Man Artist

After World War II, the introduction of magnetic tape, the 33⅓ rpm long-playing (LP) microgroove album, 2- and 3-channel stereo-recording and reproduction, all within a period of a decade, revolutionized recording and introduced exciting possibilities for editing, re-recording, longer playing time and higher fidelity. But each of these improvements also posed new challenges for engineers, and with no larger organization to set standards of practice, chaos loomed. In 1948, a small but determined group of radio and recording engineers broke ranks with the Institute of Radio Engineers, then the largest professional association for audio engineers, and formed their own professional society. They did so, in part because they had become fed up with being marginalized at professional meetings and in the literature, but also in order to further the 'promulgation of engineering information and standards' and the 'educational presentation of subjects basic to audio engineering' (Minter, 1954: 1). The founding members of the Audio Engineering Society (AES) included recording engineers, inventors, audiophiles, and hobbyists, all of whom were interested in improving the sound of recordings and furthering the development of high fidelity sound, a concept that meant little to engineers, who were more concerned with measurements, components, and theory. The recording industry was soon to enter a boom period not experienced since the 1920s. This boom was due to a combination of factors, most notably the high level of consumer demand for home appliances, including entertainment technologies like the phonograph and radio, and the introduction of the LP record. Many recording engineers and producers of this period have argued that the LP 'made' the postwar recording industry, but its success rested on more than a single technological development. By sponsoring annual 'audio fairs' in major cities in which manufacturers and inventors could demonstrate new sound recording and reproduction technologies, thus also boosting interest in high fidelity sound, the AES and the wider community of recording professionals benefited from and contributed to the success of the postwar recording boom (Horning, 2002).

In 1952, *Newsweek* magazine profiled the work of Columbia and Victor recording engineers. The 'Men Behind the Microphones' whose 'engineering cleverness', along with the technological revolution of the previous five years had introduced a 'new medium' in which both the listener and the recording engineer gained more control over the music, had vastly improved the sound of records (Anonymous, 1952). According to the article, some of the 'tricks' of the trade included: careful placement of microphones, considered in some large recording companies to be proprietary information; the use of controlled reverberation by means of parabolic reflectors, stairwells, and other chambers; the technique of boosting high frequencies, a form of deliberate distortion of the sound in order to mask the needle hiss that becomes audible at high frequencies; and cutting and splicing taped performances to achieve a 'composite' performance. The article ended with a prescient observation that the recording engineer 'could take over the recording industry and dispense entirely with the musician. . . . But today's crop of record engineers . . . are far too appreciative of the human beauty of music to betray art to a robot' (Anonymous, 1952: 59).

The Art of Microphoning

The increased ability to manipulate sound ushered in a new type of recordist by the mid-1950s, 'The Sound-Man Artist', particularly skilled in the art of microphoning – that is, the careful selection and placement of microphones in the recording studio based on the instrument or voice to be recorded (Canby, 1956). Indeed, microphoning is a good example of tacit knowledge in action as it is very hard to formalize, and those who possess the skill have acquired it in practice. As more microphones came on the market and recording engineers confronted the problem of variable quality and response, the art of microphoning evolved as a natural extension of the recordist's art of placing performers before the acoustical recording horn. Some engineers used equalizers in the mastering stage in order to make up for discrepancies in the quality of microphones used in the recording.[12] But the early equalizers, designed for the film industry, posed problems in mastering records: they were noisy, made a clicking sound when adjusted, and caused a 25 dB loss that required the use of another amplifier hooked up to the unit. Many engineers felt that using them 'was a pain in the neck'.[13] Instead, they cultivated a microphone technique. Having learned from experience what worked best for a particular instrument or voice, they selected specific microphones for specific instruments and voices based on the kind of sound they wanted. Al Schmitt began learning microphone technique early in his career, and as with many inventions, this technique evolved out of necessity. The studio where he worked, Apex Recording, had only one equalizer, so using it would affect the entire recording. Just as in photography, where the use of a filter on the camera lens would change the entire picture, the equalizer did not just affect one element within a recording. As Schmitt explained:

> When I originally started at Apex, we had one equalizer, patched in to the total overall product. You couldn't patch in to the bass or vocal or whatever . . . when you equalized, if you added a top end, you added it to the whole overall product. And that was cool when you were transferring from a tape to a disk and you wanted to brighten it up, you could brighten the whole thing up. [But there was] no way of patching it around, only had the one equalizer, no limiters, no compression. . . . So I learned to get my sounds – if I wanted a brighter vocal sound, I used a brighter mic[rophone]. If I wanted a warmer bass sound, warmer piano sound, I used maybe a ribbon mic[rophone].[14]

Because the ribbon microphone[15] did not have the full frequency sound that tube or transistor microphones had, Schmitt said they did not 'show as many errors' – in other words they were more forgiving of imperfections in a vocal performance. But to rely on microphone choice and avoid equalization altogether, Schmitt admitted, 'you've gotta really know your microphones, and what microphones do what, and where they should be placed'.[16] Some have likened this ability to 'get sounds' by careful choice of microphones to a painter mixing colors from a palette, and others considered 'the art of microphoning as the equal of many another interpretive art', arguing persuasively that they should receive credit along with the composer or performer.[17] Certainly, microphoning can be considered an art, but it also exemplifies tacit knowledge, and evolved because of the inadequacies of related technology, specifically the uneven quality of microphones and noisy equalizers. Recording engineers had to learn this by trial and error, or apprenticeship with an experienced engineer.

Tom Dowd, whom Schmitt credits as one of his first mentors, also worked at Apex, as well as the Voice of America and other small studios before becoming the principal recording engineer for Atlantic Records. Dowd had more of an engineering background than most recording engineers, having worked during World War II for the Office of Scientific Research and Development (OSRD), specifically on the Manhattan Project.[18] At his first studio job, Dowd felt amply trained, despite no experience in recording, after having just spent months, as he put it, 'chasing neutrons down a corridor all night long for chrissakes. To me, we were stone-aging records. I thought, it's so simple it's dumb'.[19] But Dowd also found recording a challenge, albeit one to which he was particularly suited, not only because of his 'smidgen of physics training and curiosity and education', but because he had also played in and conducted his high school and college bands and orchestras. His experience playing the sarusephone, which he said 'shook his fillings' when playing the low notes, was the kind of experience that helped him to know which microphones to choose:

> it prompted a lot of thought when I was recording. Because when I'd be listening to something and I'd say, 'Oh man, naw, that's the wrong mic[rophone], if he's gonna play that low I need this microphone', or 'I gotta do this and that'. I'd be switching hats in the middle of [the session] . . . they'd have made one [run-through of the song] and I'd say, 'Wait a minute, I wanna change something'. (Tom Dowd, telephone interview with author, 16 March 1999)

By 'switching hats' Dowd referred to his mental agility in drawing upon knowledge acquired from different experiences, different skills, a kind of lateral thinking that often leads to scientific as well as technical solutions. But he understood this only in retrospect; at the time he was doing everything, as he often put it, 'on the fly' because the time constraints of recording sessions left no time to deliberate. He was always thinking with his ears and his hands.

Engineers knew that microphone choice and placement were key factors in recording, but the singers also helped by their use of microphone technique, again, a skill tacitly acquired by experience. Performers could regulate their relative volume especially on powerful and weak notes, by leaning in to the microphone on low or soft notes and backing off a bit on the high or loud notes. This technique was a more subtle version of the jockeying for position that was necessary around the acoustical recording horn. Frank Sinatra is widely regarded as the first to master microphone technique. Mitch Miller, who worked with Sinatra in the studio, said 'Sinatra couldn't be heard from here to ten feet away. . . . None of them. In fact, it's part of the *art*', he emphasized, 'part of the art of recording electronically. That's why Pinza sounds so ridiculous, "Sohm enchaahnted eve-e-ning", you know?'[20] Miller here contrasted Ezio Pinza, an operatic bass accustomed to projecting his voice from the stage without a microphone, and Sinatra, universally credited as being the first performer to know how to use a microphone for dramatic effect. According to music critic and lyricist Gene Lees,

> Of its very nature, singing through a good sound system or for recording should be as different from vaudeville belting as film acting is from stage acting. One can convey on film with a lift of an eyebrow what might require a conspicuous change of voice or tone or volume or some expansive gesture on a stage. And something similar is true of singing into a sensitive microphone. . . . But, and this is insufficiently understood, the microphone is treacherous in that it magnifies not only the virtues of a performance but the flaws too. And it is a difficult instrument to use well. (Lees, 1987: 107)

The art of microphoning could be cultivated by recording engineer and performer alike, but the microphone could also pose difficulties in ensemble recording. Balancing combinations of instruments and voices could be tricky, and yet it was critical to the sound. Recording brass and strings, for instance, became quite a challenge without the use of baffles to isolate the instruments from each other. John Palladino recalled that when recording Sinatra at Capitol Records' Melrose Avenue studio, which was a converted broadcasting studio originally built to accommodate an audience of several hundred people, it was always a challenge because Sinatra insisted on recording live with the band and did not want to be isolated in a vocal booth. So they positioned him on the floor in front of the stage, as Palladino remembered:

> We just put the orchestra up on the stage and Frank was down just in front of the apron. And, that was it. . . . Just a very simple splay that really didn't give it too much isolation. Maybe it might stop some direct sound, you know? But it wouldn't really keep the sound of the orchestra out of the mic[rophone] too much. . . . and that was hard because Nelson Riddle used a lot of strings, and then against that he had a lot of brass so it was a constant fight, you know, to make all those things come out.[21]

The ability to make everything 'come out' – to record in such a way that all instruments and voices were properly balanced – was the subtlest form of 'engineering the performance', that is, making sure that what the performers heard in the studio came through on record. RCA recording engineer Ray Hall agreed the most difficult challenge was recording brass and violins at the same time, 'because the brass would go all over the violin mics', and because of the time constraints on the session, they often used baffles, and especially relied on the cooperation of the musicians in how they played and where they stood.[22]

Some engineers came up with quite inventive solutions to the problems of instruments leaking into microphones. Clair Krepps became a recording engineer when his former naval commander, Warren Birkenhead, hired him after the war to build the New York mastering studios for

Capitol Records. Krepps had no previous recording experience, but did have an electronics background and plenty of experience jury-rigging what he needed to get a job done, and this served him well when faced with problems in the studio that suggested no obvious technical solution.[23] During one recording date at MGM studios, he had difficulty 'miking' the singer so that she could be heard over the band. He realized the problem was due to the bidirectional microphone, which was picking up the band as well as the vocalist. He knew he could not place her any closer than about 18 inches from the microphone because that would eliminate high frequencies, and if he turned her microphone 180°, it would be out of phase with the other microphone used for the band.[24] He did not want to use baffles to barricade the singer, so Krepps came up with a unique solution. 'When the band took a break', he recalled:

> I got on the elevator at the 15th floor, went down the street and ran up and down Fifth Avenue until I found a drug store, and I went in and bought a box of Kotex and took them back to the studio, and taped one on one side of the microphone and it worked! . . . It cut down the sound of the band. And you can imagine, a bunch of musicians. It took five minutes to quiet them down. . . . She laughed along with them.[25]

One might speculate about how Krepps came up with this solution. Had he made a word association with the idea of 'leakage' or 'signal bleed'? Or had he simply recalled that the shape, size and density of this cotton batting would ideally fix his problem? Like Douglas Harper's garage mechanic Willie, who fixed things by 'unconventional means', Krepps' idea to use a feminine hygiene product was certainly a novel, practical, even elegant (in one sense of the word) solution, although not one that was likely to be formalized or repeated. In order to solve this recurring problem, studio engineers built string shells resembling a movable enclosure cut in half, like a half-shell, and vocal booths. Ray Hall recalled that RCA built isolation booths for vocalists like those on the quiz show, *The $64,000 Question*, but they were cramped and confining, and singers usually did not feel comfortable, preferring, like Sinatra, to hear themselves with the band.[26]

It was just this kind of cooperative work that led critic and audiophile Edward Tatnall Canby to declare that recording by the mid-1950s had become 'a social art' involving teamwork, and that no single member of that team deserved full credit for the outcome. Canby also recognized that the contingencies within the recording situation called upon, 'every bit of ability, imagination, knowledge, sensibility, intuition – and technical know-how – that our recording men can scrape together' (Canby, 1956: 61). Canby was really describing nothing less than tacit knowledge, albeit two years before Michael Polanyi introduced the concept in *Personal Knowledge* (1958). But his comment about recording as a social art is worth repeating, and can be compared with other forms of engineering. In his study of design engineers, Louis Bucciarelli (1994: 20–21) argues that 'designing is a social process . . . of negotiation and consensus', and this applies to studio recording as well. One could even say that as engineers acquired more ability to control and manipulate sound, particularly with the introduction of stereo and multi-track recording, their work entailed a kind of sound design.

Aural Thinking – Hearing in Three Dimensions

Eugene Ferguson persuasively argued in *Engineering and the Mind's Eye* (1992) that non-verbal cognition and visual thinking are central to design engineering praxis. I believe a similar *aural* thinking takes place in the mind's *ear*, as it were, of recording engineers. A broad range of hearing is important, to be sure, but more important is the ability to detect sounds embedded within a dense matrix, a knowledge of what to listen for, what to tune out, and the ability to know when your ears need a rest. Aural thinking enables the recording engineer to envision the *musical architecture*, how the various instruments and voices in a stereo or multi-track recording should be placed in the mix, not simply in terms of relative volume, but of their positioning in the aural perspective of the listener. Aural thinking evolved as the technology made it possible. It developed in concert with significant technological shifts, such as the introduction of stereo recording, then 3-track, 4-track, and so on.

For the control engineer, the concept of stereo was not a simple matter of adding another speaker to the control room and dividing the recorded signal between left and right speakers. It entailed a whole new way of listening to and 'envisioning' not only how the instruments should be miked, but how the overall sound should be planned, or designed. John Palladino recalled that as monophonic recording gave way to stereo, then to 3-channel stereo, then to 4-track, 8-track, 16-track, and more, 'every time you made a change you had to adapt your whole outlook'. Suddenly new considerations began to complicate the art of microphoning, as Palladino vividly remembered:

> [A]s you began to get more control and more channels, then you have to decide what is stereo? Is stereo something on the left? Is it a mono sound on the left, and then a mono sound on the right, and then a combined sound in the middle? I mean, what do you do with the thing? Because ... to me, as soon as you put a mono sound on the left, ... you haven't really improved the sound very much of that particular section. The only way you improve the sound is [by using] what other leakage then happens in the room, that one mic may accent mostly that sound but then there's also the sound of that section leaking over into the other side into the other mic. So, there was always a battle of whether you double mic something ... if you put two mics on something so you get a stereo sound on that particular thing or if you try for mixing various mono sounds and placing them anywhere you want, but just really [achieving] an electrical placement ... you were trying to artificially place a lot of these things.[27]

Palladino describes what I would call the mental architecture of the sound engineer, one that was undergoing continuous change in this period. The ability to control the sound meant that decisions had to be made as to how to control it and to what end. And increasingly, the producer and artist became involved in these decisions, becoming more and more conscious of the technological options they had in creative decision-making, just as the engineer began to offer a certain level of creative input, by virtue of his control over those options.

This dependency on the sound-man's technical knowledge – as well as tacit knowledge – only increased in the following decade, as 3-channel stereo gave way to 4-, 8-, 16-, and 24-track recording, offering engineers and musicians alike increased control over engineering as well as the musically creative aspects of recording. Multi-track tape recording enabled engineers to record individual instruments on separate tracks, thus making it possible to manipulate them in the mix, with profound and far-reaching consequences for music as well as for the work of engineers, producers, arrangers, and musicians. With the advent of multi-tracking, the job bundle of the recording engineer or sound mixer began to shift. Where the engineer was once strictly the operator or technician, the demands and opportunities of multi-tracking rendered the recording engineer also a member of the creative team. By the 1960s, in fact, the individual who controlled the console during a recording was no longer necessarily a 'recording engineer', and was more likely referred to as a 'mixer', the term used in the film industry. Soon the titles of 'mixer', 'recording engineer', and 'technician' had become almost interchangeable, at least to those outside the industry. But each had a distinct function, and in major record label studios where union rules prevailed, they represented different jobs. Yet they were all aspects of what was once the solo recordist's job, a job that had expanded and diversified along with the industry as well as the technology.

Sociologist Edward Kealy has documented the shifting status of sound mixers from craftsmen to artists. The changing technology, in particular multi-track recording, made it possible for recording engineers to become more involved in musical decisions made during recording, even as it enabled the music's creators to become more technical and in some cases to acquire a limited degree of engineering skill (Kealy, 1974, 1979). But mixers have always occupied liminal territory; neither engineers nor artists, they are in fact a little of both. They must act as technicians, be intimately acquainted with their equipment and its capabilities, and also know when something might not be working optimally. Not all mixers, however, like to be called engineers. Malcolm Addey, who began his career in England at EMI Studios and moved to New York in the late 1960s when he was hired by Bell Sound Studios, considers the early lathe-operators to be engineers, but he considers his own work to be more artistic than technical, and believes that the title of 'engineer' is a 'complete misnomer', and in fact 'used in a sociological way to separate us from the artists ... it's the one thing that keeps us socially separate. And I think it's used a great deal by those who want to keep us separate'.[28] Addey is not alone in this sentiment, yet ironically most recording engineers expressed affinity with the artists, and even tended to want to please the artists in the recording situation rather than the producer. Some engineers/mixers were expected to provide the voice of reason during often emotionally charged situations when artists and recording company representatives collided. Recalling his experience as manager of Bell Sound Studios from 1958 to 1974, Dave Teig said that the engineer had to be both 'a technician and a diplomat'.[29] Compare that with what Raymond Sooy recalled about his own experiences beginning in 1903 as recording engineer for Victor Talking Machine and later, RCA-Victor Records. One of the many 'Requirements Necessary for a Good Recorder', according to Sooy, was that:

> He must be a very quick thinker and patient – must know how to meet and handle all kinds of temperamental people, and govern himself under some very trying conditions. He must get the confidence of the artist with whom he has to work, whether they be good, bad, or indifferent – also must not show any signs of disappointment whether the voice he is recording be good or bad, but try under all circumstances to get the best record possible.[30]

Moreover, Sooy stressed, 'a good recording man must be the same as a good musician – he must feel his work in order to get the best results out of it, as this work cannot be done mechanically and prove successful'.[31] By this, Sooy means nothing less than artistry, but the 'requirements' he outlined are those acquired by years of experience.

Tacit Knowledge and the Skill of Disk-Cutting: Use It or Lose It

Since the work of recording engineers involved on the job training, the perpetuation of some fundamental skills relied on knowledge passed along as older engineers retired and newer engineers entered the field. From the beginning of the art of phonography until the 1950s, all recording was done on wax or lacquer disks and every recordist knew how to cut a disk operating a recording lathe. Some even possessed sufficient knowledge to build their own recording machines. By the late 1960s, as tape-recording replaced disk-recording as the primary medium, disk-cutting skills had begun to vanish. As Donald MacKenzie and Graham Spinardi (1995) discovered in their study of nuclear weapons design, skills, if not practiced, will degrade, and tacit knowledge, unlike explicit knowledge documented in texts, will be lost. A similar thing transpired in recording studios, but rather than disappearing completely, disk-cutting became a specialized field, still necessary for the mastering stage – the stage after the completion of recording and before the record can be processed and manufactured. Initially, the lathe was only part of the disk-cutting operation, which also included the cutting head apparatus.[32] Most recording engineers of the disk era had to understand disk-cutting skill, if not actually execute it, but it was never explicitly formulated. Although there were several reference works and how-to manuals published during the late 1940s, they continually underwent revision due to rapid innovations, and even then they did not provide everything the disk-cutter needed to know. Joining the lathe and the cutting head required the ability to connect by complex adjustment, wiring, fine-tuning, and fiddling, rather than plugging something into a socket or following a step-by-step guide. When the Neumann Company of Germany came out with a unit that combined the entire recording chain, from tape to master disk, the need to make those connections manually lapsed and thus, so did recordists' training and ability in that particular task. This led to a new specialization, and new types of studios called mastering houses, which did nothing but cut master lacquers. Sound engineers who specialized in mastering continued to know how to cut disks and set up a cutting system, and the most skilled of them acquired reputations for working miracles with less than perfect master tapes.

In 1969, this course of events inspired recording engineer Al Grundy to establish the first school for recording engineers, the Institute of Audio Research. Grundy, a self-taught independent recordist who went on to earn an engineering degree from Columbia University, had learned every aspect of recording while acting as a one-man traveling engineer for the Concert Hall Society in Europe. After returning to the USA, bringing with him the first Neumann cutting lathes, he was called upon so many times to train disk-cutters that he realized that this skill set was disappearing among the younger engineers. As he recalled:

> Instead of one at a time, why not teach 'em five at a time? In a way that was the origin of my thinking, that there was a need for this. ... I didn't start by teaching disk cutting. I set up a course called Studio Technology and Practice. Actually I think I called it 'Studio Theory and Practice', but I soon learned not to use the word 'theory' ... the first class was at the Barbizon Plaza. And we planned on twenty-five, and we got twenty-five students into the first class. This was September 1969.[33]

Grundy advertised in *db: The Sound Engineering Magazine*, the first new professional periodical geared toward audio engineers since the *Journal of the Audio Engineering Society* began publication in 1953. Grundy initially promoted the school as 'an education program in recording studio theory and practice' aimed at the 'working technician/engineer', and which offered courses in audio recording technology and 'seminars in advanced theory'. His first eight-week session began in September 1969, and soon he eliminated 'theory' and emphasized the practical content of the courses he offered. Disk-cutting was one of many skills taught, and by the following spring, the advertisements warned 'Your job security and advancement depend upon your skill and knowledge of present technology and practices. Our proven courses embody the latest disciplines of today's audio technology and prepare you for tomorrow's top positions in the industry'. Courses covered basic, intermediate and advanced technology, and emphasized training for future employment and advancement. By the 1970s, the competition for jobs in recording studios had begun to dictate that interns have some experience before being hired.

Grundy's efforts at formal education were well-timed, but were not the first attempts to train recording engineers. In fact, there had been a few short-lived training courses before, during, and after World War II, but before Grundy's class, very few formal training courses for audio engineers covered studio technique. However, there had been a few 'sound schools' on the West Coast. In the late 1930s, John Palladino enrolled in the music department at Los Angeles City College, but ended up spending most of his time there in a recording studio in the physics department that was used by both the physics professor and the music department.[34] The University of Hollywood, founded in 1946 by Howard M. Tremaine, a film sound specialist, offered an 18-month program in sound and audio engineering, culminating in a Bachelor of Science in Audio Engineering (Anonymous, 1949). During World War II, two engineers from Electrical Research Products Division of Western Electric taught a series of courses at the University of California at Los Angeles as part of a government war-training program, later publishing a technical book based on their courses.[35] None of these programs offered would-be recording engineers instruction in the range of skills they needed to succeed in the studio, and most US recording engineers, mixers, or 'control men' of the immediate postwar period learned their trade from scratch with the first civilian job they took. Tom Dowd recalled that in the 1940s, 'No one said, "This is the way you record, that is what you use"'.[36]

In Germany a much more formal kind of training emerged. In 1946, Dr Erich Thienhaus developed a three-and-a-half-year curriculum at the Detmold State Academy of Music aimed to teach advanced music students the skills of sound recording (Kuttner, 1959). The program culminated in a professional degree, Tonmeister, which literally means 'master of sound', or 'sound technician'. The idea spread to other European countries and an expanded program was established at the University of Surrey in England in 1970. The Surrey program involved courses in music history, period techniques, scoring, mathematics and physics, and recording techniques each year, progressing chronologically and focusing on different areas of concentration in each of these disciplines (Borwick, 1973: 26–28, 1974: 112). Despite cries for its adoption in the USA, no such formal training in both music and musical technology existed.[37] Music schools, such as the Eastman School of Music at the University of Rochester (NY), began to build professionally equipped and operated recording studios during the late 1960s, but unlike the German model these were largely aimed at supplementing the training of performing musicians, rather than training engineers to be both musically and technically proficient (Hunsberger, 1970).

Within recording departments of major labels there was a certain prejudice against musical training for recording engineers. While working in quality control at RCA-Victor Recording Studios in New York, John Woram tried to convince the management in the recording department to allow him to take courses in music theory at Columbia University, paid for by RCA. He knew he wanted to be a recording engineer, and he reasoned that since he was going to work with musicians he ought to know something about music. Woram's boss, however, was 'violently opposed' to the idea, saying, 'What would you want to take that for? It has nothing at all to do with the job!' Woram said that this was 'generally the sentiment at that time', and it took quite a bit of convincing for him to finally get his employer-paid musical training.[38]

Learning by Doing

The field of recording engineering continued to value on-the-job training over formal education, even after such education had become available and the increasingly complex nature of the work required technical expertise. There is a general attitude within industry that schooling can take one only so far, and that the real training is up to the employer and occurs in the workplace, and this is certainly true in the recording field. There are hundreds of schools teaching recording engineering today, but even these emphasize hands-on experience, working with professional mentors, and 'real-world' experience.[39]

Most engineers extolled the virtues of hands-on experience, regardless of how much formal training they may have had. Bill Stoddard was employed as instrument technician in the basic research laboratory of Cincinnati Milling Machine Company in 1952, when a passion for high fidelity led him to join the local chapter of the AES. One of their first chapter meetings involved a visit to the local King Records operation, an ambitious independent record company located in a large factory that housed its own studio, pressing plant, and packaging facility. Stoddard recalled how the experience changed his life:

> From the moment I entered the Studio control room I knew I wanted to be in the recording industry. I played hookey the next day and wandered over to King Records. The foreman of the plant was not really anxious to let me in, but finally did, saying 'Don't bother the Engineers'. I met Eddie Smith, one of the engineers. I was impressed by him, and still am! Watching him edit a tape, and watching the other engineer run the disk recording lathe (a Presto 8DG lathe), I realized that this was the business for me.[40]

This recollection reveals the excitement he felt, as well as his natural affinity with the engineer and enchantment with his work. Stoddard eventually quit Cincinnati Milling Machine, got a job as engineer in a local recording studio, worked up to owning his own studio, and eventually moved to Chicago to work at Universal Recording, and later to Fine Recording and Bell Sound Studios in New York City. These were three of the most important independent studios in the postwar period. At Bell Sound he worked with his inspiration, Eddie Smith, who left King Records for Bell Sound in 1961. When asked what place formal education had in his work as a recording engineer, Stoddard recalled that working in the research lab at Cincinnati Milling Machine,

> didn't hurt my education, but being a mechanical engineering student or getting an EE [electrical engineering degree] didn't help as much as hands on experience, or natural talent. Ed Smith was a radio amateur, and as

> such had some experience with circuitry, and a general knowledge of amplifiers. These things helped both of us in our jobs, but in Ed's case only when he was at King, because when he came to New York he was a mixer and had nothing to do with studio design or Mastering, etc. I was always drawing and designing even when I came to New York. When I went to [radio station] WOR I changed the studio, built a film mixing console and whole department as well as a new mastering room with a brand new Scully lathe, and a Westrex–Holtzer cutting system.[41]

To Stoddard, recording engineers were builders and designers of recording equipment. The mixers – those who operated the mixing console during a recording session and worked directly with the recording artists – were, he described, 'the glory boys. Theirs was the top job in any studio', particularly during the 1960s when the mixing console became the center of operations in the studio. But he was quick to mention the camaraderie that existed in the studios in which he worked, echoing Canby's concept of recording as 'a social art':

> We were all a team, and the Mastering guys were just as important to the overall success as the studio men. . . . The value of the Mixer to the studio was how the clients accepted him. His talents were in his 'bedside' manner and NOT his musical training.[42]

On the other hand, some mixing engineers felt that their musical training helped their work, particularly for orchestral dates that involved musical charts. If they could follow a score, they would know when to open a mic in the studio, for instance, to pick up a solo, then close it again when the solo ended. Walter Sear, a professional tuba player who eventually started his own recording studio, Sear Sound, recalled that 'it was understood you put the score open on the console ... you followed the score'.[43] To Stoddard, however, having a score open on a recording console was tantamount to 'doing surgery while reading the book, or driving a car while reading a map'. And he felt that 'reading music or knowing a lot of technical circuitry was absolutely NO help in mixing a session. The mixer's personality and relationship was FAR more important. And the business required many different personalities to deal with totally insane clients'.[44] These conflicting opinions about the nature of the work can be explained by different training and tacit skills: Sear was an accomplished musician before becoming a recording engineer; Stoddard was a trained engineer.

Classical producer John Culshaw expressed a similar critique of the concept of a Tonmeister in his account of the recording of Richard Wagner's *Der Ring des Nibelungen*. Culshaw declared the idea that 'the musical man, or producer, should himself handle the controls is, in my opinion, absurd. It is impossible to read a score and several meters at the same time; it is impossible to exercise musical and technical judgment at one and the same instant' (Culshaw, 1967: 169). This was exactly what the early recordists like Fred Gaisberg had done, but only because the job demanded it, and the technology was simple enough to permit it. It should be clear from these contradictory attitudes toward the role of recording engineers, or mixers, that any standard definition or rulebook never applied universally.

Recording Consoles: From Operational Ease to Too Many Options

As recording technology increased in sophistication and complexity, there was less need for recording engineers to understand how the equipment worked inside and out. By a century after Edison's phonograph, the work that the recordist had once carried out single-handed in his studio had diversified into nine different specializations, each of which might be carried out by a different individual who may or may not be called an 'engineer' and – at long last – may or may not be male.[45] Whereas early recordists knew how to assemble their machines as well as fix them, the introduction of technological innovations designed to improve sound quality, streamline the recording process, and increase efficiency and control in the studio, gradually removed the technical proficiency required of the recording engineer. The first generation of recording men were systematic tinkerers and mechanical engineers; those who began during the era of electrical transcriptions were radio hobbyists who built their own crystal sets and learned electronics on their own, and those of the World War II generation had cut their teeth on wire-recorders and disk-cutters and then moved on to build consoles. By the 1980s, few young recording engineers knew how to open the 'black box', or 'get under the hood' so to speak; more often than not, they got into recording because they wanted a career in music, felt they could improve upon the mixes they heard on radio, or sought fortune and fame, and not because they liked to tinker with equipment.[46]

This paper has looked at a number of skills that the recordist has developed through experience and the acquisition of tacit knowledge: the art of microphoning, aural thinking, and the ability to negotiate with artists and producers in the studio. One of the most important tools at the engineer's command is the recording console. This component first was introduced as a control panel in electrical recording, but it evolved very slowly until, after World War II and the rise of custom-designed consoles, it became the command center of recording. A brief look at the evolution of the console is important in understanding how the work of the recording engineer changed over time.

The Langevin Manufacturing Corporation, a New York company that produced a range of broadcast audio facilities, began building consoles specifically for recording studios in the 1950s incorporating an improved volume control mechanism. The change in this particular component gives some idea of how one small improvement, the design of the volume control, could have a much larger effect on the engineer's work. The most commonly used volume control was the German-made Daven fader. According to Bill Stoddard, 'they were stiff, and they had a terrible feel, and they were just awful. They were for submarine commanders, not mixers ... they probably will last forever [but] they just weren't very sensitive or very arty'. Both Langevin and Cinema Engineering introduced a different kind of volume control, the slide-wire faders, 'and they floated ... they had a beautiful feel and they were very conducive to getting very arty on the console'. Characteristically, Stoddard drew upon the musical instrument metaphor when describing this control. 'Daven step-type faders ... required a fair amount of force to move them. You just didn't feel like you were playing on a Steinway, whereas the slide-wires you could work ... with your little finger'.[47] This reveals how one small but significant change could further the engineer's sense of artistry.

This ease of operating the console enabled engineers to manipulate multiple controls with one hand, and became increasingly important as more simultaneous operations were expected of engineers. By 1955, Philip C. Erhorn, an independent audio design engineer who had been building consoles since the mid-1940s, described how the introduction of new technology had changed recording methods, and thus the requirements of the mixing console and engineer:

> Modern methods of operation in tape- and disc-recording studios have made necessary mixing facilities of increasing complexity. The commercial client wants and demands all kinds of exaggerated sounds. These involve the use of echo chambers, program equalizers, sound effects and sound effects filters, a variety of microphone types, vocals isolated and treated independently of the music pickup, tape-live multiple dubbing, and of course, virtually instantaneous playback facilities to both control room and studio personnel. The client tends to use all available facilities liberally in his quest for 'different' and 'more commercial' sound. The operating engineer must be prepared to conjure up various effects at the flick of his wrist. (Erhorn, 1956: 65)

Within five years of the universal conversion from disk to tape as the primary recording medium, much had changed in the control room; the engineer had more options from which to choose, and operations to perform, in the process of making a record. The client, artist, producer – whether for phonograph records or commercials – expected to be able to utilize the latest in recording techniques and to be able to hear the results on the spot. Not surprisingly, Erhorn's guiding design principles of 'operating ease and convenience' were aimed at streamlining these procedures to make it easier for the engineer.

The latest equipment is designed to increase the available options to the user, most often by performing tasks that once required human ingenuity and skill – tacit knowledge. But increased choice and control has brought undesired consequences. One experienced record producer, once known for his avant-garde synthesizer work with the band Roxy Music in the 1970s, voiced his opinion on some of the latest technology in the January 1999 issue of *Wired* magazine (Eno, 1999: 176). Having recently spent several days with what he described as probably 'the most advanced recording console in the world', Brian Eno declared, 'I have to report it was a horribly unmusical experience'. His major complaint was that, while the console had more than 10,000 controls on its surface and a computer within, the net result was more frustrating than inspiring, and it created a working situation in which:

> music-making tasks once requiring a single physical switch now require a several-step mental negotiation. My engineer kept saying 'Wait a minute' and then had to duck out of the musical conversation we were having so he could go into secretarial mode to execute complex computer-like operations. ... After days of tooth-gnashing frustration, I had to admit that something has gone wrong with the design of technology – and I was paying $2000 a day in studio fees to discover it. (Eno, 1999: 176)

Ever since the time of Thomas Edison and Emile Berliner, professional recordists and enthusiastic amateurs alike experimented with the technology in order to improve sound quality and streamline the means of achieving it; that is, to make the recording experience conducive to catching spontaneous performances. Clair Krepps recalled that in the post-World War II era, he and others who started the AES and worked for the major record labels felt they were 'carrying the torch for Edison', yet the producers and musicians they worked for, 'thought we were a bunch of nuts to improve the sound of the phonograph record. They said, it doesn't matter, it's the song that counts'.[48] Soon, the success of high fidelity rendered both song and sound equally important. But, as improving the sound of records entailed an accumulation of technological tools to aid the recording engineers in meeting those objectives, the recording session became ever more laden with extra-musical tasks. Ideally, technology should be 'transparent to the art'.[49] More technology should enable greater control, more creativity, and therefore be less intrusive. But as Eno had discovered, the monster recording console was not only an expensive tool, it carried other unexpected costs. Although it represented what Eno called the 'design philosophy that equates "more options" with "greater freedom"', what he experienced, in fact, was a *loss of freedom* – to act intuitively. As he put it,

> [T]oo many options create tools that can't ever be used intuitively. Intuitive actions confine the detail work to a dedicated part of the brain, leaving the rest of one's mind free to respond with attention and sensitivity to the changing texture of the moment ... users ... prefer deep rapport over endless options. You can't have a relationship with a device whose limits are unknown to you, because without limits it keeps becoming something else. (Eno, 1999: 176)

Here Eno laments the irony of limitless technology, that it can actually undermine the creative freedom it has been designed to enhance. Too many options in the recording studio can be a mixed blessing; as one recording artist stated, 'Limitations are what set you free'. [50] These sentiments are shared by many recording engineers who seek out and cleave to older recording technology, even as they employ some of the latest gear. Walter Sear has maintained a trove of tube recording equipment that he acquired relatively cheaply as the industry converted to solid state during the 1970s – he has been a fierce defender of analog, and a staunch critic of digital recording. As a businessman, he recognizes that some clients will prefer digital recording so he maintains the most up to date equipment, but Sear Sound is known as one of the few remaining fully equipped analog recording studios.[51] One day a group's sound engineer called Sear to book a string overdub session for the record, specifically requesting that Sear act as the recording engineer. Normally, Sear relies on his protegés to handle the sessions while he runs the business; in fact he considers them more attuned to current styles and techniques because they work with clients in the studio regularly. But the engineer insisted, and was willing to pay Sear's high hourly fee. The day came for the session, the musicians arrived at the studio, and Sear's engineers gathered around him, 'to make sure I didn't make any mistakes' and to act, as he put it, 'as my "assistants"'. One of them brought in a 48-track digital recorder and asked Sear which microphones he wanted to use, expecting him to fill up the tracks with multiple mics. Instead, Sear recalled,

> I said, 'Oh throw up a C12A, one click-off omni, and another one over there.' They said, 'You can't do that!' I said, 'Oh it'll sound great, you'll hear the whole ensemble'. They said, 'Bringing a 48-track machine in, you gotta fill those tracks!' I said, 'Okay, so we'll fly [set up] a bunch of microphones.' You know, a dog and pony act. . . . Musicians came in, they played through it once and I had the score. Then I went out, ostensibly to adjust the microphones. I went over to the bass player, I said, 'Sam you're showing off, don't dig in so much' . . . [aside] (we used to walk our kids in the park). . . . I said, 'Lamarr, tell the section I need more violas in this bar, and this bar and this bar' . . . then I went over to the concertmaster who happened to be my son-in-law, I said, 'Jim, I need more violins here, here, here, and here, and less second violins there'.[52]

Demonstrating his skills in the art of microphoning, Sear at the same time humored his staff and satisfied the client by setting up what amounted to 'dummy' microphones in order to make it look like he was filling up those 48 tracks that the client was paying for, thus performing the entrepreneurial 'dog and pony act' when he knew perfectly well the three well-chosen microphones would do. Then, having established his rapport with the musicians and instructed them how to adjust their playing to improve the sound, Sear went back into the control room, hit the record button:

> Boom! . . . and the guy from Blues Traveler said, 'Ah, marvelous!' And our engineer said, [whispered] 'How many limiters were you using?' I said, 'None'. He said [hushed, excited tone], 'BUT THE METERS ARE ALL LIKE THIS' [indicating with his hands that the levels remained steady]. I said, 'Yeah, *with the fingers*'. I know the violin's going to die out on the end of a . . . you push it! . . . I'm a musician, I know what they do. I know where the sound comes out of the instrument, know where to put the microphones . . . . And that's all gone now except here, where my people are trained, and they're very good.[53]

Here, Sear demonstrated not only his microphoning technique, entrepreneurial savvy and personal skills, but also the subtle art of mixing dynamic instruments at a steady level without the use of limiters – compressors that maintain a steady output level regardless of the input – devices that Sear argues have been over-used in recording today. While there is clearly professional pride and even boastfulness in this account, it deserves attention as an extended description of how one recording engineer knows when less is more, when to use a few carefully chosen microphones rather than filling up all available tracks, and how to draw on his knowledge, gained from experience as a musician and a recording engineer, of how to instruct the musicians to adjust their playing to fit the needs of the session. He trains his employees in this art of recording strings, which Sear asserts is 'the easiest thing in the world', but which few recording engineers know how to handle because they are no longer so widely used in sessions, at least in rock and pop music. In the 1960s, musical arrangers like Alan Lorber wrote string arrangements regularly for pop and rhythm & blues vocal groups, but as the genre shifted to self-contained rock bands and instruments that synthesized strings there was less demand for string overdubs and thus the number of engineers with the knowledge of how to record strings, like those with the tacit knowledge of disk-cutting, declined.

Conclusion

When the sound engineer used earlier forms of recording equipment, more was required of his 'ability, imagination, knowledge, sensibility, intuition – and technical know-how' in overcoming basic obstacles to getting good sound (Canby, 1956: 61). The urge to develop greater mastery over sound led to efforts to design, build, or invent new means to improve the sound of records. Such efforts led, in turn, to an evolution of new tacit skills and to a technological juggernaut; an almost blind faith in the power of technology to fix whatever might be lacking in the recording studio. The skills that always seemed to need a little 'correcting' or 'perfecting' included artistic and engineering skills, often in combination. In the worst cases, these trends encouraged incompetence and self-indulgence; in the best cases, they enabled recordings of the highest technical and artistic quality. Increasingly, the tools of recording engineers, as well as musicians, offered more and more options toward control and creative freedom, but the complexity of the tools could also frustrate the user, ultimately limiting creativity. The challenge and the excitement of engineering a recorded performance lay in exploiting both technological options and tacit knowledge for meeting the needs of a given recording situation. Like the recording itself, this challenge required a careful balance between the two. Although the recording engineer's dilemma has changed over time, from limited control over the behavior of sound to perhaps too many options for manipulating it, the need for tacit knowledge has not diminished, even in the most technologically sophisticated recording studios. Despite the ever-changing technological landscape of the recording studio, the growth of formal training in engineering, and the continued evolution of technology, individual skill and artistry in record engineering continue to be valued as the technology and practice of recording continually shapes, and is shaped by, the musical landscape.

Notes

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1. The field of audio engineering and recording studios in particular historically has comprised a profoundly male-centered culture. This is due in part to what Judy Wacjman (1991) calls 'the underlying nexus between masculinity and technology' , but also due to the fact that the first operators of recording machines were often machinists or mechanical engineers, both also male-dominated professions. This male dominance continued through the generation of World War II veterans who built the recording studios of the postwar period. Until the 1970s, with very few exceptions, women in recording were to be found behind the microphone rather than seated at the control board.
2. For more on how the early phonograph users were configured, see Gitelman (2000).
3. Raymond B. Sooy, 'Memoirs of My Recording and Traveling Experiences for the Victor Talking Machine Company', entry under 'Requirements Necessary for a Good Recorder'. N.d., unpaginated, unpublished photocopy of typescript. Copy in possession of author, courtesy Alexander Magoun. Original photocopy in Hagley Museum and Library Collection 2138, 'Files of Nicholas F. Pensiero'.
4. Ibid. See entry under 'A Few Memoirs of Temperamental Artists'.
5. See Gaisberg (1977 [1942]: 37–38). Gaisberg himself was forced into a similar role when in 1906 he and his brother made the very first recordings of the legendary opera singer, Adelina Patti, at her castle in Wales. 'It was my job', he recalled, 'to pull her back when she made those beautiful attacks on the high notes. At first she did not like this and was most indignant, but later when she heard the lovely records she showed her joy just like a child and forgave me my impertinence' (p. 91).
6. Crozier (1963), cited in Barley & Orr (1997: 14).
7. See Calvert (1967). In fact, any training the early recordists had was likely to be in mechanical engineering because that was the basis of the recording lathe, a machine that was powered by a series of gears and pulleys driven by weights.
8. Anonymous recording expert, 'who had been in the industry since the time of Edison's tinfoil records', quoted in Lescarboura (1918: 178).
9. The idea that scientists have tacit knowledge, first introduced by Michael Polanyi (1958, 1966), has been extended by other scholars to other scientific networks, to other disciplines, and to other professions. See: Collins (1974, 1992, 2001); Sternberg & Horvath (1999); Sternberg et al. (1999); Barley & Orr (1997); Turner (1994); Ravetz (1971), especially Ch. 3, 'Science as Craftsman's Work'; MacKenzie & Spinardi (1995); Pinch et al. (1996).
10. Howard Sanner, 'Talk by Cyril Francis, Recording Engineer', presented at the Washington, DC, Association for Recorded Sound Collections Chapter Meeting, Mary

Pickford Theatre, Library of Congress, 23 October 1996. Posted at <www.aes.org/aeshc/docs/acceng02.html>.

11. Electrical transcriptions were recordings made specifically for radio broadcast and included music and commercials as well as other programming. The growth of transcription library services during the 1930s brought pre-recorded programming back to radio, which had featured predominantly live performances in its early years, in part because of the poor sound quality of records played over the air. It was during this period that recording and radio engineering became more allied, and recordists acquired the designation of recording engineers. See Baum (1964), Biel (1977), and Smulyan (1994: 122–24).
12. An equalizer is a signal-processing device used to change the frequency response of the signal passing through it.
13. Clair Krepps, interview with author, 31 March 1999.
14. Al Schmitt, interview with author, 12 April 1999. 'Patching' involved the use of cables with coaxial plugs on either end to route sound signals as desired through the use of patch bays – strips or panels of female input and output sockets built into the recording console or on an equipment rack. The engineer would adjust these according to how he wanted the signal routed. In Schmitt's case, the choices were limited to all or nothing, but as signal-processing devices flourished, patching became increasingly complex.
15. The RCA 44 velocity microphone, the familiar diamond-shaped bi-directional microphone, was universally referred to as the 'ribbon mic' because its diaphragm consisted of a corrugated ribbon suspended in a magnetic field.
16. Schmitt interview, 12 April 1999.
17. Canby (1956: 44). Mitch Miller argued that the 'engineers were the strongest link in the chain' and he was among the first to suggest that they be given album credit, although the company executives balked at this suggestion. Mitch Miller, interview with author, New York City, 21 January 1999.
18. Interestingly, audio engineers at the time considered the Manhattan Project to be 'merely an extension of electronic research' (Anonymous, 1945: 8).
19. Tom Dowd, telephone interview with author, 23 March 1999.
20. Mitch Miller, interview with author, New York City, 21 January 1999.
21. John Palladino, telephone interview with author, 15 October 1999.
22. Ray Hall, telephone interview with author, 21 March 1999.
23. During the war, Birkenhead made Krepps project engineer for a flying classroom to teach Navy pilots to use radio and radar, an assignment Krepps felt should have gone 'to two MIT graduates'. Krepps built it to accommodate ten student pilots, rigging each seat with a scope and intercommunication device. Clair Krepps, telephone interview with author, 23 March 1999.
24. Cardioid microphones such as the 44BX were subject to 'proximity effect', the rise in low frequency response when used at close distances. Clair Krepps, telephone interview with author, 31 March 1999.
25. Clair Krepps, telephone interview with author, 31 March 1999.
26. Ray Hall, telephone interview with author, 21 March 1999.
27. John Palladino, telephone interview with author, 15 October 1999.
28. Malcolm Addey, interview with author, 19 January 1999.
29. Dave Teig, telephone conversation with author, July 1996.
30. Op. cit. note 3.
31. Ibid.
32. The complete system is often referred to as the 'recording lathe' or 'cutter' but in fact the lathe, originally made by Scully or Presto, includes the mechanical part with the turntable, the carriage and the feedscrew that moves across to cut the spiral groove from beginning to end. The actual head that holds the stylus, with its associated amplifiers, comprises the cutting system, then made by Westrex, as opposed to the lathe. Neumann made the whole package beginning in the late 1950s.
33. Al Grundy, telephone interview with author, 8 January 2000.
34. John Palladino, telephone interview with author, 15 October 1999.

35. See Frayne & Wolfe (1949); this book was a revised and expanded text version of their courses.
36. Tom Dowd, telephone interview with author, 23 March 1999.
37. See von Ottenfield (1951). This musician argued for greater understanding of music by engineers, and more recognition of the engineer's importance by the recording director, leading to a 'partnership with the recording engineer'.
38. John Woram, telephone interview with author, 6 December 1999.
39. One of the most successful recording schools, Full Sail, established in Ohio in 1979 and now located in Orlando, FL, markets its program as 'Full Sail Real World Education'. According to the school's website, its educational philosophy is based on three principles: 'provide hands-on training on current, state of the art equipment'; 'center the education in the heart of the industry which it serves'; and 'staff the school with instructors who are current professionals, active in their respective fields of expertise'. See <www.fullsail.com>.
40. Bill Stoddard, email correspondence, 21 February 1999.
41. Bill Stoddard, email correspondence, 9 July 2000.
42. Bill Stoddard, email correspondence, 30 June 2000.
43. Walter Sear, interview with author, 19 January 1999.
44. Bill Stoddard, email correspondence, 30 June 2000.
45. Morris (1977) covers the entire field of audio engineering, but the section devoted to recorded music (the largest) lists the following: experts in acoustics and studio design, design engineers, recording director or 'Tonmeister', console operator (mixer), tape recordist, mixdown mixer, disk recordist, maintenance engineer; and tape, cartridge, cassette duplication. In addition, the mastering engineer (what he calls disk recordist) might perform tasks above and beyond merely transferring tape to disk, and could be the proprietor of his own mastering studio, such as Bob Ludwig, whose reputation for skillful mastering earned him devoted clients willing to travel to his 'Maine outpost' to obtain his services. See Sutherland (1988).
46. Haselau (1982) and Fay (1988), in two very similar 1980s editorials concerned with realities of the job, focus on music as a guiding impetus and make no mention of the kind of technological enthusiasm that characterized earlier generations of recording enthusiasts.
47. Bill Stoddard, telephone interview with author, 11 March 1999.
48. Clair Krepps, telephone interview with author, 23 March 1999.
49. See Massenburg (1997).
50. David Thomas, interview with author, Cleveland, OH, 12 August 1997.
51. For a lengthy interview with Sear, see Davies (2004).
52. Walter Sear, interview with author, 19 January 1999.
53. Walter Sear, interview with author, 19 January 1999.

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