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A History of Electroacoustics: Hollywood 1956 – 1963

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By

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Abstract

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This dissertation argues that a cinematic approach to music recording developed during the 1950s, modeling the recording process of movie producers in post-production studios. This approach to recorded sound constructed an imaginary listener consisting of a blank perceptual space, whose sonic-auditory experience could be controlled through electroacoustic devices. This history provides an audiovisual genealogy for electroacoustic sound that challenges histories of recording that have privileged Thomas Edison's 1877 phonograph and the recording industry it generated. It is elucidated through a consideration of the use of electroacoustic technologies for music that centered in Hollywood and drew upon sound recording practices from the movie industry. This consideration is undertaken through research in three technologies that underwent significant development in the 1950s: the recording studio, the mixing board, and the synthesizer. The 1956 Capitol Records Studio in Hollywood was the first purpose-built recording studio to be modelled on sound stages from the neighboring film lots. The mixing board was the paradigmatic tool of the recording studio, a central interface from which to direct and shape sound. Finally, the electronic synthesizer offered the potential for total control over sonic timbre, as can be seen in the use of the Trautonium in Alfred Hitchcock's *The Birds* (1963). Together, these histories advance an understanding of recorded sound that de-centers the idea of reproduction, and emphasizes instead twentieth-century cybernetic ideals of influence, and, ultimately, control, through the recorded medium of sound.

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Introduction

This dissertation proposes a new history and theory of electroacoustics. It argues that electroacoustic technologies and concepts played a large role in shaping the modern environment and "control societies."[1] By the 1950s, electroacoustics was an established, visible, and public discipline in the United States, its principles deployed by an entertainment industry that sought higher quality sound recordings. Electroacoustic recording technologies such as microphones, amplifiers, mixers and loudspeakers became de-facto tools for movie production, music recording, and radio broadcasting. In this decade, music recording newly recognized and exploited the array of sonic effects afforded by systems of electroacoustic recording. Music recording was transformed, in the late 1950s, into an art of electroacoustic control, in ways that coincided with emerging ideas of urban and social space, areas that planners, architects and administrators believed to function like control systems themselves. My alignment of music recording and urban design emphasizes their shared preoccupation with spatial control, as well as the systems theory that influenced the specialized techniques and intellectual developments generated in both disciplines.

I ground my research in Hollywood, the "entertainment capital of the world," home to the first purpose-built music recording studio and numerous developments in electroacoustic recording. The entertainment industry both modelled and projected new modes for living through sound and image. I focus on three different case studies in Hollywood, which cover different elements of the electroacoustic system. Chapter 1, tells the story of the modern recording studio, through the 1956 construction of the Capitol Records Tower. Chapters 2 and 3, center on the audio mixing console: Chapter 2 shows how the mixing board helped to produce new, distinctively modern conceptions of sound, while Chapter 3 situates the mixing board in relation to psychoacoustic theories and mid-century research into hearing. Chapter 4 turns to the synthesizer, analyzing popular conceptions of the frightening power of sound synthesis, in part by analyzing the role of the Trautonium in Alfred Hitchcock's 1963 movie, *The Birds*. Each chapter traces how instruments of control were brought to bear on the engineering of fantasy environments. My aim is to show how sound technologies helped to normalize one of the defining fantasies of late modernity: the fantasy of total control.

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Before embarking, it makes sense to define the word "electroacoustics," as a term, not once-and-for-all, but by describing the multiple ways in which it has been used in modern history. In the following pages, I move from sober, technical accounts of great inventors and corporations advancing technological progress to more fantastical stories that circulated amongst practitioners of audio technology, who sustained vernacular

[1] Gilles Deleuze, "Postscript on the Societies of Control," *October* 59 (1992): 3–7.

belief in the magic of electroacoustics. First, I explore some of the ways that electroacoustics has been retrospectively cited to designate a new area of knowledge, a field of inquiry, or disciplinary domain. This literature tends to rely on an elite-focused history, one that frames electroacoustics as a disinterested discipline that emerged within the experimental sciences, at the intersection of acoustics and electrical research. Second, I show how artists, working with new audio technologies, configured electroacoustics as a mysterious, Promethean force, valued for its creative potential rather than its ability to establish verifiable "truths" about electrified sound. My priority in the third and final account is to think through the occult and utopian beliefs that sustained practitioners and consumers of electroacoustic technology. In sum, I move from the top-down perspectives of institutional scientific theory to the vernacular, bottom-up stories that shaped electroacoustic practice.

From Discipline to Magic

Mainstream histories of science typically situate the idea of electroacoustics in a larger story of technological progress, and so turn to particular institutions and industries as the progenitors of this new discipline. According to Roland Wittje, the first use of the word "Elektroakustik" occurred in Germany around 1900.[2] In the English language, according to the *Oxford English Dictionary*, the term "electro-acoustic" first appeared in technical literature around 1926. The story goes that German physicist Walter Schottky wrote a paper titled "Das Gesetz des Tiefempfangs in der Akustik und Elektroakustik," which was translated in *Science Abstracts* as "The Law of Depth Reception in Acoustics and Electro-acoustics."[3] Schottky's paper directly addressed the twofold nature of electroacoustics, analyzing the effectiveness of "the reciprocal theorem" in the realm of both acoustics and electrical circuits. This article perfectly illustrated one of the founding aims of this approach to electroacoustics: to map and reproduce phenomena from one realm in, and through, another. Researchers and technicians wanted to define the exact nature of transduction – the transformation of acoustic energy into electrical energy – and to explore how acoustic properties were represented by electrical values in an electroacoustic system.[4] Schottky's paper also hinted at another focus of electroacoustics: acoustic phenomena could not only be transcribed in electronic form but controlled.

Electroacoustic knowledge was not only generated within the academy, however. The telephone had been invented on the principle of transduction. Founded in New York

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[2] Roland Wittje, "The Electrical Imagination: Sound Analogies, Equivalent Circuits, and the Rise of Electroacoustics, 1863–1939," *Osiris* 28, no. 1 (2013): 44, https://doi.org/10.1086/671362.

[3] Walter Schottky, "Das Gesetz Des Tiefempfangs in Der Akustik Und Elektroakustik.," *Zeitschrift Für Physik* 36 (1926); Physical Society (Great Britain), Institution of Electrical Engineers., and Physical Society of London., "Science Abstracts. Section A, Physics," *Physics* 29 (1926): 653, https://catalog.hathitrust.org/Record/004528175.

[4] Jonathan Sterne, *The Audible Past: Cultural Origins of Sound Reproduction*, 47701st edition (Durham: Duke University Press Books, 2003), 22.

in 1925, the Bell Telephone Laboratories employed technicians who would develop a theory and practice of electroacoustics that addressed the specific technical demands of their telephone system. M.D. Fagen writes:

> By 1900, a theoretical basis for electrical communication began to emerge based on application of the fundamental research taking place both within and outside of the Bell System. By 1925 this had grown to a fairly comprehensive background of basic knowledge, and the new Bell Laboratories proved to be an ideal vehicle for expanding and building on this knowledge.[5]

A view of technical publications from the period indicates that the knowledge that Fagen identified as an achievement of the Bell institution was not yet referred to as "electroacoustic." When Bell Laboratories researchers, J.P. Maxfield and H.C. Harrison, described their efforts to electrify the phonograph in 1926, they used the phrase "telephone transmission theory" to distinguish Bell Telephone's approach to recorded sound from that of Edison's mechanical phonograph.[6] The word "electroacoustic" was only used in Bell's in-house journals from 1929, beginning with an article that described the master reference system for the telephone network. The authors argued that the new reference system "should provide similar base lines for the performance of electroacoustic converters."[7] Bell's researchers wanted to measure and quantify the exact nature of transduction. Again, the concept of the electroacoustic was used to establish a solid and transparent theoretical space to mediate the realms of acoustic and electronic thought.

Around a decade later, the radio industry was similarly motivated to fix a set of universal principles proper to the defining precepts of electroacoustic theory. In 1938, the Institute of Radio Engineers in New York published their *Standards on Electroacoustics*. This handbook was part of the Institute's long-running desire for "the establishment of standards" in an emerging technical and scientific field.[8] Both Bell Telephones and the Institute of Radio Engineers used the term "electroacoustic" in projects that aimed to fix some general principles by which to apprehend the nature of electrified sound. "Electroacoustic" was a multivalent word that not only defined a scientific field. It also connoted a level of mastery over an audio phenomenon, and a set of verifiable, universal principles that could be applied to it.

Following the Second World War, electroacoustic principles became paradigmatic

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[5] Bell Telephone Laboratories and M. D. Fagen, eds., *A History of Engineering and Science in the Bell System: The Early Years (1875-1925)* (New York: Bell Telephone Laboratories, 1975), 58.

[6] J. P. Maxfield and H. C. Harrison, "Methods of High Quality Recording and Reproducing of Music and Speech Based on Telephone Research," *Bell System Technical Journal* 5, no. 3 (July 1, 1926): 493, https://doi.org/10.1002/j.1538-7305.1926.tb00118.x.

[7] W. H. Martin and C.H.G. Gray, "Master Reference System for Telephone Transmission," *The Bell System Technical Journal*, July 1929, 540.

[8] Institute of Radio Engineers. Standards Committee, *Standards on Electroacoustics.* (New York, N.Y.: The Institute of Radio Engineers, inc., 1938), v, https://catalog.hathitrust.org/Record/001616590.

of such world-defining disciplines as cybernetics, information theory and general systems theory. Looking back, from the point of view of these mid-century procedures of thought, we can identify traces of how electroacoustic concepts were generalized and systematized in order to answer a variety of technical problems having to do with sonic and spatial control. As early as 1928 the British physicist William Eccles described the conceptual bridging of acoustic and electrical knowledge as one of "translation." "Many acoustical problems can be translated into problems concerning electrical networks," Eccles wrote, "and as there exists a great body of knowledge of such networks, the problem is often solved in the act of translation."[9] Eccles suggested that "translation" was the electroacoustic technique *par excellence*. Electroacoustic theory promoted the idea that the complexities of acoustic phenomena could be expressed in electronic terms. As such, electronic circuits could be used to model and manipulate complex acoustic environments in ways that had been impossible for physicists of the past. Electronic circuits, therefore, not only offered acousticians the ideal research environment, but also a language with which to describe acoustic phenomena. Electroacoustics had both a material and linguistic force: transduction had led to translation.

The conceptual framework of "translation," so important to electroacoustic research, had a profound impact on the system and information theories that formed in the 1950s. The "translation" of acoustic problems into electrical circuits provided a general model for problems in other engineering systems. In his study of engineering cultures that preceded the establishment of cybernetics, David Mindell notes that control engineers in many fields were beginning to view their systems as electronic circuits. Discussing the engineers who operated on electrical power systems in the late 1920s, Mindell describes their conceptual approach in the following terms: "if all systems were circuits, then one could study a system by modelling one form of circuit with another."[10] Here, the interchangeability of system and electronic circuit in the minds of engineers is strikingly clear.

Traces of electroacoustic translation resurface in cybernetic thought of the 1950s and 1960s. Cybernetics was a term coined by the scientist Norbert Wiener in his landmark text, *Cybernetics: Or Control and Communication in the Animal and the Machine* in 1948. Cybernetic researchers frequently referenced the work of electroacoustic engineers, even if obliquely. Mindell describes the Bell Telephone Company as "a company that sought to translate ever more of the world into transmissible messages."[11] Cybernetics came to designate a field of research that took communication systems as a conceptual framework for thinking about a diverse group of problems. In cybernetics the "translating" act was generalized. One of cybernetics' most influential ideas was that "information" was a universal currency, the texture of a media language distributed through any given system,

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[9] W. H. Eccles, "The New Acoustics," *Proceedings of the Physical Society* 41, no. 231 (n.d.): 233.
[10] David A. Mindell, *Between Human and Machine: Feedback, Control, and Computing before Cybernetics*, Johns Hopkins Studies in the History of Technology (Baltimore: Johns Hopkins University Press, 2002), 146.
[11] Ibid., 106.

and analyzable as the content of that electrical structure. Using cybernetic principles, therefore, the telephone network, the thermostat and a host of other control systems could be defined according to the information they received, manipulated and generated. Ronald Kline argues that by 1951 "information" had become the "guiding metaphor" for cyberneticians.[12] Because information could be applied to any system, whether it involved temperature or sound, it functioned as the paradigmatic concept of translation.

The rising popularity of cybernetics occurred at the same time as a series of texts were published that revisited and reviewed the cumulative work of electroacoustic research from the first half of the century. In the United States a number of books took the discipline as their central subject. Frederik V. Hunt's *Electroacoustics* appeared in 1954, while Michael Rettinger's *Practical Electroacoustics* and an English translation of German physicist F.A. Fischer's *Fundamentals of Electroacoustics* were both published in 1955. Electroacoustic studies were well suited to an era enamored with the analysis and application of control systems; the very idea of the "sound system," we shall see, was beholden to cybernetic fascinations. The renewed attention to electroacoustics in the era of cybernetics represents something of a feedback loop between the two disciplines: electroacoustic concepts had contributed to the cybernetic worldview, which in turn shaped the work of electroacoustic engineers in the 1950s.

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The English word "electroacoustic" actually predates its applications in the kind of technical literature and scientific journals that I have discussed thus far. In tracing its earliest uses, we encounter another, submerged dimension of this story: the magical, sinister, or manipulative power of electroacoustics. Neil Wynn Williams's 1906 bizarre science fiction thriller *The Electric Theft*, which coined the term "electro-acoustic," is perhaps more notable for its early fascination with electricity than its novelistic technique.[13] The protagonist, Reginald Burton, is an electrical engineer and superspy who investigates the "theft" of electricity in Athens and London by the archvillain Ivan Boleroff, a Russian anarchist. In the course of the narrative Burton conceives of and produces an electric megaphone. One of the first uses of this new device is to intimidate a group of Greek brigands, with the engineer hoping that his ultra-modern invention would terrify and confuse the superstitious militia group.

The electric megaphone is described in the thriller as "a system of electro-acoustic relays"[14] – an imagined mechanism of this imaginary technology is reminiscent of the

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[12] Ronald R. Kline, *The Cybernetics Moment: Or Why We Call Our Age the Information Age*, New Studies in American Intellectual and Cultural History (Baltimore: Johns Hopkins University Press, 2015), 60.
[13] Everett Franklin Bleiler, *Science-Fiction, the Early Years: A Full Description of More Than 3,000 Science-Fiction Stories from Earliest Times to the Appearance of the Genre Magazines in 1930 : With Author, Title, and Motif Indexes* (Kent State University Press, 1990), 821.
[14] Neil Wynn Williams, *The Electric Theft* (Boston: Small, Maynard & Company, n.d.), 111.

vacuum tube patented by Lee de Forest in 1907, a development that enabled electronic amplification. In the fictional megaphone,

> The voice, after entry, passed in and out of a series of minute telephonic mechanisms to which were attached the electro-acoustic relays, transmitting or reflecting itself cumulatively from sound into electric energy, from electric energy into sound, and so on up to any required tone degree.[15]

Williams's description evokes the feedback process of a vacuum tube amplifier continuously building up the strength of an electronic signal by folding it in on itself. The megaphone appears here in ways that highlight the perpetual "translations" between electric and acoustic energy, an equivalence that electroacoustic science would later set out to explore and measure.

The Electric Theft thematizes many of the period's anxieties about electric power and electricity, a phenomenon still conceived as something of a novelty for the general public in 1906. Williams's text is striking for the ways it explores many of the potential social, psychological and environmental effects of sound technologies. Williams frequently conflates technological advances with natural forces, describing a world of "sound-riots" and "sound-storms," where electrified sound not only embodies elemental nature but activates animalistic responses in listeners. Anxieties about the loss or depletion of the distinctively human frequently resurface in literature describing electroacoustic technologies, both fictional and non. Some of the more prominent anxieties concerned the relation of nature and technology, the social consequences of increasingly loud sounds, and the potential for electroacoustic technologies to exert excessive control over both the physical properties of sound and the people hearing it. These worries were perennial, and built in to both fascist self-understandings and popular fears about fascist technologies in the 1930s and 40s. Jacques Attali's oft-repeated quote from a Nazi radio handbook records Hitler's belief that "without the loudspeaker we could have never conquered Germany."[16] Beliefs about the overweening power of sonic violence connect these fascist sonic imaginaries to more recent studies, by Steve Goodman and others, of the technological weaponization of acoustic power.[17]

The reductive idea that amplified sound could somehow explain the success of extremist or authoritarian political ideologies is clearly a widespread fantasy – one that shapes most of the events in *The Electric Theft*. In this story, the general public are typically portrayed as constantly on the brink of mob rule in the face of their seduction by electric media. When the antagonist, Ivan Boleroff, disables London's electricity supply, bringing chaos to the capital city, the novel concludes with what is essentially a war of loudness between the engineer hero and anarchist villain. The hero uses his electric

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[15] Ibid., 110.

[16] Jacques Attali, *Noise: The Political Economy of Music* (Manchester University Press, 1985), 87.

[17] Steve Goodman, *Sonic Warfare: Sound, Affect, and the Ecology of Fear* (Cambridge, Massachusetts: MIT Press, 2012).

megaphone while the villain turns nothing other than St. Paul's Cathedral into a gigantic loudspeaker, via an unlikely subterranean electrolytic lake. Both characters try to dominate the ears and minds of the helpless London masses caught between two forms of propaganda. The success of each side is determined in the end by who could transmit the louder sound. Any notion of free will, democratic debate, or shared reasoning is, it hardly needs saying, irrelevant in this public sphere: discourse has become an electronically amped-up shouting match. Williams did not need to be taught that the medium is the message.

Contemporaries often portrayed electroacoustic systems as if they were a late addition to the modernist project of subduing the natural world. Frederik V. Hunt began his 1955 textbook on the history of electroacoustics with the elemental forces of the atmosphere: "Electroacoustics is as old and as familiar as thunder and lightning," Hunt writes, "but the knowledge that is the power to control such modes of energy conversion is still a fresh conquest of science not yet fully consolidated."[18] Such characterizations of the elemental force of electroacoustic phenomena echoed the protagonist's belief in *The Electric Theft* when he declared that "the human voice should have more power – power like thunder."[19] The potential of electroacoustic technology was frequently expressed via sublime conceptions of the environment, as both a product of the atmosphere and a tool to conjure a new atmospheric power.

The ghosts of Hollywood fantasy were thus always already active at the dawn of electroacoustic experimentation. Electroacoustic thinking conjured as much a language of fantasy as a lexicon of rigorous technical terms. Even during the "high fidelity" craze of the midcentury, which I shall explore further later in Chapter 1, the details of technical developments were obscured and exaggerated in the public imagination by marketing hype and the mass media. Cybernetic knowledge itself thrived on the blurring of fact and fantasy: the reasoned discourse championed by cybernetic theoreticians notwithstanding, it too was hardly immune to the popular mania for science fiction. In his 1950 book *The Human Use of Human Beings*, for example, Wiener considered the scientific possibility of "telegraphing a man" using the principles of communication championed by cybernetics.[20] Ronald Kline has also noted that Wiener initially had to work hard to differentiate his scientific theories from the work of Scientology founder, L. Ron Hubbard.[21] Midcentury optimism was such that given the apparently unlimited potential of this world-shaping technology, science fiction scenarios were often taken to be immanent scientific realities. In such an alternative narration of the history of electroacoustic endeavor in the English-speaking world, in short, the ideas of electrically mediated sound were just as at home in the fantasy realms of fiction as they were in the

[18] Frederick V. Hunt, *Electroacoustics: The Analysis of Transduction, and Its Historical Background* (New York: Published by the American Institute of Physics for the Acoustical Society of America, 1982), 1.
[19] Williams, *The Electric Theft*, 110.
[20] Norbert Wiener, *The Human Use of Human Beings: Cybernetics and Society* (Hachette Books, 1988), 104.
[21] Kline, *The Cybernetics Moment*, 92.

sober annals of scientifically-verified fact.

The enigmatic nature of electronic sound generated a unique form of mysticism that haunted the scientific aims of the discipline. Electronic audio equipment awakened a dormant spiritualism in many of its practitioners, and these spirits haunted the very matters of music and sound recording. In 1952, for example, two Catholic priests, engaged in the acoustic capture of Gregorian chant, reported that the voice of one of their deceased fathers could be clearly heard on the subsequent recording. The phenomenon they perceived, now classed among "Electronic Voice Phenomena," was the byproduct of the sensitivities of electronic microphone technology, which offered the means to tap into a normally unperceived spiritual realm.[22] Auditory necromancy was a recurrent feature of the world of electroacoustic music recording. Take the case of maverick music producer Joe Meek, who claimed to hear the dead speak through tape recording sessions he held in graveyards; his unhealthy obsession with Buddy Holly culminated in a series of seances, wherein he tried to contact the rock n' roll star, who had been tragically killed in 1959. Dub reggae pioneer Lee Scratch Perry, meanwhile, developed unique rituals to imbue his recordings with spiritual power, blowing smoke on his magnetic tapes in order to recover their fetish-power.[23] In the hand of its lay practitioners, electroacoustic technology, while a rigorous discipline formed by authoritative theoretical and scientific work, never lost its aura of mystery.

The Story of Hollywood Sound

It is the claim of this dissertation that the Hollywood movie industry played a key role in creating the modern recording studio in music recording, fully exploiting the affordances of electroacoustic technology. Hitherto, the importance of movie sound in the history of music recording has gone unrecognized. The methodological error is this: too often, the mechanical phonograph has been posited as the single source and predecessor for any discussion of the history of technologies of sound reproduction, despite the fact that electroacoustic recording methods have had a more substantial impact on the music recordings of our present. Scholarship has so far underestimated the extent to which electronic technology and post-production practices in the movie industry have shaped the way musicians capture sound. In what follows, I demonstrate that the techniques most associated with modern recording – such as cutting and editing different takes, mixing multiple audio sources, and incorporating audio effects – stem from movie production practices originally developed for electroacoustic control.

It is well-known that movie production went through a period of rapid transformation from silent to sound pictures in the late 1920s following the popularity of the 1927 Warner Brothers hit, *The Jazz Singer*. It is equally well-known that music

[22] See Carolyn Abbate, "Sound Object Lessons," *Journal of the American Musicological Society* 69, no. 3 (Fall 2016).
[23] Michael Veal, *Dub: Soundscapes and Shattered Songs in Jamaican Reggae* (Wesleyan University Press, 2013), 160.

recording practices were not subject to such dramatic change. The recording of music up until the late 1950s remained tied to its acoustic foundations, both conceptually and practically. The acoustic foundations of music recording were established, in principle, in the first iteration of the phonograph, as seen in Edison's wax cylinders of 1877. Early phonographs relied on the "natural" acoustic power of a sound source to imprint upon a recording material. The emphasis for engineers of the phonograph was to ensure the effective transfer of acoustic energy onto a permanent record.[24] This process of recording allowed for little control over the sound itself as it was being captured. One might say that phonographic sound, because it was written or cut into a groove, lacked the sonic plasticity that would come to be prized in the transduced Hollywood ideal.

The introduction of electroacoustic principles to the phonograph, as many historians observe, put sound recording onto an entirely different track.[25] After the First World War, as we have seen, the Bell Telephone Company founded a research group headed by J.P. Maxfield that was dedicated to the improvement of sound recording.[26] The work of this research group would coincide with the technological requirements of the sound film in the late 1920s. Because of the prestige of telephonic experience, researchers at the Bell Laboratories were pressured to use their electroacoustic knowledge, not only to improve the phonograph, but also to enhance the sound technology used for the recording and reproduction of movie sound.[27] This latter observation is crucial. The effect of the research undertaken at Bell had a revolutionary impact, not so much on the music industry, as on the film industry. For the music industry, Bell's research produced an electrical recording method and a redesigned phonograph for playing these records. In the movie industry, Bell technicians demonstrated the feasibility of sound films by reproducing sound electrically, in ways that worked for the environmental experience of the theatre. Electroacoustic technology would increasingly become an essential component of the filmmaking process. Never before had sound been so visual.

I want to emphasize that electroacoustic recording technologies introduced a number of changes to movie and music production – but not with equal effect. In music recording practice the electrical recording system was treated as a mere enhancement of existing methods. Until the 1950s music records were, for the most part, simply recordings of a live take. Musicians would perform a selected song in the studio and the microphones would pick up the sound destined to be cut onto a disc in the same way as the large phonograph cone had done before electronic recording arrived on the scene.

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[24] Austin C. Lescarboura, "At the Other End of the Phonograph," *Scientific American* 119, no. 9 (1918): 178.
[25] Michael Chanan, *Repeated Takes: A Short History of Recording and Its Effects on Music* (London; New York: Verso, 1995); Sterne, *The Audible Past*; David Morton, *Sound Recording: The Life Story of a Technology* (JHU Press, 2006); Steve J. Wurtzler, *Electric Sounds: Technological Change and the Rise of Corporate Mass Media*, Film and Culture Series (New York: Columbia University Press, 2007); Greg Milner, *Perfecting Sound Forever: An Aural History of Recorded Music* (New York: Farrar, Straus and Giroux, 2010).
[26] Robert E. McGinn, "Stokowski and the Bell Telephone Laboratories: Collaboration in the Development of High-Fidelity Sound Reproduction," *Technology and Culture* 24, no. 1 (January 1983): 42.
[27] Ibid., 53.

The introduction of electrical recording methods in movie productions, by contrast, was game-changing. Movie sets now had to be designed for sound as well as sight: noisy lights, reverberant stages, and mumbled dialogue became pressing matters of concern for movie producers. The procedures, practices and designs of studios required reconstruction in order to keep up with the audiovisual demands of sound films.

For movie productions the technological changes brought on by sound recording had dramatic aesthetic consequences. For many in the industry at the advent of sound film, it was not clear how audio elements should fit with the moving image. In 1928, for example, the same J.P. Maxfield who worked at Bell Labs gave his own view on the problem of "auditory perspective" for cinema. Maxfield had been invited to the United Artists' set to consult on microphone placement for music recording. He found himself appalled by the movie audio engineers' practice of setting up microphones as close to the actors as possible without being in view of the camera. Maxfield declared that because the camera represented the eyes of the audience, two microphones should be attached to the camera, to act as the ears of the audience. The audio on the resulting footage was a disaster.[28] This anecdote reveals some of the challenges faced by audio engineers on how best to capture and represent sound. Electroacoustic technology had arrived on the movie set, but for movie producers it was not obvious how sonic elements should interact with the events captured on film: the microphone had not been reconciled with the camera.

The phrase "auditory perspective" was a concern peculiar to movie sound, one that generated a large amount of discussion. James Lastra argues that early models for sound reproduction were divided between a "telephonic" model, which privileged intelligibility, and a "phonographic" model, which privileged auditory perspective. Lastra claims that in general, the phonographic model was long considered the better option despite the fact that the telephonic model was more prevalent.[29] Maxfield's attempt to treat the camera as the concrete site of the audience's perspective fits Lastra's claim that the desire for sound reproduction that mimicked the camera's changing perspective was celebrated more in theory than in practice. Ultimately, Lastra argues that a third model arose, one that understood a film's sonic space as a kind of virtual location based on the perspective of an "invisible auditor." By postulating this invisible auditor, sonic elements of a movie could be focused and centered, regardless of the dispersed sonic events captured by a camera. The task was to achieve an auditory perspective that much like the editing techniques used on the images, reflected the shifting attention of an invisible witness.

The idea of movie sound as representing the perspective of an invisible listener underlines the paradoxical relationship of sound to ideas of realism in cinema. Steve Wurtzler explores this paradoxical predicament in his research on radio practices that faced similar audiovisual challenges. Wurtzler contends that two competing frameworks

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[28] Edward Bernds, *Mr. Bernds Goes to Hollywood: My Early Life and Career in Sound Recording at Columbia with Frank Capra and Others* (Scarecrow Press, 1999), 78–79.
[29] James Lastra, "Fidelity Versus Intelligibility," in *The Sound Studies Reader*, ed. Jonathan Sterne (New York: Routledge, 2012), 248–49.

for aural representation arose in radio and movies during the second half of the 1920s in relation to the emergence of electroacoustic sound. He argues that on one side a "transcription model" emerged that envisaged recording as the capturing of a real, live event; and on the other side a "signification" model surfaced that understood recording as a kind of illusion.[30] Of this latter signification model, Wurtzler explains that with the introduction of electroacoustic recording technologies, sound could be manipulated in a variety of ways before being committed to record. Subjected to manipulation, the resulting recording was not so much a reflection of a "real" event, but rather was constructed using a series of effects to make the recording seem real. For the purposes of movie production, it didn't matter if the sound was faithful to the events on a screen, so long as it seemed realistic to the audience. The task was not to ground auditory perspective in any one space, but to ground it in the perceptual space of each listener. Sound, that is, no longer represented the acoustics of a space on the screen or anywhere else. What it represented, when deployed electroacoustically, was a psychoacoustic space in the mind of each viewer.

Wurtzler is clear that his "signification" model is indebted to the technological advances and affordances of electroacoustics. He does not suggest that all sound recordings prior to electronic amplification were exclusively engineered according to a "transcription" model, as there were many acoustic recordings made to "signify" other spaces. Rather, his point is that the values of the "transcription" model comingled with the kinds of control offered by electroacoustic technology. The synchronization of aesthetic aims and technical affordance, for him, is striking. Wurtzler suggests that the driving force behind this transformation in aural representation derived from "the ability of electrical acoustics to signify fidelity to (non)existent events."[31] With the adoption of electroacoustic recording technology, notions of a recording's "faithfulness" became irrelevant. Sound designers for movies exploited this fact, creating sound effects that were not recorded live but reinserted into the film during post-production. The "realism" presented in the movie theater was, in fact, a studio effect.

The most obvious sign of the impact of film-industry standards on the art of twentieth-century sound recording was the proliferation of post-production practices. "Post-production" refers to all the work done to a film after shooting has ended, such as editing, applying visual effects, color correction and rerecording sound. This after-the-fact work had become standard practice in the movie industry after the rise of sound films.[32] The ability to "fix" audio in post-production led to the widespread technique of re-recording a movie's audio elements in more controlled acoustic spaces. One recording manager estimated that by 1931 at least half, if not all, sound films were rerecorded off-

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[30] Wurtzler, *Electric Sounds*, 231.
[31] Ibid., 272.
[32] George Larkin, *Post-Production and the Invisible Revolution of Filmmaking: From the Silent Era to Synchronized Sound* (Routledge, 2018), 2.

site.[33] During the course of post-production, sound could be edited, manipulated and processed through audio effects in ways that revitalized events on the screen. This practice offered another level of detachment from the “live” events being captured by the recording device and the camera. In addition, it allowed for more artistic flexibility, in ways that would allow for the standardization of audio quality, and total audio control.

In the late 1920s then, the movie industry in Hollywood was a hub for innovations in electroacoustic sound, both in its recording techniques and recording philosophies. Music recording had not, for the most part, followed these developments. Conceptually, recorded music was still considered the recording of a performance event, a “transcription,” and not a spectacle produced at the control desk in the studio. Movie productions, on the other hand, afforded opportunities to explore the many different ways in which sound might be manipulated through electronic devices and post-production techniques. It was only by the 1950s that music recording engineers began to borrow these techniques from their movie production counterparts, adopting technologies and recording models embraced by the movie industry wholesale. The post-production studio, therefore, offered a powerful model for music recording studios, in ways that transformed the audio product from a representation of a live event into a sonic reconstruction of that event.

Chapters

Chapter 1 addresses the Capitol Records Tower in Hollywood, completed in 1956, and promoted as the “first purpose-built studio in the world.” I explore the Tower as a locus for historical developments in cybernetics, architecture, electroacoustic recording and urban space in the late 1950s. The Tower was “totally designed,” its studio and office spaces extensively mapped and optimized for maximum efficiency. “Total design” was the guiding principle of head architect, Welton Becket, and the phrase had cybernetic overtones that radiated outwards from the Capitol Tower. The Tower itself was a controlled space, its studios designed to craft music recordings marketed as “high-fidelity.” These records were often presented as sonic landscapes, auditory spaces that claimed to channel the exotic worlds of faraway places into a product that could be played from the comfort of a suburban lounge. While the Tower was still under construction, the city of Los Angeles itself was grappling with issues of total design. Large-scale tract housing, much of which had also been designed by Welton Becket, and the construction of a large freeway system were two places where ideas of total design were shaping urban space at large. Los Angeles itself was simultaneously cast both as a potential utopia for urban design and as a city on the verge of being out of control.

Beginning with the construction of the Tower, I draw out connections between Capitol Studios and the Hollywood movie industry. Although the majority of music labels were based on the East Coast, Capitol Records Inc. was well situated to draw on the

[33] Wurtzler, *Electric Sounds*, 272.

developments of movie audio that had not yet penetrated the music industry. Capitol borrowed studio designs from movie sound stages, and portrayed their product, the music recording, as an object of Hollywood-style fantasy. Many releases from Capitol Records were promoted as a luxurious experience, an unreal performance directly in contrast to earlier commercial representations of music recording as the transcription of a real event. Capitol, like the Hollywood movie industry, promoted the fantastical elements of sound recording. Terms like "high fidelity" and "full dimensional sound" were applied to Capitol's audio products in ways that challenged traditional notions of "fidelity" while capitalizing on the enhanced experience of electroacoustic recordings.

The construction of an ideal recording studio in the Capitol Tower coincided with cybernetic fantasies about the ideal urban space. The blending of controlled spaces and fantasy spaces was especially prevalent in the cities of the Los Angeles basin. More than any other city, Los Angeles came to represent the post-war, Californian update of the American Dream. Spacious suburban homes, filled with a host of appliances designed to make life easier, were all marketed in the various planned communities of Southern California. In this chapter, I show the ways in which Los Angeles presented the very image of a cybernetic city, a system connected by multiple freeways, kept stable by a permanent flow of people and goods. While the Capitol Tower studios were situated in a newly conceived city, the city itself was increasingly imagined according to the underlying principles of studio control and communication.

Chapter 2 is a study of the "audio mixer" or "mixing board," which became a central feature of such modern recording studios such as the ones built inside the Capitol Records Tower. The audio mixer was designed as a centralized space for controlling and manipulating sound. Through an in-depth exploration of three historical roots of the mixing board, I trace the ways in which this interface promoted "modern" ways of conceptualizing and approaching sound. Emily Thompson has argued that a "modern sound" emerged in the wake of the introduction of electroacoustic technologies like radio and telephone.[34] She suggests that this sound was characterized by an absence of natural reverb, a telephonic sound that privileged intelligibility over "naturalness." Advancing her important argument, I claim that the mixing console – functioning at the center of the recording studio – was the definitive site of "modern sound." The mixer was designed to control different aspects of an audio wave independently, transforming the way in which its practitioners could shape and interact with sound.

I explore three genealogies, each of which can be said to lead to the "modern" mixing board. The first genealogy follows the development of Public Address Systems. P.A. Systems were technologies requiring that multiple audio channels be brought together and then directed to various loudspeakers. Mixing consoles for P.A. systems

[34] Emily Ann Thompson, *The Soundscape of Modernity: Architectural Acoustics and the Culture of Listening in America, 1900-1933* (MIT Press, 2004), 233.

were designed to provide clear, loud sound and many engineers argued that they should exist as an invisible technology, a transparent conduit for extending the voice. My second genealogy explores the construction of "Dramatic Control Panels" for radio. These units were specifically designed for aesthetic purposes, making use of electroacoustic effects for the construction of fantasy audio spaces. In this genealogy the Dramatic Control Panel is shown to function as a techno-aesthetic tool in ways similar to the mid-century mixing board. The mixing device takes on both technical and aesthetic importance as a tool for environmental design. Finally, a third genealogy traces the role of mixing and the mixing console in movie production. The unique attributes of the movie experience encouraged a highly developed form of mixing. Post-production practices and the carefully designed acoustic space of the movie theatre both informed new ways of constructing auditory experience and mixing sound.

Chapter 3 approaches the mixing board from a neurological perspective. I argue that the mixer was designed to model the perceptual space of an average listener. "Auditory space" is an elusive and yet recurring idea in the history of sound. While auditory space is something the listener creates in their mind it is triggered by physical, external stimuli. Sound can be perceived as possessing spatial qualities, and this particular facet has been manipulated by technologies like the mixing board. I ground a perceptual/spatial approach to the mixing board in the work of experimental psychologist Donald Broadbent and his 1958 book *Perception and Communication*. Broadbent work was infused with cybernetic theories; and in this study he conceived of the brain as a kind of communications system, replete with channels and filters. While engineers regarded the mixing console as the "brain" of the recording studio, psychologists such as Broadbent portrayed the brain itself as a neurological mixing board.

The mixing board affords two main ways to manipulate sound, both of which are built into its interface: equalization and faders. Equalization (EQ), refers to electronic filters that manipulate the frequency characteristics of an electrical wave. In sonic terms this tool can be used to change the bass sound or treble notes. The deeper history of EQ stems from experiments on human perception made throughout the nineteenth century. Researchers conducted experiments to ascertain the limits of the human perception of frequency. In the search for frequency limits numerous technologies were developed to create and measure frequency, from whistles and tuning forks to electronic oscillators and microphones. In each development, scientists sought greater levels of exactitude, as general musical terms were replaced with scientific units of measurement that could be compared across different domains. With the growth of the telephone network, audio frequency was bound to electronic devices constructed to analyze the efficiency of the telephone system. Telephonic understandings of frequency reconceived the idea of "frequency limits." Telephone engineers were motivated to discover the frequency limits of intelligibility in speech, shifting the focus of frequency studies towards a communications model.

The fader also has its roots in nineteenth-century experimentation. The fader controls the amplitude of a signal, which correlates, to a large degree, to the perception of loudness. Unlike frequency, loudness was a difficult phenomenon for researchers to grasp, and there were few methods of accurately measuring the magnitude of a sound. Loudness was studied on a perceptual basis and was intrinsically understood as a relative value. The psycho-physician, Gustav Fechner, conducted a series of experiments prior to the publication of his *Elements of Psychophysics* (1860) to ascertain the gradients of loudness as they were perceived by a test subject. Fechner measured the perceived difference between the magnitude of one sound and another. From this work he developed a logarithmic scale that predicted how loudness was perceived. This scale later became the basis for the decibel system, as conceived by Bell Telephones. The fader and the equalizer were, therefore, modelled on the perceptual characteristics of human hearing. As such, the mixing board functions not only as an instrument to bring sounds together but also as a way to program the sonic reality of human perception.

In Chapter 4 I isolate a single case study that bears out my central claim that modern sound belongs, in the end, to Hollywood. Here, I follow the Trautonium from its beginnings as a new electronic instrument in Berlin to its role as a synthesizer in *The Birds* (1963), a movie from the director Alfred Hitchcock, shot in California. The discourse surrounding the Trautonium brings together the themes of "high fidelity," control, fantasy and environmental engineering present in the previous chapters. In *The Birds*, the Trautonium was called upon to create the sound of the eponymous animals, and Hitchcock's use of sound in the movie was foundational to the subsequent history of sound design in film.[35] The Trautonium was adept at creating sounds on the border of musical underscoring and audio effect, blurring the distinction between these two sonic practices. Like the challenge of "high fidelity" to phonographic fidelity, the synthesizing capacity of the Trautonium challenged notions of sonic representation on the screen.

I begin by situating the instrument in the burgeoning electronic music scene of Berlin, where its inventor, Friedrich Trautwein, drew upon technical developments in electronic sound synthesis as well as psychological and phonetic research from his native Germany. In a familiar pattern, research into the perception and creation of timbre directly informed electronic instruments designed to control these particular facets of sound. The development of the Trautonium in the second half of the 1920s brought together numerous debates and ideas surrounding new instruments for sound and conceptions of timbre. However, in the hands of Trautwein's protégé, Oskar Sala, the instrument abandoned its roots in the music conservatoire to take up residence in the world of movies. The Trautonium was reconceived less as a research tool devoted to the creation of new sounds and timbres than as an instrument useful to achieving absolute control over sound. In *The Birds* the Trautonium is revealed as the instrument of

[35] Richard Allen, "The Sound of 'The Birds,'" *October* 146 (2013): 98.

centralized auditory control, much like the mixing board of Chapter 2. The synthesizer, in this narrative becomes the sonic equivalent of the auteur's vision in film.

My history of the Trautonium is an audiovisual history. It focuses on the deep connections existing between technologies of sound and light in the period of my study. The Trautonium's most defining sonic characteristics stemmed from the neon tubes that were used as sound generators within it. Neon tubes were cheaper alternatives to vacuum tubes, and German manufacturers were especially interested in this technology. Unlike vacuum tubes, which produce clean, sine wave tones in audio circuits, the neon tube produced a "saw tooth" waveform and a rich sound imbued with overtones. I connect the neon technology embedded in early versions of the Trautonium to developments in neon lighting in Germany. Neon lighting became popular in Weimar Berlin, and was later appropriated by the Nazi Party in the cause of dazzling visual propaganda. Both the Trautonium and neon lighting were bound up with the audiovisual spectacle of Nazi power in the 1930s. The cinematic philosophy and technological preoccupations of the Nazi regime are, I argue, uncanny portents of California's post-war movie industry, in which themes of total control and environmental engineering reappear.

Chapter 1

The Capitol Records Tower: Total Design in the Recording Studio

Figure 1.1: Capitol Records Tower. Image from Chris Nichols, ed., *Built by Becket* (2003), 27.

<u>A Hollywood Tower</u>

In 1956 the world's first circular office building was completed near the corners of Vine Street and Hollywood Boulevard, the recording studio and company headquarters for Capitol Records. For contemporaneous observers, the Capitol Records Tower (Figure 1.1) resembled a "monstrous stack of records" an image irresistible to mid-century writers already fascinated by the numerous Los Angeles establishments designed to look like their products, such as the hat shaped Brown Derby restaurant and the Hoot Hoot I Scream's owl façade.[1] *Down Beat* magazine poked fun at the building's resemblance to a science fiction set when reporting on the opening of the tower:

> The latest story concerning the circular Capitol Records tower here has to do with two Martians who landed their space ship in the parking lot adjacent to the building. "You go look around it, and I'll wait here for you," said one of them. Carefully the second Martian approached the tower, then made the

[1] Bob Thomas, "L.A.'s Circular Building," *Los Angeles Evening Herald Express*, January 12, 1956, 250 edition, sec. C., Reyner Banham, *Los Angeles: The Architecture of Four Ecologies* (Norwich: Penguin Books, 1973), 112.

> complete circle around it. With a relieved look, he returned to his friend and said, "They'll never get it off the ground!"[2]

The Capitol Records Tower, that is, was seen to exhibit fantasy elements of the sound stages and movie studios of Hollywood.[3]

Capitol Records arose amidst the glamour and fantasy of the film industry. The grand opening of the tower was conducted like a movie premiere. The *Los Angeles Times* reported:

> Giant searchlights stabbed the sky as top recording stars and film personalities arrived.… The ceremony began when Miss Leila Morse of 1725 Whitley Ave., granddaughter of Samuel Morse, inventor of the telegraph, punched a telegraph key which lighted a red beacon atop a 92-foot spire on the building. The beacon spelled out Hollywood in the international Morse code.[4]

The historic legitimacy of electronic communications provided by Morse's granddaughter, the publicity garnered by a procession of celebrities: all of this bore witness to a grand Hollywood-style opening that provided the ultimate showcase for electroacoustic technology.

Yet downtown Hollywood during the 1950s was not an obvious choice for a record company's headquarters. Hollywood was not a commercial hub or a large city. The Capitol Tower itself was built on a former parking lot. Founded in 1942, Capitol Records had begun as a small West Coast operation at a time when the film industry was dominated by East-Coast firms. The "big three" recording companies of the 1940s were Columbia, RCA Victor and Decca, all labels primarily based in New York City.[5] Two years before the founding of Capitol Records, in 1940, for every three records sold, two were issued by RCA and Decca.[6] By 1945, Capitol, MGM and Mercury formed the second tier of U.S. recording companies challenging the dominance of the New York labels. These three companies gained ground on the major labels despite the fact that numerous obstacles were presented to the music recording industry.

The first challenge for record labels arose two months after the founding of Capitol Records. The American Federation of Musicians instigated a nationwide recording ban in

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[2] "It Might Roll," *Down Beat*, May 2, 1957, 35.

[3] In fact, all of Hollywood was being imagined as a film set. During the Tower's construction, leading members of the movie industry finalized their own proposal to inlay physical tokens of their star power within the sidewalk of Hollywood Boulevard.

[4] "Capitol Records Opens Building a La Premiere," *Los Angeles Times*, April 7, 1956, 21.

[5] Peter Martland, *Since Records Began: EMI, the First 100 Years* (Batsford, 1997), 158. Janet Sturman, *The SAGE International Encyclopedia of Music and Culture* (SAGE Publications, 2019), 1513.

[6] Ray Eldon Hiebert, Donald F. Ungurait, and Thomas W. Bohn, *Mass Media: An Introduction to Modern Communication* (Longman, 1979), 317.

response to the loss of musician jobs from emerging sound technologies.[7] The strike highlighted the growing concern amongst musicians about the changes wrought by technologies like radio and sound recording. This was a complex situation for musicians. Whilst they earned money for recording sessions, these recordings contributed to a decline in live gigs. "Unlike other striking workers demanding higher wages, better working conditions, and greater control of the workplace," James P. Kraft writes, "the striking musicians said simply that they would make no more of the instruments of their own displacement."[8] The strike culminated in the union announcing a ban on recordings, one that prevented members from participating in recording sessions. It forced record labels to mine their archives for unreleased master records or settle with the union by providing royalty fees.

Another challenge revolved around an important material in the production of 78-rpm records: shellac. Shellac is the resin of the lac beetle and was mainly harvested in India under terrible working conditions, a material extracted at great ecological and human cost.[9] At around the time Capitol Records was up and running, the Allies faced severe shortages of shellac, as trade routes were disrupted by the advances of the Japanese army.[10] That Capitol Records was able to continue record production at all during this time has become the subject of controversy, most involving co-founder Glenn Wallichs' uncanny ability to source shellac from unlikely places. Wallichs was a record store salesman who owned an archive of old records that could be melted down to make new ones. One story claimed that during a meeting with a shellac distributor, Wallichs discovered that the distributor's son had recording ambitions, prompting Wallichs to sign the youngster to Capitol in order to get a deal on the precious material.[11]

For Capitol Records the Tower was a monument to unlikely success, its circular shape symbolizing the company's progressive approach to the music business. According to one newspaper report, Wallichs desired "a modern building which would reflect the spirit and vision of the company."[12] The eye-catching design of the tower represented the record company's forward-thinking approach to the music industry, the building itself being testament to Capitol's establishment as a major label in the 1950s. Perhaps because of their smaller size and the difficulties they faced from the music industry at the time, Capitol Records had been willing to pioneer new strategies to stay afloat. Capitol used the 1942 recording ban to gain a monopoly on pre-recorded material and promoted their records by proactively sending them to radio stations to be played on air. The company

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[7] Paul Grein, *Capitol Records: Fiftieth Anniversary, 1942-1992*, Limited ed (Hollywood, Calif: Capitol Records, 1992), 11.
[8] James P. Kraft, *Stage to Studio: Musicians and the Sound Revolution, 1890-1950*, Studies in Industry and Society 9 (Baltimore: Johns Hopkins University Press, 1996), 137.
[9] Kyle Devine, "Musicology Without Music," in *On Popular Music and Its Unruly Entanglements* (Springer Nature, 2019), 29; Kyle Devine, *Decomposed: The Political Ecology of Music* (MIT Press, 2019), 55.
[10] Richard Osborne, *Vinyl: A History of the Analogue Record* (Routledge, 2016), 67.
[11] Philip Furia, *Skylark: The Life and Times of Johnny Mercer* (Macmillan, 2004), 137.
[12] "Unique Building Rises On Hollywood Site," *Los Angeles Times*, December 4, 1955, 145.

was also the first to adopt magnetic tape in the recording process in 1948.[13]

Capitol chose an architectural firm with a comparable story to its own and a similar progressive outlook to design their new studio headquarters. Welton Becket and Associates were a brand-new architectural firm based in Los Angeles that took a modern approach to building design. Becket arrived in Los Angeles in 1933 forming his first company in a partnership with Walter Wurdeman and Charles Plummer. Wurdeman and Becket's iconic "Streamline Moderne" format for the Pan-Pacific Auditorium, built in 1935, established the reputations of two architects who had made a living during the Depression years designing commercial structures.[14] After the deaths of both his partners Becket continued as Welton Becket and Associates in 1949, centralizing his architectural practice around his own vision, employing associates to carry out big projects rather than enfranchising partners.[15] By creating a firm with associates, Becket maintained full control over his practice. His corporate model meant that his business structure was more aligned with the larger companies who were contracting him.

Becket enjoyed many of the same connections to Hollywood and the movie industry as Capitol Records. After his first major commission designing the Pan-Pacific Auditorium, Becket found work designing homes for Hollywood stars in a variety of architectural styles. He was always willing to accommodate his work to the vision of his clients.[16] Becket lived in Hollywood himself; his neighbors included Bing Crosby and Judy Garland.[17] He was also good friends with Walt Disney, advising Disney on his plans for his 1955 theme park, Disneyland. Becket convinced Disney that no architectural firm would be able to design Disneyland for him, advice that persuaded Disney to use his movie set designers in the construction of the park.[18] One of Becket's most visible contributions to the Hollywood movie industry was his design for the 1963 Cinerama Dome on Sunset Boulevard, "the only concrete geodesic dome in the world," originally intended as a prototype theatre for the Cinerama system, an early widescreen technique premiered in 1952.[19]

Welton Becket and Associates conceived of the Capitol Tower with the special effects and engineering of their Hollywood aesthetic. For the design of the tower, Welton Becket created a floating effect by "pinching in" the lower floors.[20] The first couple of circular levels were made smaller in diameter than the higher levels so that from the third floor upwards it appeared as though the building was suspended above Hollywood, an illusory effect that made the concrete structure seem organic. Integral to the building's

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[13] Grein, *Capitol Records*, 21.
[14] Chris Nichols, ed., *Built By Becket*, 2003, 5.
[15] Robert Cahn, "The Man Who Changes Sky Lines," *The Saturday Evening Post*, November 22, 1958, 96.
[16] Annabel Jane Wharton, *Building the Cold War: Hilton International Hotels and Modern Architecture* (University of Chicago Press, 2001), 52.
[17] Cahn, "The Man Who Changes Sky Lines," 96.
[18] Bob Thomas, *The Walt Disney Biography* (New English Library/Times Mirror, 1977), 194.
[19] Nichols, *Built By Becket*, 38.
[20] "Unique Building Rises On Hollywood Site," 145.

design were systems of environmental control. It was one of the first office structures in Los Angles to incorporate air conditioning and its distinctive exterior contained adjustable sun shades that cooled the building.[21] The Capitol Tower was born out of an image-conscious architecture that seemed to project a movie-style aesthetic in keeping with its location but it also contained all the affordances of modern environmental technology.[22]

Welton Becket and Capitol Records were companies at the center of a new post-war lifestyle. The latter had grown as a record label in the years following the war, promoting "high-fidelity" records for a newly affluent middle class that had the means to buy them and the technology to play them. On the other hand, Welton Becket and Associates created the model for the kinds of homes for which Capitol was making records. One of the firm's earlier projects had been the influential "Post-War house" in 1946, or "house of tomorrow" as it was renamed in 1951, which came equipped with a, "built-in radio system and a multitude of all-electric appliances (disposal, blender, dishwasher, washer/dryer, home freezer)."[23] This model was subsequently used as the basis for tract housing in Panorama City in 1948, the first planned community built in the San Fernando Valley.[24] New standards for American living were being formed around developments within Los Angeles County and Welton Becket's future-oriented architecture was symptomatic of the systems thinking embedded in U.S. culture that had taken root during wartime.[25]

In their buildings and sound recordings, Capitol Records and Welton Becket sold a quality of life associated with the modernity of post-war California. If their West Coast roots seemed a disadvantage in a predominantly East Coast music industry, their location also gave them a unique selling point. Capitol drew upon the sound innovations of the Hollywood movie industry in their recording practices, producing slick, high-fidelity recordings highlighted by their early releases of "exotica" albums. Whilst exotica records were often advertised as capturing the sounds of forgotten islands of the Pacific, they also drew on a long history of exoticizing California itself within the United States. Exotica records simultaneously pointed to the past allure of California and the present state of its studio culture in the mid-century. The idea was that the listener of these records would be transported to a Californian fantasy through the speakers of their at-home high-fidelity sound system.

My argument, so far, is that the Capitol Tower exemplified post-war, Californian

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[21] Alan Hess, "The Record Company Headquarters That Revived 1950s Hollywood with Iconic Architecture," ArchDaily, January 28, 2017, https://www.archdaily.com/804265/the-record-company-headquarters-that-revived-1950s-hollywood-with-iconic-architecture.
[22] Reyner Banham, *The Architecture of the Well-Tempered Environment* (Elsevier, 2013).
[23] Barbara Miller Lane, *Houses for a New World: Builders and Buyers in American Suburbs, 1945–1965* (Princeton University Press, 2015), 41.
[24] Nichols, *Built By Becket*, 6.
[25] Andrew Michael Shanken, *194X: Architecture, Planning, and Consumer Culture on the American Home Front* (Minneapolis, MN: University of Minnesota Press, 2009).

values. Welton Becket was influential in shaping the construction growth in Los Angeles through his numerous projects, embodying a modern Californian architecture. His West Coast design aesthetic was exported beyond the Golden State, one newspaper article noting that "Becket tries to inject into most of his buildings, even those in the East and Midwest, the spaciousness, bright colors, casualness and warmth that have become associated with California-type living."[26] Welton Becket and Associates were, much like Capitol Records, selling more than just their central product. "California living" had become a kind of signifier for the aspirational dreams of post-war America. Becket providing its four air-conditioned walls and Capitol Records giving it a high-fidelity soundtrack.

In what follows, I situate the Capitol Records Tower within the histories of cybernetics and electroacoustics. I explore how cybernetic ideas shaped Capitol Record's operations as well as the construction of their flagship studio. I then unpack some of the ideas surrounding the term "high fidelity" and how this term complicated notions of auditory "fidelity" that had been established with Edison's acoustic phonograph. I argue that the phonographic "high fidelity" championed by Capitol Records was a departure from the idea of music recordings as faithful representations of a musical event. Rather, "high-fidelity" recordings presented a paradoxical relationship to auditory realism, simultaneously promoted for their life-like sound whilst also lauded for their ability to conjure fantasy environments that went far beyond reality. "High fidelity" could be better understood as "perceptual saturation," a fidelity not tied to the experience of a musical performance but to the ability of a sound system to "fill" the space of human perception. I trace some of the origins of this new form of fidelity in the "Fantasound" recording system, developed for Disney's 1940 movie *Fantasia*, and in experiments by electronic engineers who conducted auditory tests to establish the need for "high-fidelity" music recordings. Finally, I connect the cybernetic ideas that informed the modern recording studio to notions of the ideal modern city in the 1960s. I view the Capitol Tower as representative of urban theorists' vision for the city of Los Angeles, both places seen as attempts to achieve total spatial control.

<u>Cybernetic Management Systems</u>

Capitol and Welton Becket were both influenced by the emergence and proliferation of "cybernetics" and "systems theory" in mid-century America. The term cybernetics was coined by the scientist and mathematician Norbert Wiener in his 1948 book, *Cybernetics: Or Control and Communication in the Animal and the Machine.* Wiener saw in control systems a defining metaphor for thinking about a diverse set of problems. His central theses were that "the problems of control engineering and of communications engineering were inseparable," that a system's effectiveness was governed by control and

[26] Cahn, "The Man Who Changes Sky Lines," 96.

communication, and that there could be no control without communication and no communication without control.[27] For Wiener, every "system" involved both humans and machines, though the principles of communication and control were not based on the division of human from non-human. His project was structural: to ascertain the principles by which animals and machines were all connected within a total system.

Wiener's book was a surprise best seller, bringing the concepts of feedback, systems, and information into the public sphere. By the end of the 1960s the principles of cybernetics had influenced numerous fields, ranging from Marshall McLuhan's visions of media "nervous systems" to the more unwelcome similarities of Scientology's method for healing trauma, "dianetics."[28] Nor were companies and manufacturers immune to cybernetic influence, as managers drew upon the language of cybernetics to describe and analyze the internal workings of their business. In the inaugural issue of *Administrative Science Quarterly*, Edward Litchfield drew on cybernetic theory when he wrote that the 1950s had "seen the introduction, or the first major unfolding, of operations research, game theory, cybernetics, and communication theory." He continued:

> These are contributions of far-reaching consequence, for they have not only added factual data which help in our understanding of administration, but they have also provided a conceptual depth which is urgently needed. When fully absorbed and accepted in our thinking, the new materials will greatly assist administration's effort to achieve scientific stature.[29]

Litchfield's analysis of the state of administrative theory betrays that throughout the mid-century a cybernetic understanding of control and organization came to dominate academic research, industrial practice, and the popular imagination. Cybernetics promised a scientific approach to fields that had previously been considered beyond scientific reasoning.

Influenced by the core values of cybernetics, researchers and writers of this period tended to view issues of administration and engineering as one and the same. In the 1957 textbook *System Engineering: An Introduction to the Design of Large-scale Systems*, for example, the author underlined the connection that "management has a design and operation function, as does engineering."[30] Many writers drew parallels between engineers working with complex systems and company managers operating with corporate structures. Publications like Ludwig von Bertalanffy's 1955 essay, "General System Theory," broadened the scope of systems thinking, creating a universal

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[27] Norbert Wiener, *Cybernetics: Or, Control and Communication in the Animaland the Machine* (Cambridge, Mass: Technology Press, 1948), 15–16.
[28] Kline, *The Cybernetics Moment*, 170. Ibid., 92.
[29] Edward H. Litchfield, "Notes on a General Theory of Administration," *Administrative Science Quarterly* 1, no. 1 (1956): 4, https://doi.org/10.2307/2390838.
[30] Harry Herbert Goode, *System Engineering; an Introduction to the Design of Large-Scale Systems* (New York: McGraw-Hill Book Company, Inc., 1957), 514, http://hdl.handle.net/2027/uc1.b4132167.

methodology for thinking through problems of organization. In these scenarios, the problems of the engineer became the problems of management. Both problems were engaged at a fundamental level in systems of control and communication.

The application of system theory to issues of corporate management evinced an emerging obsession with organization and structure. Managers applied control engineering logic to their work, becoming particularly interested in planning and prediction in their respective industries. The prevalence of such concepts as "human engineering," which described the fusion of engineer and manager, worked to evaluate the human workforce as an input-output mechanism much like the machines that they were working with. [31] The planning and design of how employees interacted with a system, whether it was a company or a manufacturing plant, brought issues of organization to the forefront of management techniques. In the preface to Ernest Dale's 1952 work, *Planning and Developing the Company Organization Structure*, Lawrence Appley, president of the American Management Association, wrote:

> The application of systematic methods to the conduct of business is one of the most striking developments of the present day. The successful pursuit of business activities is increasingly based on carefully developed plans and well-ordered arrangements. The body of knowledge, called Organization, has become increasingly helpful in accomplishing the objectives of the enterprise.[32]

For businesses that saw themselves as large systems, "organization" was the guarantor of effectiveness. In the corporate world, organization became arguably the most defining ethical value inherited from cybernetic thought.

In 1957, the American Management Association published papers from a Manufacturing Conference in Chicago where Capitol Records had been invited to give a presentation. These papers, which publicized company principles for the operation of their business, betray the extent and influence of cybernetic thinking. The research showed that previous growth at Capitol had been haphazard, based as it was on only a few products becoming best-sellers. Moving forward, the company expressed its intention to apply more rigorous scientific methods to their business strategy. Vice President, James W. Bayless explained:

> Accurate production scheduling is the fruit of cultivated forecasting, planning, and control techniques. A complex process, it can be simplified only through the adoption of systematic, standard procedures. The keys to

[31] Ibid., 481.

[32] Lawrence A. Appley, "Preface," in *Planning and Developing the Company Organization Structure*, by Ernest Dale (New York, NY: American Management Association, 1952), 5, http://hdl.handle.net/2027/uc1.b4415321.

> success are good company-wide communications and effective planning at every level of operations.[33]

For Bayless, Capitol Records was perceived to operate as a kind of cybernetic system, prioritizing communication and control. In the concluding paper of their presentation, Capitol executives attributed the practical elimination of service complaints to the implementation of their system of operations.[34]

Another managerial insight was that the record label's success was necessarily and directly related to their ability to predict the sales of their music product. The company was aware of the difficulty in predicting the success of a "single" record and had high hopes for the introduction of the long playing, micro-groove record in the early 1950s. Executives believed that the album format was the future of their business, since sales could be better simulated in ways that were a major advantage for their system of production. Capitol's Market Research Manager wrote in 1957 "we believe that the expansion of the high-fidelity music market is beginning to give us a more stable foundation on which to base our long-range forecasting."[35] It was not so much the better quality of the records that was at stake. Rather, it was the stabilizing effect of high-fidelity albums on their ability to predict sales. With a more stable product, predictions would be more accurate, allowing for better planning and design.

Like these executives, Welton Becket and Associates, applied a "systems" approach in their practice. The fantastical exterior of the Capitol Tower notwithstanding, its design exhibited all the rationalist traits of cybernetic theory. The Tower was based on the design of a young employee at Welton Becket, Lou Naidorf. Naidorf was a class of 1950 graduate in UC Berkeley's Master's Program in Architecture, his dissertation having explored the efficiency benefits of a circular structure.[36] Naidorf arrived at Berkeley in the first year of a new dean of the architecture school, William Wurster. Wurster would go on to reorganize the Beaux Arts school to form the UC Berkeley College of Environmental Design nine years later, and so Naidorf began his training in the midst of a poignant shift in architectural practice. Press releases from Capitol Records and Welton Becket and Associates extolled Naidorf's ergonomic structure, downplaying the fantastical elements of a circular building, and preferring to emphasize their impressive technical achievements. Floor plans were designed to minimize the number of steps between office spaces. Whereas service areas took up 20% of any rectangular building, the Capitol

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[33] James W. Bayless, "Operations and Organization," in *Case Studies in Production Forecasting, Planning, and Control*, Manufacturing Series 223 (New York, NY: American Management Association, 1957), 9.

[34] Thomas J. Davis, "Immediate Planning: Production Scheduling and Control," in *Case Studies in Production Forecasting, Planning, and Control*, Manufacturing Series 223 (New York, NY: American Management Association, 1957), 31.

[35] Arthur D. Duncan, "Long-Range Sales Forecasts," in *Case Studies in Production Forecasting, Planning, and Control*, Manufacturing Series 223 (New York, NY: American Management Association, 1957), 11.

[36] Grein, *Capitol Records*.

Towers cylindrical shape reduced "wasted space" to 14%.[37] This kind of statement drew on the history of corporate architecture in the United States where architects such as Albert Kahn tackled the design of factories in Detroit during the first half of the Twentieth Century.

The meticulous attention to every possible detail of design in the Capitol Tower was typical of Welton Becket's way of working. His architectural firm developed a principle called "total design," where every aspect of a construction project could be planned in-house. In his overview of Welton Becket and Associates, William Dudley Hunt offered an extended definition of total design:

> The phrase connotes both architectural philosophy and practice that embrace all of the services required to analyze any architectural problem, perform the necessary studies and research to solve the problem, and translate the solution into a building or group of buildings complete down to the last detail of furniture, sculpture and other art, landscaping, and furnishings, even to ashtrays, menus, and matchboxes.[38]

The philosophy of "total design" incorporated many of the values of cybernetic ideology at Capitol Records. Welton Becket and Associates treated construction projects like a complex system of interlinked components. The firm was noted for its forward-thinking approach to corporate structure, recognizing that buildings of the future would become increasingly larger and complicated, reflecting the complex organizations that were commissioning them.[39] The utopian overtones of total design and its aim of finding a solution to every problem highlights how Welton Becket and Associates "created not just buildings but also a whole new way of life."[40] This way of life was rooted in cybernetic ideas, as we have seen, ones that became synonymous with the ideal mid-century lifestyle.

The Capitol Records Tower, in other words, brought together the fantasy aesthetics of Hollywood and the hyper-rational systems approach of cybernetics. Reyner Banham described one form of Los Angeles style as "Fantastic Architecture," highlighting that "Los Angeles has seen in this century the greatest concentration of fantasy-production, as an industry and as an institution, in the history of Western man."[41] For Banham the Hollywood movie industry brought "technical skill and resources in converting fantastic ideas into physical realities," and therefore, "the movies were thus a

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[37] "Hollywood's Record Tower," *Pacific Telephone Magazine*, 1956, 24.
[38] William Dudley Hunt, *Total Design; Architecture of Welton Becket and Associates* (New York: McGraw-Hill, 1971), 4.
[39] Muriel Emanuel, *Contemporary Architects* (Springer, 2016), 82.
[40] Mark Shiel, "Daniel Bell, Post-Industrial Society, and Los Angeles Cinema circa 1967-72," in *The City in American Cinema: Film and Postindustrial Culture* (Bloomsbury Publishing, 2019), 55.
[41] Banham, *Los Angeles*, 124.

peerless school for building fantasy as fact."[42] The Capitol Tower blurred reality and fantasy, manifesting an over-the-top statement of West Coast music recording establishing itself in a style familiar to Hollywood.

Figure 1.2: Capitol Records Logo.

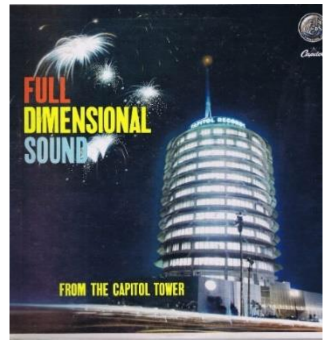

Figure 1.3: Album artwork for *Full Dimensional Sound from the Capitol Tower* 1957.

Capitol Record's original logo used a silhouette of the Capitol Building in Washington D.C. with the addition of four stars, symbolic of a military badge (Figure 1.2). This image was meant to cement the site as "the sound capitol of the world" in the mind of its audience, aligning it with the political power of the State and the entertainment capital of Hollywood. With the Tower's construction, in 1957, this promotional slogan was now linked to a silhouette of the tower itself. The company, in fact, marked the introduction of stereo recordings in the same year by the release of an album titled, *Full Dimensional Sound from the Capitol Tower* (Figure 1.3). By the 1950s, the political reference of the Capitol Building in the logo was no longer as powerful a signifier, since the tower itself had become synonymous with a power of its own making. "Full dimensional sound" radiated outwards in all directions from the central hub, powering the network surrounding it. The Tower was a paradigmatic emblem of media power.

Fantasy Sounds

Where the fantastical exterior of the building succeeded in showcasing a modern approach to the recording industry, inside the Tower, Capitol Record's West Coast studios were widely acknowledged as the most state-of-the-art recording facilities built in history. These interiors, situated on the ground floor of the Capitol were the first to be designed specifically for the recording of sound.[43] Earlier recording studios had always been refashioned from preexisting structures. Famous studios of the 1930s and 40s had all been modified. Liederkranz Hall in New York, for example, had been the home of a German singing society, while the Abbey Road Studios in London operated within a

[42] Ibid., 124–25.
[43] M.T. Putnam, "A Thirty-Five Year History and Evolution of the Recording Studio," in *Proceedings of the 66th Audio Engineering Society Convention* (Los Angeles, CA: Preprint 1661, 1980), 6.

residential building.[44] Capitol set a precedent. Its purpose-built studio was shaped by the changes in sound technologies and recording techniques that had been slowly introduced to the craft of record production.

The Capitol Tower studios manifested a continuation of the close relationship between the record label and the movie industry, as observed in the architectural construction of the tower. The studios were designed in view of electroacoustic technologies developed for movie productions since the late 1920s. The revolution of the "talking movie" in film production had brought the principles of electroacoustics, and engineers trained in it, to Hollywood. With the introduction of sound recording to the filmmaking process, studio sets began to be designed with acoustic properties as the primary consideration. Similarly, a whole new work force was added to production teams who had previously only been concerned with the visual components of the movie.

The transition from silent to talking movies created overwhelming demand for technicians trained in electroacoustic technologies. At the end of the 1920s, these electroacoustic technologies were primarily associated with radio and the telephone. In a 1930 review for *Projection Engineering* journal, one writer commented on a new talking motion picture course offered by the Radio Corporation of America's (RCA) institutes, writing: "since the talking motion picture uses radio technique to such a large extent, it was thought only natural that those in whose hands the teaching of radio has been raised to an exceedingly high standard should also undertake to teach talking motion picture technique.[45] Many other motion picture handbooks hastily added columns devoted to sound recording, drawing from the research publications of Bell Telephones and radio broadcasting. James R. Cameron's 1929 textbook, *Motion Pictures with Sound*, was representative of the flurry of interest in basic sound theory offering several chapters on the newest aspect of filmmaking.

The movie industry's approach to sound recording revolutionized the process that had been utilized in recorded music. Whilst the phonograph and movies were both technologies of sound, and have often been grouped together in studies of media, their technical roots are very different. The phonograph was designed as a mechanical instrument, using acoustic power to drive a disc cutter that engraved soundwaves onto a disc or cylinder. In movie productions, sound was captured in a contrasting way, drawing on techniques from telephone research, where transducers like microphones and loudspeakers converted sound waves into electrical waves and vice versa. Movie sound began as an electroacoustic process, whilst music recording began as a mechanical process that would gradually incorporate electroacoustic technologies.

Notwithstanding such early and short-lived experiments using disc recordings as Western Electric's Vitaphone system, most movie productions adopted a method that

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[44] Susan Schmidt Horning, *Chasing Sound: Technology, Culture, and the Art of Studio Recording from Edison to the LP* (JHU Press, 2013), 87. Alistair Lawrence, *Abbey Road: The Best Studio in the World* (A&C Black, 2012), 288.

[45] "Learning the Science of Sound on the Silver Screen," *Projection Engineering* 2, no. 9 (September 1930): 20.

recorded sound onto the same film as the moving image. Sound recording for music industries, on the other hand, relied upon such more permanent recording materials as Edison's wax cylinder and Berliner's shellac disc. The material difference of the recording medium itself points to some of the contrasting ways in which sound recording was understood and treated by rival industries. In movie production, sound was conceived as part of a wider electroacoustic system that converted sound into electricity and ultimately into light when it was exposed onto the film strip. In music recording, sound was engraved onto a more permanent object not so easily edited or manipulated. The production of music records was made possible by artisanship and mechanical know-how; early recordists had a limited ability to alter the quality of sound, whereas film engineers pursued sonic plasticity.[46]

From its inception, movie sound recording was a fundamentally electroacoustic process. Sound was treated as an effect rather than a performance. If the focus for engineers of music recording had been to capture sound in its "purest" form, the focus for developers of movie sound was to entertain. Untethered from the responsibility of reproducing a live event, sound engineers in the movie industry invented novel ways to affect the sound that was imprinted on the film. Film historian Lea Jacobs has written about the role of re-recording in movie production from 1932 onwards. "As the quality of photographic recording and reproduction improved," Jacobs writes, "it became obvious that many alterations could be made in the level and quality of original dialogue."[47] With sound recorded onto film, not only did the media format lend itself to the kind of editing already prevalent in cinematography, but the sound it contained could be altered after the initial recording. To engage with sound through the electroacoustic system was to treat, know, and process sound as a "live," malleable material and post-production techniques exemplified this fact.[48]

New methods and conceptions of recording emerged alongside electroacoustic recording technologies. Whereas the mechanical method of recording was structured around a need for clean, unfettered records of a live music event, electroacoustic recording afforded "total" control, to recall the design philosophy of Welton Becket and Associates. The engineer was presented with unprecedented opportunities to manipulate sound. With the introduction of media formats like magnetic tape the final recording could be an amalgamation of various music events spliced together into one form. Electroacoustic technologies were often bound to the idea of "effect," where electronic

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[46] For a description of techniques developed by early recordists see Susan Schmidt Horning, "Engineering the Performance: Recording Engineers, Tacit Knowledge and the Art of Controlling Sound," *Social Studies of Science* 34, no. 5 (2004): 706.
[47] Lea Jacobs, "The Innovation of Re-Recording in the Hollywood Studios," *Film History: An International Journal* 24, no. 1 (March 10, 2012): 5.
[48] French composer, Jean Claude-Risset describes electronic music as "more ductile" than sample-based tape compositions. See Jean-Claude Risset, "Foreword," in *Electroacoustic Music: Analytical Perspectives*, ed. Thomas Licata, Contributions to the Study of Music and Dance, no. 63 (Westport, Conn: Greenwood Press, 2002), xv. "

methods were used to shape the sound within the recording system. In 1948, Capitol Records pioneered an industry-wide transition from master records to magnetic tape, a move that offered greater flexibility in the ways artists could record.[49] The adoption of magnetic tape as the studio's determining media format brought sound recordings in line with movies in the sense that both now had a recording medium that lent itself to editing. Sound on tape functioned much like images on film, where multiple takes could be combined into one montage. One of the more powerful "effects" associated with the electroacoustic system (as opposed to the phonograph) was arguably this last: the idea that the recording was no longer strictly a record but a production of several takes presented as a singular performance. The musical event itself was transformed into "an effect."

Such a transformation was audible, involving the setting of new creative and industry standards. Two key records engineered by Chicago-based producer Bill Putnam, in particular, pushed the boundaries of the "realist" approach to recorded music, utilizing electroacoustic audio effects in music records during the second half of the 1940s. For example: the 1947 recording of "Peg O' My Heart" by the Harmonicats featured large amounts of artificial reverberation, whilst a recording of "Confess" by Patti Page in the same year featured multi-tracked vocals, a technique where Page seemed to accompany herself in the chorus refrain by recording onto two tracks.[50] These recordings were fantastical, in ways made possible by electroacoustic practice. To the average listener, trained to associate sound recordings with live events, these audio effects were the musical equivalent of breaking the fourth wall. Their popularity was vouchsafed by the way in which they manipulated sound, standing out from other records because of their "abnormal" use of audio effects.

This is not to claim that the affordances of electroacoustic sound recording technology induced an immediate change in recording methods. For most music recordings before 1950 the idea of recording a live, "real" event was still the dominant way of thinking about the craft. David Morton observes that despite the introduction of electroacoustic technologies to the recording process before 1950, "it remained necessary for performers to deliver a perfect or near-perfect song in the studio."[51] The process of recording music at this time was still largely understood as the practice of faithfully capturing a live performance rather than the act of sculpting sound in the studio.

It made sense then that Capitol Records would draw upon the technical knowledge of electroacoustic systems from the neighboring movie industry in the construction of their recording spaces. Music recordings were starting to draw from the paradigms established by movies and radio, beginning to embrace the use of audio effects and post-recording editing. Powerful technical and aesthetic transformations were

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[49] "The Capitol Story - A Decade of Growth and Success," *Billboard*, August 2, 1952, 51.
[50] Peter Doyle, *Echo and Reverb: Fabricating Space in Popular Music Recording, 1900-1960*, annotated edition edition (Middletown, Conn: Wesleyan, 2005), 144.
[51] Morton, *Sound Recording*, 141.

underway. It is no coincidence that the term "producer" started to be used around the time the Capitol Tower was built. By the end of the 1950s, music recording discourse had taken on many of the characteristics of sound recording discourse in movies. The music producer was envisaged as an artist managing the space between the technics of the recording equipment and the aesthetics of the final sound, adopting a role that had parallels with the producer's function in the movie industry. Writing about the music recording industry, Peter Doyle notes that before 1957 this role was often given the label of "'arranger', 'supervisor,' 'engineer' or most commonly 'artists and repertoire (A&R) man.'" [52] The change in name was further evidence of the extent to which the filmmaker's craft was transforming the ritual practices of music recording.

Many of Capitol's personnel and design consultants were drawn from movie studios. Michael Rettinger, for example, served as the main acoustic consultant for the construction of the Capitol Studios. Rettinger, an acoustic engineer, worked at the film recording department of RCA in Hollywood which he joined in 1936.[53] A figure we have met before, James Bayless, joined Capitol after working at RCA Victor in Hollywood and the Sound Department of movie production giant Metro-Goldwyn-Mayer.[54] The Capitol Tower was colloquially dubbed "the house that Nat built," a reference to the financial success brought in by Capitol artist Nat King Cole during the 1940s. Yet in terms of design and mechanism, these recording spaces were film production studios built to Hollywood audiovisual standards. The music operations at Capitol Records, in other words, were heavily informed by the presence and proximity of the movie industry.

Furthermore, Capitol Records used construction techniques for sound-stage design borrowed from film production techniques.[55] One such borrowed technique re-engineered the acoustics of recording spaces. The microphones used in high fidelity recordings of the 1950s, such as Frank Sinatra's microphone of choice, the Neumann U47, were more sensitive than earlier iterations.[56] To accommodate these highly-responsive microphones, one of the first design concerns for the studios was to create acoustically isolated rooms. To achieve sonic isolation the first-floor studios were "floated" within the structure, seated on a bed of cork and surrounded by other material that dampened passing sound waves.[57] These floating rooms were the acoustic equivalent of movie sets. They were isolation chambers constructed within interior spaces that could be acoustically divorced from outside environments. For one writer who described the

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[52] Doyle, *Echo and Reverb*, 164.
[53] R.K. Morrison, "In Memoriam," *Journal of the AES* 34, no. 1/2 (February 1986): 109.
[54] Bayless, "Operations and Organization," 8.
[55] James W. Bayless, "Innovations in Studio Design and Construction in the Capitol Tower Recording Studios," *Journal of the AES* 5, no. 2 (April 1957): 75.
[56] Gordan M. Freeman, ed., "Records Make Records," *The Electrical Worker's Journal* 55, no. 2 (February 1956): 16. Horning, *Chasing Sound*, 112. Charles L. Granata, *Sessions with Sinatra: Frank Sinatra and the Art of Recording* (Chicago Review Press, 2003), 23.
[57] Freeman, "Records Make Records," 16.

studios, "the inside noise level is apparent to the human ear as dead silence."[58] These "dead rooms" as they came to be known, essentially furnished an auditory blank canvas, an idea with powerful acoustic and psychological implications. These rooms replicated an imagined space – the perceptual realm of an ideal listener – that functioned as a kind of blank slate, sitting in isolation at home waiting to be engulfed in sound.

The construction of "dead rooms" was also informed by the increasing use of audio effects in the music recording process. Press releases of the 1950s were fond of repeating the claim that each studio was "designed exclusively from the ground – and even the underground up – for the production of high fidelity [sic] recordings."[59] The writer of these words was keen to reference the subterranean reverberation chambers located beneath the parking lot of the Capitol Tower. Whilst audio effects like artificial reverberation offered new tools for the sound recorder to play with, they were often sensitive to, and created their own, distortions. Dead rooms were designed in order that clear and direct sound could be captured within the electroacoustic system. This meant that any audio effects added in the process would not diminish the overall quality of the final sound output. It also meant that sound ideally needed to be effectively isolated, hermetically sealed from the potential distortions of any external environment.

Cybernetic Echoes: Control and Flexibility

Reverberation chambers – or echo chambers as they were also known – were rooms designed to simulate the reverberant effects found in churches and other large spaces. Sound would be sent to a loudspeaker in one of these chambers where it would then be captured by a microphone, gaining the acoustic characteristics of the chamber in the process. Radio broadcasting studios of the 1930s incorporated custom-made echo chambers into their design, music recording engineers having used men's bathrooms or stairwells to produce the desired effect.[60] At Capitol Records, reverberant sound could be controlled like any other audio channel. Effects could be managed within the overall mix of a recording session.

The first piece of technical equipment installed in the Capitol studios was the reverberation chamber amplifier, material proof of the importance of audio effects in the modern recording process.[61] The reverberation effects produced beneath the Capitol Records Tower would become highly sought after and a central feature of the Tower. The recording innovator and guitarist Les Paul is frequently credited with the design of the four original chambers, although Capitol's documentation gives the credit to their

[58] "Most Modern High Fidelity Studios In World Will Be In Service at Hollywood's Capitol Tower This Month," *Music Views*, February 1956, 5.
[59] Freeman, "Records Make Records," 16.
[60] Horning, *Chasing Sound*, 93.
[61] "Most Modern High Fidelity Studios In World Will Be In Service at Hollywood's Capitol Tower This Month," 5.

acoustic consultant, Michael Rettinger.[62] The trapezoid-shaped chambers were accessed from the main building via a tunnel and were arranged adjacently to form one half of an octagon. To enhance the acoustic qualities of the chambers, the walls and ceiling were coated in epoxy paint.

The sacred significance of these reverberation chambers to the recording studios was highlighted by Bayless in a 1957 article detailing the studios design. "Close control of reverberation is the most important single factor in satisfactory recording acoustics," he wrote: "such control could be achieved here because compatible reverberation chambers could be simultaneously designed to complement the studios."[63] For audio engineers, the ability to control acoustics was definitive of the modern recording space, in ways made possible by the total design of studios. The control of the acoustic space was directly linked to new recording standards that incorporated audio effects such as those afforded by Capitol's paradigmatic reverberation chambers.

Like the office spaces and corporate structure of Capitol Records, the studios were conceived and realized as individual parts within a governing cybernetic organism. Bayless attributed their success to Capitol's ability to construct the studios as an integrated system. The engineers, that is, thought about each module, each component of the studios in relation to the recording system as a whole in ways unavailable to earlier studio technicians. The balanced acoustic design of the studios reflected the electroacoustic technology housed within them. Electroacoustic recording systems demanded the seamless integration of an assemblage of components working together in perfect harmony. Microphones, mixing boards, effects units, loudspeakers and recording equipment were all interconnected in the electrical recording system and had to be balanced accordingly. The studio ecology required absolute bureaucratic incorporation.

Thus, the conceptual feedback loop between the design of the Capitol Tower and the construction of its studios. We have seen that many aspects of the Capitol Tower's design stemmed from a cybernetic milieu that had become popular in the 1950s. It is perhaps better to claim that cybernetics itself had roots in early electroacoustic systems like the Bell Telephone System. David Mindell identifies the Bell Telephone Company as an "engineering culture" that informed Norbert Wiener's 1948 conception of a more general theory of control and communication. Mindell observes a transformation in the way that the telephone network was understood by its engineers with the introduction of vacuum tube amplification in 1914. The network was no longer conceived as a passive collection of wires. Rather, it was imagined as an active system with its own organic needs. In Mindell's words, "the Bell System became not merely a set of voice channels but a generalized system capable of carrying any signal as a new currency: information."[64] The telephone network was an early example of a technology beginning to think of itself as a

[62] Jim Cogan and William Clark, *Temples of Sound: Inside the Great Recording Studios* (San Francisco: Chronicle Books, 2003), 24.
[63] Bayless, "Innovations in Studio Design and Construction in the Capitol Tower Recording Studios," 74.
[64] Mindell, *Between Human and Machine*, 106–7.

general system in ways popularized later in the terms of cybernetic theory.

The systems approach to design in the studios was, therefore, reflective of the kind of electroacoustic technology utilized in the recording of sound. The principles of stability and control that were drawn from electroacoustic engineering became the guiding principles for all actants within a single studio environment. This was evidenced in the desire, amongst Capitol's engineers for recording spaces with "completely controllable reverberation characteristics."[65] As with the architectural side of construction the acoustic and physical properties of the studio were extensively mapped and bureaucratized for optimum performance. It was clear that all of the elements that made up the Capitol studio were designed around the needs of the electroacoustic recording technology. The demands of the electrical circuits shaped the physical environments around them. And the audio signal came first.

I have argued that the reverberation chambers represented a model of sound recording that relied on the power of audio effects, a recording practice primarily developed for movie and radio dramas. I have also shown that the reverberation chambers epitomized a cybernetic understanding of sound, where control was a necessary function of the system. Bayless himself identified that for the design of suitable studios Capitol "would have to utilize new principles to achieve a degree of versatility and control previously unavailable."[66] These twin values – versatility and control – represented the twin demands of the modern recording system. An aesthetic need for a variety of sounds and a technical need for control became paramount, these two requirements being particularly pertinent to the recontextualizing capacities of artificial reverberation. The echo chambers were at once an aesthetic and technical innovation.

The studios were arranged so as to allow as little reverberation as possible. Whilst splays were fitted in the studios that could increase or decrease the general reverberation characteristics of the room physically, in general, Capitol Records kept reverberation times short. "Since reverberation can be added but not removed, the studios were designed for a minimum natural reverberation time," Bayless wrote of his choice of an acoustically absorbent room, "the main advantage of the short reverberation time [being] the flexibility it affords."[67] Here, Bayless alluded to the fact that with a dry audio signal obtained from a "dead room," the mixing engineer could add artificial reverberation electronically with much greater control than recording in a "naturally" reverberant room. Artificial reverb was promoted over the "natural" reverberation of a recording space because of newly-attained artistic sovereignty over sonic control and flexibility.

The favoring of "artificial" over "natural" reverberation highlights how much the value of versatility was linked to the growing value of audio effects in the recording process. The director of electrical engineering at Capitol Records, John P. Davis,

[65] Bayless, "Innovations in Studio Design and Construction in the Capitol Tower Recording Studios," 71.
[66] Ibid.
[67] Ibid., 74.

publicized some of the changes enacted in the studios after their opening. In a 1963 article for the *Journal of the Audio Engineering Society* Davis, not only restated Capitol Record's commitment to "flexibility," but emphasized the growing importance of effects to recording-studio practice. His opening statement reads:

> A fundamental requirement in commercial recording studios is system flexibility. Without it, creative experimentation in the art of recording is impossible. The constant search for new effects by artistic personnel regularly taxes the ingenuity of the recording engineer in achieving desired esthetic values within the technical constraints of his recording system.[68]

The desire for heightened control was foundational to "studio art," the push for greater flexibility of the recording system in this article attributed to the desire for heightened aesthetic effects.

We are witness here to a transformed conceptual relationship between sound and environment, the treatment of reverberation in the design of the Capitol Tower studios and the increasing importance of sound effects in recorded music in view. Reverberation was seen as an incidental aspect of sound, subjected to control through architectural design and ultimately electronic design. Electronically mediated reverb became more desirable than "natural" reverb because of its affordances of control; reverberation was treated as a controllable facet of sound that could be both eliminated and reintroduced. When Capitol Records trumpeted that they sought control and flexibility in the design of their studios, we can understand this claim in terms of a philosophy of versatility *through* control. The treatment of reverberation in the studios was an attempt to create a cybernetic reverb that privileged "controlled" sounds over "natural" sounds.

Emily Thompson has explored the process by which reverberation came to be seen and treated as a separate aspect of sound, no longer intrinsic to it. In *The Soundscape of Modernity* (2002) Thompson argues that electroacoustic technologies like the telephone and radio brought to public attention a "new modern sound," lacking in spatial qualities. Thompson writes that by these new technologies, "the sound of space was effectively eliminated from the new modern sound as reverberation came to be considered an impediment, a noise that only interfered with the successful transmission and reception of the desired sound signal."[69] The acoustical design of the Capitol Records studios, to follow Thompson's argument, functioned to advance this reifying trend. Catalyzed by discoveries in electroacoustic communications, engineers created studio spaces where sound could be captured clearly and directly within the recording system. The ideal was a "dry" sound, Thompson claims, free from acoustic contingency and uncontrolled reverberation.

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[68] John P. Davis, "A Multi-Purpose Studio Recording System," *Journal of the AES* 11, no. 4 (October 1963): 360.

[69] Thompson, *The Soundscape of Modernity*, 2004, 234.

Yet, as our consideration of the reverberation chambers in the Capitol Records studio suggests, the "modern sound" was hardly so "dry." Jonathan Sterne challenges the purely architectural view of reverberation-as-noise traced by Thompson, arguing that "as soon as they could produce a detachable echo, engineers, artists, and musicians treated it as aesthetic raw material: sonic space itself became the object of an artistic palette."[70] Consideration of the Capitol Tower studios suggests a conceptual rapprochement between Thompson and Sterne's narratives on reverberation both as an architectural acoustic space and as a creative tool for manipulating sonic spatiality. By dint of the construction of the Capitol studios, the recording studio was becoming an instrument.[71] The treatment of reverberation at the Capitol tower reveals the tension between recorded sound as a medium of communication and a means of artistic expression.

Cocooned within the recording booth studios, Capitol Tower music producers began to treat sound in the same way that film producers and editors treated sound for movies. Film theorist Michael Chanan writes of the relationship between filmmaking techniques and the development of sound technologies in these terms:

> Coupled with devices for mixing, equalization and the addition of reverberation, the first of which were introduced in 1930, Hollywood was thus assured not only of the economic benefits but also of the requisite control for treating sound in the same way as the picture, and constructing it according to the same rationalized principles of montage.[72]

Chanan highlights the extent to which sound was being treated filmically, subject to the same editing and cutting procedures used in the montage technique in movies. This approach filtered into conceptions of music recording, as shown in the design of the Capitol Studios.

Peter Doyle has also noted the overlapping treatment of recorded sound in the music and movie industry in Hollywood. In a chapter reviewing the style of West Coast music recordings Doyle writes:

> Produced in the city from which the U.S. film industry operated, it is not surprising that these pop products should have made such a show of sonically fabricating space, and that those spaces should be so glossily rendered.[73]

For Doyle, the "glossiness" of Capitol's reverberation chambers and studio space, planned around the use of audio effects, mirrored the showiness of movie production on the West Coast. Their music records, that is, involved "putting on a spectacle." Doyle contends that

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[70] Jonathan Sterne, "Space within Space: Artificial Reverb and the Detachable Echo," *Grey Room* (July 1, 2015): 112, https://doi.org/10.1162/GREY_a_00177.
[71] Adam Patrick Bell, *Dawn of the DAW: The Studio as Musical Instrument* (Oxford University Press, 2018), xvi.
[72] Chanan, *Repeated Takes*, 77.
[73] Doyle, *Echo and Reverb*, 162.

the production of these sonic spaces transformed audiences into passive consumers of "pop." However, it could be just as persuasively argued that audiences were more than willing to participate in their role as silent witnesses to the glossy auditory mirage of Hollywood's emerging sound productions. In any case, the Capitol Tower studios and their design were a clear, concrete example of a music recording paradigm that sonically privileged "the fantastic fake" over "the uncontrollable real."[74]

Fantasound in your Living Room

The relationships I have drawn between the music and movie industry in view of the Capitol Tower can be traced as part of a longer history of collaboration between the techniques of the screen and the loudspeaker. For example, conductor Leopold Stokowski was involved in many inter-war developments in electronic sound technology. Stokowski conducted the Philadelphia Orchestra for Victor Talking Machine Company's first record using an electronic recording system in 1925, and began to visit the Bell Telephone Laboratories in the 1930s to further explore the musical use of electroacoustic developments.[75] Stokowski's relationship with the Telephone Company would result in several concerts and demonstrations that showcased electronically manipulated sound, including early experiments in stereophonic recording and a famous concert of "enhanced music" at Carnegie Hall in 1940.[76]

Stokowski was involved in another collaboration in 1940, working with Walt Disney for his film, *Fantasia*. *Fantasia* was an animated movie set to several pieces of classical music. One section featured Disney's famous character Mickey Mouse in a story set to *The Sorcerer's Apprentice* by Paul Dukas. For the film Disney imagined a completely rehauled sound system for both recording and performance. "Music emerging from one speaker behind the screen sounds thin, tinkly, and strainy," Disney explained in a 1941 article in *Popular Science*, highlighting his desire for sonic impact: "we wanted to reproduce such beautiful masterpieces as Schubert's 'Ave Maria,' and Beethoven's Sixth Symphony so that audiences would feel as though they were standing on the podium with Stokowski."[77] To achieve the unparalleled audio quality necessary to Disney's expectations, a new sound system was devised. This "system" was given the name Fantasound.

Fantasound was developed by both RCA and Disney engineers who, in the process of designing the system, pioneered many control devices now considered standard in sound technology. The system introduced multitrack recording for the first time, pushing the limits of sound recording onto film. It also pioneered the incorporation of spatial

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[74] I am drawing on Umberto Eco's language for describing the hyperreality of Disneyland. See Umberto Eco, *Travels in Hyperreality* (HMH, 2014), 45.
[75] McGinn, "Stokowski and the Bell Telephone Laboratories: Collaboration in the Development of High-Fidelity Sound Reproduction," 45.
[76] "Sound Waves 'Rock' Carnegie Hall As 'Enhanced Music' Ls Played," *The New York Times*, April 10, 1940.
[77] Andrew R. Boone, "Mickey Mouse Goes Classical," *Popular Science*, January 1941, 66.

effects in recorded sound. To create the illusion of sound moving across the screen Disney sound engineers developed a panoramic potentiometer dubbed "The Panpot," that could gradually send one audio track to three outputs representing the left, right or center of the screen.[78] This device served in an extensive re-recording process that produced the final soundtrack and was developed along with another automated control device, the Togad. Togad, an acronym for "tone operated gain-adjusting device," essentially functioned as an automated volume control.[79] Through control devices like the Panpot and the Togad, sound could be shaped to mimic the movements of on-screen animation.

For its creators, Fantasound offered a total system for representing all types of sound in the theatre. Music director, Edward Plumb, pinpointed what he thought were the most important features of the system, writing:

> Fantasound is able to make its greatest contribution in combining dialog, music, and sound-effects. In ordinary reproduction one of these three mediums must, with rare exceptions, be dominant while the other two are sacrificed. In Fantasound it is possible to follow the continuity of the dialog clearly and still receive the full emotional impact of the music, or the dramatic realism of atmospheric sound-effects.[80]

The audio system developed by Disney and RCA was seen to unify, in arguably cybernetic ways, all the myriad aspects of sound present in the drama of a feature film. While Plumb differentiated between the music scoring, actor's dialogue and dramatic effects, in practice all sound had become an effect. At the controls of his Fantasound system, the producer constructed a sonic "atmosphere" – a total environment for immersive living.

Despite the technical advances offered by the Fantasound system, it was unclear what its long-term impact would be on sound reproduction for movies. Plumb noted that with Fantasound, "we have the tools and we have not decided what we intend to build with them."[81] The *Fantasia* project was a project of remediation, presenting a media form from a previous era, the orchestral music conducted by Stokowski, in the modern media form of an animated movie. Whether future film projects would utilize the advances of the new sound system remained to be seen. "It is within the power of Fantasound, as an idea," Plumb went onto claim, "to revitalize the industry."[82] Whilst Plumb probably made that claim from a technical standpoint, it is significant that he should locate the power of Fantasound in an "idea." That "idea," greater than the sum of its technical achievements, could be applied to recorded sound more generally.

The concept at the center of the Fantasound project, to be clear, was the concept

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[78] W. E. Garrity and J. N. A. Hawkins, "Fantasound," *Journal of the SMPE* 37 (August 1941): 129.
[79] Ibid., 131.
[80] Edward H. Plumb, "The Future of Fantasound," *Journal of the SMPE* 39 (July 1942): 21.
[81] Ibid.
[82] Ibid.

of treating the recording of sound as the construction of a wrap-around fantasy environment. As we have seen, the Capitol Tower was firmly rooted in the idea of sound as fantasy, revealed in the aesthetic choices of its building and in the functional development of its studios. Fantasound was also an idea formative to the history of electroacoustics, as electronic technologies of sound were used to create auditory fantasies. For both music producers and listeners, the high-fidelity record of the 1950s embodied a fantasy of technical control and artistic illusion.

The music commodities produced at Capitol's studios were promoted and devised as a kind of Fantasound for the living room, a technological and fantastic experience that could be consumed in the modern home. To return to my earlier discussion of mid-century design, the kind of musical recordings made in the Tower reflected the aspirational fantasy of modern living found in tract housing developments like the ones designed by Welton Becket. Capitol Records' music releases were in themselves imaginative sonic experiences, manifesting a cinematic approach to recording. While Capitol had been releasing records that offered a fantasy experience before building their own headquarters, the Tower established the Fantasound model for music recording.

Making Records Hi-Fi

When *Downbeat* magazine joked about the Capitol Tower's external likeness to a failed spaceship, outer space was exactly the kind of fantasy environment that was utilized by Capitol's recording artists as the backdrop to their music. The most extreme versions of these fantasy environments were packaged as the "exotica" genre that came to prominence in the 1950s. One pioneer of the genre and a signed Capitol musician, Les Baxter, produced his first album *Music Out of the Moon* in 1947. The recording artwork featured a surreal moonscape with a reclining model and was one of the first album covers to use full color. The music played into the exotic, technical fantasy of a lunar experience featuring the ethereal sounds of an electronic instrument, the Theremin. Baxter's record was a hit, and in a strange twist of events would go on to fulfill the conceptual premise of its title. In 1969, on Apollo 11's flight to the moon astronaut Neil Armstrong broadcast *Music Out of the Moon* back to his wife on earth using a portable cassette player.[83]

The Capitol Records studios were hailed as groundbreaking on two distinctive counts. For its owners, first, the recording studios were "purpose-built," as we have seen. Second, they afforded a never-experienced-before standard of "high-fidelity" music recordings.[84] The latter idea was promoted more than the former, but both were facilitated by developments in electroacoustic technology. The acoustic treatment of the recording spaces and the incorporation of audio effects like reverberation chambers betrayed the studio's construction around electroacoustic recording techniques that had

[83] James R. Hansen, *First Man: The Life of Neil A. Armstrong* (Simon and Schuster, 2006), 423.
[84] Freeman, "Records Make Records," 16.

a precedent in radio and movie studios. Capitol's desire to situate the studios themselves within the post-war craze for "high fidelity," on the other hand, was new. High-fidelity sound was more frequently associated with consumer technologies of sound reproduction, home stereo systems and record players, rather than with spaces of record production.

In this section I reexamine the history of audio fidelity to situate mid-century discussions around "high fidelity" but also to emphasize the subtle changes brought about by electroacoustic technology to the fidelity concept. Emily Thompson has shown how Edison's phonograph was judged on its capacity for fidelity or faithfulness to a sonic event, noting that what actually constituted successful fidelity has varied over time.[85] Audio fidelity, she shows, was a concept that predated electrical methods of sound recording, having undergone a transformation in meaning from its original use.[86] The talking machine was first configured as a simulator of reality with the first tone test in 1915, where Edison's final iteration of the phonograph, the Diamond Disc player, was compared to live musical performances. Thompson argues that fidelity was based on the inability of a listener to distinguish human from machine. Regardless of the effectiveness of the tone test, the challenge for sound technology had been laid down. As Thompson writes, the equation that set musical performance against machine reproduction became commonplace.[87]

Where "fidelity" was a term used to promote the mechanical phonograph, "high fidelity" was a phrase applied exclusively to electroacoustic technologies. The high-fidelity concept entered the language of sound researchers and technicians in the first half of the 1930s, and was originally employed to describe advances in audio technology for radio and movies. The editor for *Radio Engineering* briefly narrated the origin of the phrase in 1933:

> It is indicative of the present trend of radio engineering thought that the term "high fidelity" has become current in receiver terminology. The term was employed a year or two ago in the talking picture field in connection with the performance of microphones, audio amplifiers and loudspeakers.[88]

The high-fidelity concept, in essence, signified electroacoustic fidelity. It referred to the ability for an electrical system of transducers like microphones and loudspeakers to accurately present a sonic event.

High-fidelity thinking not only re-enforced the standard set in Edison's tone tests by attempting to capture sonic reality. It also brought in ideas of human perception that had been utilized by telephone engineers. Alfred Goldsmith, a consulting engineer,

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[85] Emily Thompson, "Machines, Music, and the Quest for Fidelity: Marketing the Edison Phonograph in America, 1877-1925," *The Musical Quarterly* 79, no. 1 (1995): 137.
[86] Jonathan Sterne states that fidelity was first applied to sound in 1878. See Sterne, *The Audible Past*, 221.
[87] Thompson, "Machines, Music, and the Quest for Fidelity," 160.
[88] Donald McNicol, "Editorial," *Radio Engineering* 13, no. 11 (November 1933): 4.

explained the properties of high fidelity at a meeting of the Institute of Radio Engineers in 1933. In his description of the requirements for a high-fidelity radio receiver Goldsmith aligned his project for high-fidelity sound with the aims of the Edison tone test:

> Let us assume that we desire to reproduce in the home, or rather in the mind of the listener, precisely the impression which would be created were the listener actually present in the studio or concert hall. In other words, there is sought the 'illusion of reality.'[89]

For Goldsmith, Edison's tone test continued to cast a long historical shadow. Yet there was a new sense of the location where that auditory illusion was taking place. The site of reproduction was no longer the inside of a machine; rather, reproduction took place within the mind of an imaginary listener.

The mind of the listener was thus established as the ultimate destination for transmitted sound, even when that subject could not be trusted to judge the level of fidelity. Electroacoustic engineers sought an objective, scientific approach to analyzing the quality of sound. Frank Massa, a research engineer for RCA-Victor, determined in a 1934 paper that:

> Unfortunately, until relatively recent times acoustical engineering was not sufficiently developed to quantitatively determine and specify the conditions necessary for real high-fidelity reproduction; consequently, the use of the term served only to qualitatively state that the new equipment sounded better than the one which it was intended to replace. Today, however, we have reached a stage where we are capable of quantitively specifying most of the conditions necessary for high-fidelity reproduction.[90]

Massa went on to list seven factors that determined the relative fidelity of an audio system, showing how true sound could be measured and quantified. Unlike Edison's tone tests which matched machine against human in a parlor, electroacoustic engineers sonically mapped all components of the system, human and machine, and assessed them along known parameters through laboratory testing.

The fact that radio and movie sound occurred as the effect of large, haphazard assemblages further complicated understandings of fidelity. Engineers knew that improving one component of the system didn't necessarily improve the fidelity of any of the others. Better transmitters could not fix the listening experience offered by a poorly made radio receiver. Goldsmith identified the problem with large communication systems as a problem with "goodness," writing,

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[89] Dr. A. N. Goldsmith, "Conditions Necessary for an Increase in Usable Receiver Fidelity," *Radio Engineering* 13, no. 11 (November 1933): 22.

[90] Frank Massa, "Acoustics and High Fidelity," *Radio Engineering* 14, no. 5 (May 1934): 10.

> In the strictly scientific sense the best receiver is, of course, that approaching the scientific ideal of perfect fidelity; but under existing conditions the goodness of a receiver must be judged by the engineer as being a measure of the adaptation of the receiver to the conditions encountered.[91]

These words betray a subtle shift in thinking about fidelity. Whilst Goldsmith upheld a scientific ideal of perfect fidelity, he acknowledged the need for adaptation. A technology that could handle and accommodate the inconsistencies of a large system also had to confront the vagaries of a potentially unstable environment.

High-fidelity sound was a scientific ideal assumed to have transparent qualities; the perfect sound device added no distortion to the system. A "flat response" within all the devices of a sound system was theoretically desirable, the assumption being that sound was captured and projected within controlled acoustic environments designed for electronic sound systems. The "flat response" approach, however, failed to take into account the wide variety of environments where the sound system would be used, as one writer argued:

> High Fidelity reproduction is not obtained through the use of "flat characteristic" components alone because it is rare indeed that room acoustics are ideal. Some means for controllable compensations for the acoustic irregularities of the room in which the loudspeaker operates is of the utmost importance.[92]

The desire for "controllable compensations" outweighed the need for perfect components and offered a practical solution to the value of adaptation that Goldsmith identified. The benefits of high-fidelity sound reproduction were not in technology's ability to provide an undistorted reflection of a sonic event. Rather, they were to be found in its capacity to fix "bad" signals at the point of input.

High-fidelity sound transcended the assumptions of Edison's tone test and its attempts to simulate reality. The electroacoustic system offered a way to enhance "real" performance. It offered a "higher reality" and an augmented auditory perspective, a level of experience familiar to movie producers. The developers of Fantasound recognized that their goal for a new sound reproduction system went further than the capturing of a live performance. "It might be emphasized that perfect simulation of live entertainment is not our objective," wrote head engineers William Garrity and John Hawkins, "motion picture entertainment can evolve far beyond the inherent limitations of live entertainment."[93] The aim of the creators of Fantasound was to transcend the sonic construction of an illusion of reality and approach the illusion of fantasy. In the domain of electroacoustic sound, reality was simply another effect.

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[91] Goldsmith, "Conditions Necessary for an Increase in Usable Receiver Fidelity," 22.
[92] I.A. Mitchell, "A New High-Fidelity Metal-Tube Amplifier," *Radio News* 17, no. 7 (January 1936): 403.
[93] Garrity and Hawkins, "Fantasound," 127.

The electroacoustic standard of fidelity that was developed in the 1930s both engaged and departed from the equation set by Edison's tone tests. Whilst discussions of high fidelity maintained an idealized notion of capturing reality, the process of engineering electrical sound perpetuated new practices and conceptions of audio fidelity. In electroacoustic engineering, the fidelity concept became useful as a means to analyze the performance of a system. Tone tests challenged the machine's "fidelity" in relation to the sounds of a human performer; electroacoustic notions of high fidelity were centered around the internal fidelity of components within a system. In high fidelity discourse, ultimately, a proto-cybernetic understanding of faithfulness prevailed. To speak of fidelity was less to make an assessment about a performance of music and more to make a judgement about the performance of the audio system itself.

From the perspective of the electroacoustic engineer, the electronic sound system presented more stability than the environments in which they were deployed. A controlled environment was required for the system to work at optimum. This is what the interiors the Capitol Studios provided. The acoustically dead rooms and flat response of the recording spaces were all designed around the needs of the high-fidelity recording system. This protective stance towards sound recording was reflective of a cybernetic fidelity that didn't presume that performances were stable, idealized events that could be extracted and reproduced perfectly. Rather the assumption was that the environment of performance needed to be controlled and made stable. In discussions of high fidelity at the Capitol Records Tower and elsewhere, it was ultimately the external acoustic environment that posed the greatest challenge to the perfectibility of any electroacoustic system.

When the mechanism of recording sound changed from a purely acoustic process to an electroacoustic one, sound recordists and producers also began to explore the conceptual components of their craft. Steve Wurtzler has explored how two seemingly competing models of sound recording emerged within recording practices. First, he describes a "transcription model" which was based on the idea that the task of recording was to document a sonic event. The second concept Wurtzler defines is the "signification model," a recording philosophy that understood the reproduced sonic event as an entity that was constructed on a blank canvas or "silent space."[94] Edison's tone tests were rooted in Wurtzler's "transcription model," whilst radio and movie productions increasingly drew upon a signification model for representing sound.

The two models that Wurtzler proposes are closely related to the two different methods of recording. The "transcription model" was established during the development of the mechanical phonograph whilst the "signification model" became dominant with the introduction of electroacoustic methods of sound recording. Wurtzler notes that whilst electroacoustic recording methods changed the way sound recording was understood they still drew upon the narratives of transcription. "Although innovators

[94] Wurtzler, *Electric Sounds*, 231.

announced electrical acoustics with grand claims about enhanced fidelity in sound reproduction," Wurtzler writes, "the material practices of representing with sound moved inexorably away from the transcription of acoustic events."[95] The paradox of high-fidelity sound was that it claimed greater faithfulness to an "original" – a hangover from the older "transcription model" – whilst recorders and producers abandoned this idea altogether. Instead, ideas of aural "realism" were folded into the newer "signification model."

Jonathan Sterne has also explored the way in which electronic media altered sound recording philosophies. He describes a similar shift in sound representation claiming that "one of the important shifts in the history of sound reproduction was from an imitation of the causes of sound to imitations of sound as an effect."[96] We could read this transition as being in line with Wurtzler's understanding of the change from a transcription model to a signification model. In both cases, engineers came to conceptualize sound as an effect. For Sterne, the shift from transcription to signification relates to "tympanic" technologies that were designed to model the inner diaphragm of the human ear. "Tympanic" technologies of sound sought to imitate the electroacoustic mechanisms of the human body itself, where acoustic waves were transduced into electronic nerve signals. Unlike the mechanical phonograph that was developed to capture sound waves as accurately as possible, electroacoustic technologies were informed by psychoacoustic theories concerning the holistic perception of sound in the mind.[97] Electroacoustic systems, one could argue, served a phenomenological logic.

Despite all the measuring and objective proof associated with electroacoustic sound, it was unclear whether audiences would accept the gift of high fidelity presented to them by acoustical engineers. In his 1954 textbook on electroacoustics, Frederick Hunt assumed that the success of electroacoustic technologies meant that "'high fidelity' [was] its own best salesman."[98] However, during the first wave of high-fidelity innovation in the 1930s, the inevitability of success was far from assured. In a comprehensive review of the impact of radio in the United States by the American Academy of Political and Social Science, one writer noted "an odd characteristic of the average broadcast listener is that he does not seem to appreciate high-fidelity reproduction of radio programs."[99] Listeners didn't seem to care.

The editors of *Radio Engineering* were similarly confused by the lack of interest in high-fidelity sound despite having high hopes for a new era of sound quality. In response to the release of the first "hi-fi" radio receivers the editorial of the 1934 February issue declared:

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[95] Ibid., 283.
[96] Jonathan Sterne, "The mp3 as Cultural Artifact," *New Media & Society* 8, no. 5 (2006): 837.
[97] Ibid.
[98] Hunt, *Electroacoustics*, 69.
[99] James C. McNary, "New Technical Horizons for Broadcasting and Their Significance," *The Annals of the American Academy of Political and Social Science* 177, no. Radio: The Fifth Estate (January 1935): 210.

> There appears to be little doubt that the public will react favorably to any improvement made in broadcast-receiver response. The listener, once a rather perplexing "sound degenerate," has been awakened to his condition by the poor quality of the majority of midget receivers. His ears are now acute, and he has unquestionably become sound conscious."[100]

However, by October of the same year the mood had changed. The American public had seemingly not become as "sound conscious" as previously hoped. "More than likely the sale of high-fidelity receivers will not reach any great proportions for a while to come," a later editorial lamented, "the radio listener is not as yet 'quality conscious.'"[101] These editorials pushed an engineer's perspective on sound. Quality was supposedly obvious and objective. Much like the environmental danger of bad acoustics in the recording system, the average listener presented a threat to the natural advancement of electroacoustic science.

Phonographic High Fidelity

The Capitol Tower, to consolidate the story so far, was constructed at a time of renewed attention to listener preferences and high-fidelity audio for the phonograph. Its studios were built at the apex of a series of electroacoustic interventions into the originally mechanical art of recorded sound. As we have seen, the concept of high fidelity grew out of developments in electroacoustic technologies, largely confined to radio and film. Perhaps surprisingly, the phonograph would have its own "high fidelity" revolution in the 1950s spawning a craze that had a large impact on U.S. culture in the 1950s.[102] To fully understand developments at the Capitol Tower studios, we need to make a brief detour: to explore the history of electroacoustic interventions into the phonograph, showing how even that mechanical technology fell under a cybernetic spell.

In 1948, Marvin Camras, lead researcher for the Armour Research Foundation in Chicago, drew together many of the arguments and challenges around high fidelity in view of its application to the phonograph. In an article appropriately titled "How High is High Fidelity?" Camras made a historical overview in order to help the reader situate the emergence of high fidelity discourse in relation to the phonograph. Camras recognized three forms of fidelity thinking, generally defining high-fidelity devices as those that reproduced a wider frequency range. A first group of listeners, according to Camras' taxonomy, perpetuated a kind of radio snobbery characteristic of the 1930s. This group believed that "the public has heard low fidelity phonographs and radios for so many years that they are accustomed to poor quality, and reject anything different without considering whether it is really better."[103] A second group, though equally pessimistic

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[100] "Editorial," *Radio Engineering* 14, no. 2 (February 1934): 4.
[101] "Editorial," *Radio Engineering* 14, no. 10 (October 1934): 4.
[102] Milner, *Perfecting Sound Forever*, 138.
[103] Marvin Camras, "How High Is High Fidelity?," *Tele-Tech*, July 1948, 26–27.

about the acceptance of high fidelity, believed that "for psychological reasons an extended high frequency response is unpleasant even if distortionless."[104] A final group of critics, according to Camras, held that extending the frequency ranges of sound reproducers would be desirable if only they could be made without adding distortion.

Camras' essay was, in essence, a review of work undertaken by RCA engineer, Harry Olson. A year earlier than the essay appeared, Olson published the results of an experiment that sought to better understand why listeners often claimed to prefer a limited frequency range in sound reproduction. In this experiment, Olson created an acoustic filter that was placed in front of a live orchestra. The acoustic filter consisted of a group of doors that could be turned in and out along a similar a design to the acoustic splays installed at the Capitol Tower Studios. When the doors were turned inwards, they shut out the higher frequencies of the orchestra. When they were turned out, the full frequency range of the sound reached the listener's ear.[105] The experiment involved exposing listeners to the sounds of a full orchestra with the filter and without, whereupon the test subjects were asked which situation they preferred. Olson observed that his experiment demonstrated "a preponderant preference for the full frequency range." He was enthused to discover that 69% of the examinees chose the high-fidelity option.[106]

For Olson, the experiment proved that there was no psychological barrier to appreciating the full frequencies of sound. The problem lay with the machines. Olson's findings made it clear that if engineers could eliminate distortion from mechanical reproduction, the public would have no problem accepting high-fidelity, full-frequency sound. The experiment proved influential. When compared to the earlier tone tests, the setup represented a strange reversal of events. Olson's experiment essentially consisted of live performers being manipulated by purely acoustic means in order to simulate electronically reproduced music. If Edison's tone test posited the idea that "natural" human performance might be simulated by "artificial" machines, Olson's took the machine's mode of sound production as the natural way to listen to sound. Rather than systems being organized according to the preferences of human test subjects, human test subjects were organized according to the logic of the system.

The first electroacoustic interventions into the phonograph were conducted at the Bell Telephone Laboratories in New York, an institution established in 1925. Bell researcher Joseph P. Maxfield led a group tasked with improving the phonograph, according to an electroacoustic approach that was at that time named "telephone transmission theory."[107] Telephone researchers were predisposed to identify the

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[104] Ibid., 27.

[105] Harry F. Olson, Oral-Histroy: Harry F. Olson, interview by Mark Heyer, July 14, 1975, IEEE History Center, https://ethw.org/Oral-History:Harry_F._Olson#High_Fidelity.

[106] Harry F. Olson, "Frequency Range Preference for Speech and Music," *The Journal of the Acoustical Society of America* 19, no. 4 (July 1947): 553.

[107] Maxfield and Harrison, "Methods of High Quality Recording and Reproducing of Music and Speech Based on Telephone Research," 493.

limitations of the phonograph despite the different ways each technology had developed. The telephone company and the phonograph originally shared the same limitations, both relying on the "natural" strength of a soundwave to power their transmissions. For the phonograph to record effectively, the captured sound had to carry enough intensity to cut into a groove; in the phone system, speech could only be transmitted as far down a line as its amplitude would allow: both were technological practices of power and distance. Bell had overcome the problem of distance with the incorporation of vacuum tubes in their 1914 transcontinental line. By contrast, developers of the phonograph had not yet embraced the "electrical turn" powering radio and talking movies of the 1920s. The phonograph, apparently, was behind the times.

Bell Laboratories approached the phonograph in the same way as their telephone system in several ways. First, they treated the recording process as a network of various components connected within a system. Each aspect of the phonograph was treated separately. In Maxfield's electronic model the host of individual functions present in the one instrument were now given over to a variety of electroacoustic devices. The phonographic horn used to capture sound was replaced by an invention patented by fellow Bell Labs member E.C. Wente: the condenser microphone. The phonograph stylus used to etch the sound waves onto a disk was replaced by the "rubber line recorder" an electro-mechanical device carefully tuned to balance the mechanical and electrical components of the system. By such processes of substitution, Maxfield and his group of researchers turned the phonograph into an electroacoustic system not too unlike the one transmitting conversations across the country.

Another way in which Bell Laboratories adopted a distinctly telephonic method for improving the phonograph was by extensively mapping and measuring the vibrational capacities of both the acoustic and electric phonograph. Bell researchers had utilized audiograms in their analysis of transmission systems, graphs that indicated frequency along the horizontal axis and sonic intensity on the vertical axis. By means of these graphs, the sensitivity of a device across a specified frequency range could be plotted and analyzed. In their 1926 article for the *Bell System Technical Journal*, Maxfield and Henry C. Harrison reproduced an audiogram to illustrate the improved response of the electrical system in comparison to the best acoustic phonographs on the market at that time (Figure 1.4).[108] These audio maps served to diagnose defects in an audio system and provided a way to compare different systems. In this case, they illustrated the wider frequency range and more linear response of a Bell-designed phonograph.

[108] Maxfield and Harrison, "Methods of High Quality Recording and Reproducing of Music and Speech Based on Telephone Research," 523.

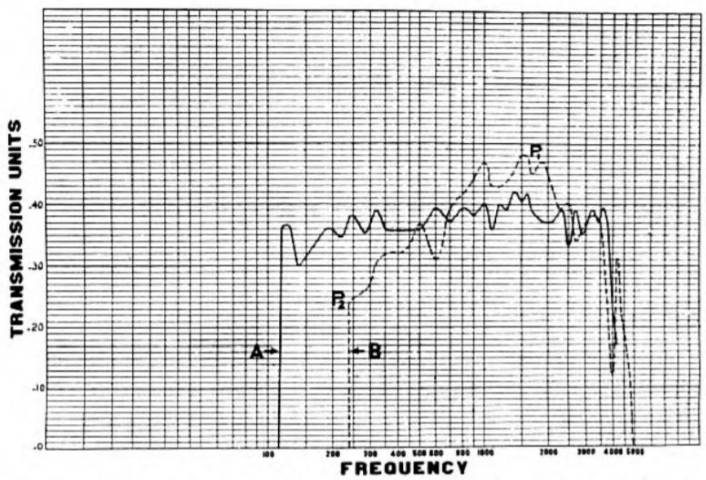

Figure 1.4: Sonogram graph. "Curve A," shows the frequency response of Bell's phonograph loudspeaker, against "Curve B," the response of the best commercial machines available at the time. Image from Maxfield, J. P., and H. C. Harrison, "Methods of High Quality Recording and Reproducing of Music and Speech Based on Telephone Research," *Bell System Technical Journal* 5, no. 3 (July 1, 1926): 523.

The intensive mapping of the phonograph by Bell Lab's researchers was facilitated by the company's involvement in audio testing and the study of hearing loss.[109] Using specially-made "audiometers" Bell researchers tested the hearing range of test subjects, a project that had a dual purpose. Sterne describes the process:

> There were really two sympathetic projects at work in this series of audiometer test: Bell Labs' desire to map the boundaries and topography of a hearing subject so that it could better calibrate its equipment for profit, and the medical-political desire to identify and remedy (or even prevent) deficiencies in hearing.[110]

The acoustic phonograph was treated as if a human subject: a nonhuman patient suffering from acute auditory shortcomings.

The telephonic overhaul of the phonograph, in other words, involved the cybernetic intermingling of human and machine. Phonographs were often referred to as "talking machines," as in the eponymous Victor Talking Machine Company. It was this company that bought licensing rights to the newly designed electrical recording system developed by the Bell Laboratories team in 1925. Victor executives chose to commercialize this electrical recording process by using the term "orthophonic" for their new range of acoustic phonographs. The Orthophonic Phonograph was released to coincide with the new electrical recording method. Orthophonic was a revealing choice of word, an adjective created from the noun, orthophony, meaning correct speech or enunciation. To

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[109] Mara Mills, "The Dead Room: Deafness and Communication Engineering" (Cambridge, Massachusetts, Harvard University, 2008), 32.
[110] Jonathan Sterne, *MP3: The Meaning of a Format* (Durham: Duke University Press Books, 2012), 59.

label the electrical recording process "orthophonic" was to suggest that electroacoustic methods promised a medical cure for deficient sound reproduction. It was also to suggest that hearing deficiencies were experienced as much by machines as by humans.

The Orthophonic phonograph was first demonstrated in 1925 at a dinner held in a ballroom at the Waldorf hotel in New York. News of the event made the front page of the *New York Times*. The journalist in attendance noted the improved frequency range and tonal quality of the phonograph writing that "its performance besides that of its predecessors is like a fine oil painting beside a copy in black and white."[111] The Victor Talking Machine Company employed bandleader and composer John Philip Sousa to assist in their phonograph demonstration. Sousa had famously denounced the "canned music" produced by the phonograph in 1906 in an article titled "The Menace of Mechanical Music."[112] In 1925, during the demonstration of the Orthophonic phonograph, Sousa gave a very different appraisal. "Gentleman, that is a band," he declared: "that is the first time I have ever heard music with any soul to it produced by a mechanical talking machine."[113] Hearing the electronic recording system, Sousa was prepared to not only recognize the superior quality of a talking machine. He heard, in these sounds, the presence of souls.

The electrification of the talking machine promised to counteract the increasing popularity of radio, which was widely believed to have negatively impacted record sales.[114] Whilst the Orthophonic phonograph wasn't an electric phonograph, it marked a transition from the purely mechanical process phonography had been rooted in for decades to an electroacoustic one. Perhaps because the primary function of phonographic recording was to inscribe sound waves onto a disk, the technology afforded a more fixed understanding of sound, which was captured for archiving, reproduction, and exchange. Electroacoustic technologies, resisting the preservationist ethos, invoked the image of sound in circulation, betraying a newfound fascination for the ways in which the original sound, once transduced into electrical waves, could be manipulated within the very mind of the listener.

Despite the increased affordances for manipulating sound the idea of capturing a "real" performance still proved an irresistible narrative for electroacoustic engineers. When Capitol Records sold their own phonographs, they drew upon the well-worn concepts of recording outlined above. "Excitement swirls around you when you hear the new stereophonic recordings!" claimed a 1958 advertisement, but "there is only one way to enjoy *all* the unequalled pleasure of *true stereo's total realism*… that is by following this *advice from recording engineers.*" [115] Claims of "total realism" were no longer freighted with

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[111] "New Music Machine Thrills All Hearers At First Test Here," *The New York Times*, October 7, 1925, 1.
[112] John Philip Sousa, "The Menace of Mechanical Music," *Appleton's Magazine*, 1906.
[113] "New Music Machine Thrills All Hearers At First Test Here," 1.
[114] McGinn, "Stokowski and the Bell Telephone Laboratories: Collaboration in the Development of High-Fidelity Sound Reproduction," 43.
[115] "New Capitol Stereo Phonographs," *Life*, December 1, 1958, 8.

the sense of fidelity to a performance. Capitol's machine, rather, offered a fantasy experience. In a similar fashion, by emphasizing the technical knowledge of their own recording engineers, the consumer's home underwent the same kind of spatial ordering and control adopted for the construction of the Tower, the building featured on Capitol's call-in card (Figure 1.5). From Tower to home, the high-fidelity recording not only connected domestic space to the developments of control engineering, it could also be a vehicle, delivering sound that transformed the mundane space of the home into a fantasy space.

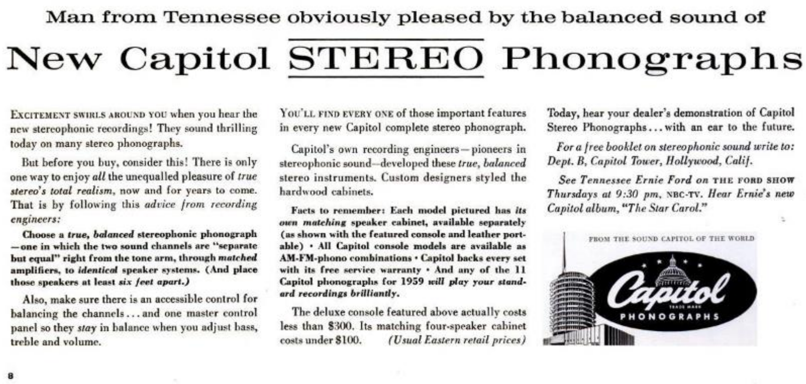

Figure 1.5: "New Capitol Stereo Phonographs" advertisement. Image from *LIFE*. Dec 1, 1958, 8.

<u>Studio City: Los Angeles</u>

Throughout the previous sections of this chapter, I have continually tied the construction of the Capitol Tower to developments in control theory and the powerful intellectual movement that grew out of it – cybernetics. I have also drawn connections between the way that Capitol's studios were imbricated in mid-century architectural practices, a discipline that was also impacted by the cybernetic principles established by Norbert Wiener. As seen, the studios at Capitol Record's headquarters were "totally designed," with every electronic, mechanical and acoustic element planned as part of a connected network. The studio was in many ways the ideal cybernetic system; an organism of inputs, outputs, feedback and control mechanisms that provided a high level of stability. The modern, electroacoustic recording studio, as pioneered by Capitol Records, functioned as a centralized area for control, the apex of an array of technologies designed to organize space.

We could say that music recording and production practices were developed around the idea of spatial control. The record "producer," much like their movie counterpart, was a role tasked with ordering space. This included the physical spaces of the studio as well as the virtual, sonic spaces constructed in the recording process. In the physical construction of a studio, some rooms were designated as acoustically "dead" spaces, where reverberation was effectively eliminated, whilst other parts of the studio were designed to be the polar opposite, such as the subterranean echo chambers. The chambers functioned as the space where reverberation could exist, and in excess. The separation of acoustic spaces in the construction of the recording studio both reflected and generated new recording practices. With the affordances of control proffered by electronic technology, recorded sound could be "placed" within the overall mix of a recording. As such, the mixing console became one of the more prominent tools of the recording studio, as it was a device that could actively manipulate the spatial experience that a listener perceived when listening to a sound recording.

The mechanisms of spatial control, present in cybernetics and sound recording practices, were "built in" to the architecture of the recording studio, but they also manifested in emerging urban environments. The Capitol Tower could be seen as a microcosm for the city that surrounded it. The specialized issues faced by the designers of high-fidelity recording studios were reflective of general problems faced by urban planners: both were led by the cybernetic idea of overcoming the environment with more effective systems. Jennifer Light has argued that the cybernetic ideas applied to military strategies during the second world war influenced urban planning in peacetime. She writes:

> Beginning in the late-1950s, systems analysts – and an increasingly wide array of government leaders – began to speculate that if society could be viewed as a self-regulating organism or machine, one of the complex social systems to which cybernetic principles might be applied most productively was government. Eventually this view would encompass understanding, regulating, and troubleshooting the governance and operations of American cities.[116]

Spatial control thus extended outwards into the city the urban space now viewed as a problematic environment in need of new systems of control.

In the late 1950s cybernetic theorists broadened their views on what constituted a system and an environment. W. Ross Ashby, in his 1956 textbook *An Introduction to Cybernetics* understood cybernetic theory to be applicable to the minutiae of a biological experiment as well as to larger theories of society. "Is there not a possibility that we can use our present powers of regulation to form a more highly developed regulator, of much more than human capacity," Ashby enquired, "that can regulate the various ills that occur in society, which, in relation to us, is a very large system?[117] At the other end of the scale, the concept of the cyborg as first described by Manfred Clynes and Nathan Kline in 1960, posited that human beings were also a modifiable system that could be regulated with technology.[118] For its adherents, the stability offered by cybernetic systems afforded the power to solve a wide variety of political problems from large networks right down to the

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[116] Jennifer S. Light, *From Warfare to Welfare: Defense Intellectuals and Urban Problems in Cold War America* (JHU Press, 2005), 45–46.
[117] William Ross Ashby, *An Introduction to Cybernetics* (New York, J. Wiley, 1956), 271, http://archive.org/details/introductiontocy00ashb.
[118] Ronald Kline, "Where Are the Cyborgs in Cybernetics?," *Social Studies of Science* 39, no. 3 (2009): 331–62.

individual.

In the years following the 1948 publication of *Cybernetics*, Norbert Wiener himself increasingly applied his theories of communication towards societal problems. Wiener's 1950 book *The Human Use of Human Beings* explored the social and moral side of cybernetics in an increasingly technologically automated world. Around the same time Wiener wrote an unpublished manuscript with two collaborators from MIT addressing the design of urban spaces in the event of a nuclear attack. The final draft of the manuscript bore the somber title "Cities That Survive the Bomb." It offered cybernetic solutions to wartime concerns in urban planning. The writers treated the city as a communication network made up of channels, information and feedback loops. "Minor disasters may be our salvation under the blast of an atomic bomb if they cause us to improve our channels of traffic," Wiener claimed, "and in fact, to produce the extra channels necessary to save us when the day of reckoning comes.[119] As Robert Kargon and Arthur Molella write, in Wiener's design for a city, "the purpose of anticipatory defense was to maintain the stasis of the information."[120]

Ideas from Wiener's manuscript, extraordinarily, cropped up in an article in a 1950 issue of *Life* magazine. In the article, images of a congested New York street were juxtaposed with Wiener's plan for a defensive city in the era of the A-Bomb. The cybernetic city was conceived as a city of "life-belts," secondary transport routes that could be relied upon when usual connections were knocked out. The article noted that even in peacetime these life-belts could alleviate the crowding of inner cities, urban space increasingly appearing as if a disorganized mess through the lens of communication systems.[121] Here, when cybernetic theory was applied to conceptions of urban space, the city itself became an out-of-control environment, a system in need of amplified regulation.

The language of communication systems and cybernetics, more remarkably still, infiltrated president Dwight Eisenhower's plan for national defense and transport. The 1956 Federal Highway Acts was termed the "Eisenhower System of Interstate and Defense Highways" with the president arguing that:

> Our unity as a nation is sustained by free communication of thought and by easy transportation of people and goods. The ceaseless flow of information throughout the Republic is matched by individual and commercial movement over a vast system of interconnected highways crisscrossing the

[119] "Cities That Survive the Bomb" (Wiener MS, MC 22, box 29A, folder 638, n.d.), 9. In Robert Kargon and Arthur Molella, "The City as Communications Net: Norbert Wiener, the Atomic Bomb, and Urban Dispersal," *Technology and Culture* 45, no. 4 (2004): 774.
[120] Kargon and Molella, "The City as Communications Net," 774.
[121] "How U.S. Cities Can Prepare For Atomic War," *Life Magazine*, December 18, 1950, 79.

country and joining at our national borders with friendly neighbors to the north and south.[122]

The president's report observed the need for a new network of highways, given the purported threat of an atomic attack on U.S. cities. Eisenhower's conception of the United States' transport system as a "ceaseless flow of information" highlights the wide influence that cybernetic thought had achieved by the 1950s. City space and national transport were understood as systems of information that needed order and stability to survive.

The concept of urban-space-as-a-communications-system arguably already took concrete form in the development of mid-century Los Angeles. Wiener's life-belts and Eisenhower's system of highways manifested forms of city design conceived according to Southern Californian values. The Arroyo Seco Parkway, the first freeway by many definitions, had been built in Los Angeles. Constructed during the 1950s, a network of highways would continue to supply the infrastructure for the new city, a feature that would be "considered the world over a symbol of Los Angeles."[123] If anyone appreciated the importance of communication networks and organization, it was the architectural firm of the Capitol Records Tower, Welton Becket and Associates. Their guiding principle – "total design" – was one way in which the cybernetic values of control and communication were imprinted on building projects, but the firm also ventured into urban planning and lobbied for new freeways to connect the sprawling cities of the Los Angeles basin.[124]

Los Angeles was home to some of the more spectacular cases of controlled spaces, blurring the boundaries between the functional and the fantastic. When Welton Becket was commissioned to design a new city on the Fox Movie stage lot, the company hosted the press release on the old Western movie set. Century City, completed in 1963, was a planned urban space built according to principles of "total design," with every residential need provided for. It was a city of tomorrow from the makers of the house of tomorrow. In Anaheim, as we have seen, Becket's friend Walt Disney opened Disneyland in 1955, another controlled space of fantasy that was imbued with visions of futuristic living. One of the park's realms, Tomorrowland, featured its own House of Tomorrow and included a Disney-style take on the transportation systems that were so symbolic of Los Angeles

[122] United States Congress House Committee on Ways and Means, *Highway Revenue Act of 1956: Hearings Before the Committee on Ways and Means, House of Representatives, Eighty-Fourth Congress, Second Session, on H.R. 9075...* (U.S. Government Printing Office, 1956), 561, https://books.google.com/books?id=koeqiLSmzKAC.

[123] Martin Wachs, "The Evolution of Transportation Policy in Los Angeles," in *The City: Los Angeles and Urban Theory at the End of the Twentieth Century*, ed. Allen J. Scott and Edward W. Soja (University of California Press, 1998), 106.

[124] Rita Daraio Lewis, "'Cure-All' Freeway Sparked," *Westwood Hills Citizen*, February 7, 1957, Box 13, MacDonald Becket papers documenting the work of Wurdeman and Becket, Welton Becket and Associates, and the Becket Group, 1944-2011.

with the park's monorail.[125]

In the 1980s several theorists began to reconceptualize the history of urban development in the city of Los Angeles. Riffing on Walter Benjamin, geographers Edward Soja and Allen Scott declared that Los Angeles was the "very capital of the late 20th century, *the paradigmatic industrial metropolis of the modern world.*"[126] Just as Manchester in the United Kingdom represented the city of the industrial revolution and Paris, the city of the *Belle Époque* in France, Los Angeles was configured as the city that encapsulated the values and global power of the United States. In this theoretical turn, Los Angeles was considered as the model for post-war living because of both its functional and fantastic form. Michael Dear and Steven Flusty argue that "California in general, and Los Angeles in particular, have often been promoted as places where the American (suburban) Dream is most easily realized." They go on to suggest that "architectural dreamscapes are readily convertible into marketable commodities, i.e., saleable prepackaged landscapes engineered to satisfy fantasies of suburban living."[127] Earlier, we explored the "prepackaged landscapes" that shaped the suburban fantasy in the 1950s through the architectural practices of Welton Becket. The extent to which fantasy design also had a parallel in music recording production is striking.

I have also suggested that recordings of the 1950s where often presented as "prepackaged landscapes" themselves. *Music Out of the Moon*, and other *exotica* records presented fantasy environments like outer-space or forgotten islands of the Pacific. These studio products, often promoted as the highest of high-fidelity recordings, blurred reality and fantasy in their portrayals of fantasy space. The effectiveness of these records was precisely in their use of electroacoustic technology to manipulate the sonic space of sound on the recording, and awaken the imaginative potential of its listener. But the aesthetic desire for spatial control over sound was wrapped up in the technical developments of the modern recording studio as developed in Southern California. As Capitol artist Lex Baxter joked when describing the origins of his *exotica* records, "I don't think I got any further than Glendale."[128] Just as the recording studio was the privileged space of sonic control and auditory landscapes, the urban development of the Los Angeles basin was also a model for new forms of cybernetic control.

For Edward Soja, spatial manipulation is the defining feature of what made Los Angeles the paradigmatic city of the late twentieth century, a facet directly related to its urban structure. Soja's descriptions of Los Angeles mimic Wiener's description of a city as a cybernetically-linked communications system. "Los Angeles is everywhere," he writes,

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[125] John M. Findlay, *Magic Lands: Western Cityscapes and American Culture After 1940* (Univ of California Press, 1992), 95.
[126] E. W. Soja and A. J. Scott, "Los Angeles: Capital of the Late Twentieth Century," *Environment and Planning D: Society and Space* 4, no. 3 (1986): 249.
[127] Michael Dear and Steven Flusty, "Postmodern Urbanism," *Annals of the Association of American Geographers* 88, no. 1 (1998): 56.
[128] David Toop, *Exotica: Fabricated Soundscapes in a Real World* (Serpent's Tail, 1999), 43.

adding that “everywhere seems also to be in Los Angeles.” The city becomes the same kind of media hub that characterized the Capitol Tower as, “to it flows the bulk of the transpacific trade in the United States,” with “global currents of people, information and ideas accompany the trade.”[129] The city of Los Angeles itself promoted their spatial connectivity in three surveys undertaken between 1960 and 1963. These surveys, called the “Centropolis Reports” laid the groundwork for “Central City,” a name given to the downtown area and the basis of a new urban plan. In a 1964 booklet issues by the Los Angeles Planning Department, the plan is described in the following terms: “Central City is going through a multi-form change, becoming an interrelated net of administrative, executive, and cultural centers – nuclei of entirely new developments designed to serve the far-flung metropolitan complexes of the Western United states and the Pacific Basin.”[130] This proposal for L.A. revealed a conception of urban space along the same lines as Wiener’s conception of the city even using his terminology when they describe the city as a communication “net.”

The golden age of the recording studio, to conclude, aligned with the golden age of Los Angeles. The Capitol Records Tower and the Los Angeles urban area were both paradigmatic emblems of cybernetic, spatial control. Whilst audio engineers framed their approach to the recording studio as an attempt to negate acoustic space and extract “pure” sound, the spaces of the recording studio were in fact “tuned” to an electroacoustic recording system, a system that had deep connections to theories of listening and perception. A similar process of incorporation was applied to the urban space of Los Angeles, the city becoming a model for a new form of urban living defined by “connected urban microcosms.”[131] Urban development in Los Angeles was itself “tuned” to its systems, each city atomized and yet connected, as tract housing and planned communities followed the spatial pattern determined by existing freeways. Whilst the Capitol Studio was the first purpose-built recording space, and the first of many recording studios built in Los Angeles in ensuing years, the function of the recording studio in the present is being challenged.[132] Where the Capitol Studios pioneered the integration of all the elements of audio control in one environment, this role has now become a feature of the personal computer and the various software packages that can replicate the electroacoustic recording system digitally. The Capitol Tower contributed to the concept of a centralized space for controlling sound, but perhaps the lasting impact of the Tower on modern recording practice was its Los Angeles approach to the recording process: music recording as the construction of fantasy space.

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[129] Edward W. Soja, *Postmodern Geographies: The Reassertion of Space in Critical Social Theory* (Verso, 1989), 222–23.
[130] Los Angeles Planning Department, *Centropolis: The Plan For The Central City Los Angeles*, n.d., 5, http://archive.org/details/CentropolisThePlanForTheCentralCityLosAngeles.
[131] Soja, *Postmodern Geographies*, 223.
[132] Nathan Olivarez-Giles, “Studios Left out of the Mix,” Los Angeles Times, October 13, 2009, https://www.latimes.com/archives/la-xpm-2009-oct-13-fi-smallbiz-studios13-story.html.

Chapter 2

A Critical Organology of the Mixing Console

In Chapter 1 I explored the construction of a modern recording studio: the 1956 Capitol Records Tower. I identified the drive towards spatial control as the principal *raison d'être* of electroacoustic sound systems. The Capitol Records studio was designed as a tightly controlled acoustic space. At the same time, sound recording itself was reconceived as the construction of a spatial event. One of the novel affordances of the electroacoustic recording system was the ability to imbue sound with spatial qualities, through effects like artificial reverberation, or by changing amplitude and frequency characteristics of the audio signal. Recordings made with this technology, often described as "high-fidelity" records during the 1950s and 60s, not only offered improved sound quality but also introduced notions of auditory perspective. Music producers took an increasingly environmental approach to their craft, a method that had roots in earlier sound systems developed for movies, such as the Fantasound system of Walt Disney's 1940 film, *Fantasia*. Both aspired to a fantastical and environmental aesthetic.

In this chapter I focus on the sound that was created in the modern recording studio. If the Capitol Tower can be considered a "modern" studio, as I argued in Chapter 1, I now explore how "high-fidelity" recording revolutionized notions of "modern sound." Emily Thompson in *The Soundscape of Modernity* (2002) has argued for the growth in listener consciousness and the ascendency of that she calls "modern sound" by the 1930s. For Thompson, "modern sound" was "clear and focused," lacking the spatial properties of an acoustic environment that was often the result of reverberation.[1] Thompson's history largely focuses on architectural acoustics and the sound engineers who sought to control and eliminate reverberation, recasting this property of sound as noise.

My argument is that following the development of electroacoustic systems, modern sound was born in plasticity. The modernist impulse was not just to strip sound of properties deemed superfluous, but to imbue sound with infinite possibilities, and a certain three-dimensionality. With the development of electroacoustic technologies and "artificial" audio effects, sound became malleable. Jonathan Sterne adds a caveat to Thompson's narrative about the elimination of reverberation. For Sterne, who focuses on the audio arts in general, the direct qualities of "modern sound" were also met with the creative possibilities of "detached echo." In reference to sonic practices that manipulated reverberation as an effect, Sterne claims, "sonic space becomes ever more plastic."[2] And yet, one could go further than Sterne: it was not so much space, as *sound itself* that was increasingly qualified as *plastic* by practitioners of electronically mediated sound.

Take the conductor Leopold Stokowski, who anticipated claims about music's

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[1] Emily Thompson, *The Soundscape of Modernity: Architectural Acoustics and the Culture of Listening in America, 1900--1933* (Cambridge, Mass.: The MIT Press, 2004), 233–34.
[2] Sterne, "Space within Space," 115.

newfound flexibility through electroacoustic technologies in an article for *The Atlantic Monthly* in 1935. "New Vistas in Radio" was a sweeping, mountain-top narrative for the future of music, aided by electronics. At the time of the appearance of Stokowski's article, "talking" movies and radio had been utilizing some of the founding principles of telephone technology to transmit sound for around a decade. Stokowski drew attention to the ways that these media industries were manipulating sound electronically, methods he had demonstrated himself in a series of collaborative efforts with Bell Laboratories. Stokowski's experience with electroacoustic systems embodied the beliefs incarnated in his article. "The potentialities of music, with reference to dynamic power and frequency," he exclaimed, "have reached new heights of plasticity and controlled power, never dreamed of in the past as possible of attainment."[3] The ability to manipulate the loudness and tone of a sound through electroacoustic technology had plasticized sound itself. In this chapter I will focus on the kind of sound that was conceived *through* the modern recording system, which leads me to consider its central device – the mixing console.

Where building a recording studio from the ground up allows for more permanent methods of control over sound quality, the mixing console is the final destination for the ongoing spatial manipulation of recorded sound. The mixing board is a mosaic of various technologies, the container for a variety of audio effects. As such, they often include amplifiers, electronic filters, dynamic range compressors and resistors as built-in components. Mixers have also been known by a variety of names, ranging from the militaristic overtones of "control turrets" to more technical and mundane forms such as "mixing desks," "dramatic control panels," and "speech input equipment." "Mixing consoles" and "consolettes" were popular terms in radio broadcasting and evoke the language of furniture catalogues whilst the colloquial "mixing board" implies a more rustic technology. In many cases mixing devices were developed on-the-fly, the influential producer Tom Dowd perhaps coming closest to a literal "mixing board" when he built one out of a salvaged door.[4]

The mixing board installed in the Capitol Records Tower (Figure 2.1) was continually developed and updated to follow new trends in sound recording. The original 1956 console had ten inputs, eight of which could be routed to the reverberation chambers, whose volume could be "*continuously* controlled" (according to a 1957 article in the *Journal of the Audio Engineering Society*).[5] A 1963 article in the same journal revealed some of the changes that had been applied to the original designs of the studio following the introduction of stereophonic recording. Notably, technical details for the mixing console occupy much more print-space in the later article. A simplified block diagram for the mixing circuitry is provided, and the numerous sonic effects embedded in the console are described: variable effect equalizers that could alter the bass and treble of

[3] Leopold Stokowski, "New Vistas in Radio," *The Atlantic Monthly*, January 1935, 8.
[4] Horning, *Chasing Sound*, 119.
[5] Bayless, "Innovations in Studio Design and Construction in the Capitol Tower Recording Studios," 75.

individual channels, reverberation mixes, and panning controls for placing sound to the left or right were all built into the console.[6] The ability to monitor sound levels was also enhanced in the later mixing console, with meters for the program levels, the reverberation channel and the limiter devices used to control loudness.[7] The audio mixing console was not just a system to mix the relative levels of sound, but the control center of an increasingly complex system of technologies, effects and people.

Figure 2.1: The Capitol Records Mixing Console. Image from Bayless, James W. "Innovations in Studio Design and Construction in the Capitol Tower Recording Studios." *Journal of the AES* 5, no. 2 (April 1957), 75.

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What is a mixing console? Let's begin with an organological description. The standard design utilized in most audio mixers consists of individual sound inputs which correspond to channels that run across the board from left to right. This horizontal arranging underlines the synthesizing properties of the mixing board, acting like an additive electronic synthesizer. In processes of additive synthesis, selected elements are added to a single soundwave to create a rich sound. In a similar fashion, the mixing console creates a combined timbre by summing its channels into a master output. This synthesizing effect betrays the normalized assumptions at the heart of electroacoustic media: that sound can be channeled into individual tracks in the first place, before being combined, controlled and sent out in various ways.

The mixing board creates limits, ranges and thresholds, imposing these delineations onto sound. In its horizontal channels it creates a range determining the number of inputs and the types of sounds available for a given mix. Compared to standard linear keyboards that frame a sound range between its lowest and highest keys, the mixing board offers a range of timbres based on the sonic input of the channel. Whilst

[6] Davis, "A Multi-Purpose Studio Recording System," 369–70.
[7] Ibid., 370.

the circuitry of the sound board is fixed in copper, it is a flexible interface whose only requirement of the various sounds it receives is that they be in electrical form. These sounds can then be manipulated by altering their frequency response using equalization, a technology that utilizes wave filters. Equalization can change the amplitude of specific frequency ranges usually set between the two limits of human perception of frequency, 20Hz to 20,000Hz, and represents another way in which the mixing board creates a bounded range of sonic control.

Within the horizontal separation of sound inputs are the vertical divisions applied to each channel. These might include individual equalization for each track but nearly always culminate in the fader. The fader is technically a potentiometer, a variable resistor opposing the incoming voltage of an electroacoustic signal. As acoustic sound pressure is represented by voltage in its transduced form, resistors control a large component of the *perceived loudness* of an audio source and therefore the term "fader" reflects the acoustic phenomena caused by the electrical function of the resistor. Originally developed as rotary knobs that could be twisted left or right for quieter or louder effects, legend has it that the modern linear fader in music recording mixers was developed by a figure we have already seen, Tom Dowd, who sought an easier way to handle multiple faders in the late 1950s.[8] Dowd drew inspiration for his linear fader from the piano key and its capacity to play loud or soft in correlation with physical force.[9] So whilst the mixing console functions as the electrical centerpiece of the recording system, many aspects of its form reveal it to be the product of an auditory, even musical design.

The mixing board became the prominent technology of the sound studio in the 1950s. In that decade, mixing consoles were specifically designed for music recording studios. Various iterations of mixing boards had been in use for broadcasting since the 1920s but few, if any, had been specifically designed for recording. Companies that had manufactured mixing consoles for radio broadcasting began to make similar devices specifically for recording studios in the middle of the century.[10] As seen in Chapter 1, the 1950s saw renewed attention given to the phonographic record. The construction of mixing boards designed for music recording reflect the new techniques and demands of this trend.

On a similar note, the sonic impact of the mixer and the "sound-man" at its helm, was beginning to be a heard and valued component of the musical experience in the 1950s. In 1956 music critic Edward Tatnall Canby presciently noted "that the time is almost here when the microphone artists, the men responsible for the acoustics of the recorded sound, should be billed on our record covers along with the composer, the conductor, the performer."[11] Canby concluded, in an article entitled "The Sound-Man

[8] Roey Izhaki, *Mixing Audio: Concepts, Practices and Tools* (Taylor & Francis, 2013), 174.
[9] Horning, *Chasing Sound*, 107.
[10] Ibid., 117.
[11] Edward Tatnall Canby, "The Sound-Man Artist," *Audio*, June 1956, 44.

Artist," that "sound recording is now an art and a potentially big art."[12] Whether or not he knew it, Canby was witness to the developing role of electroacoustic devices in the recording process. He recognized that these technical alterations of the sonic event that were happening in the recording studio, and that the mixing console, had instituted a new kind of social actant and creative polity. Sound recording had become an art form.

The increased role of the mixing board in recordings of the 1950s points to a prominent feature of modern sound that has often been overlooked – the idea that "modern sound" is "mixed" sound. To return to Emily Thompson's argument, whilst the modern soundscape was radically divorced from "live" environments, sound was, in many cases, extracted only to be mixed together. I want to suggest that through electroacoustic devices, such as the mixing board, sound was designed, and that a defining aspect of modern sound is the practice of sound design. "Sound design" is a term now common in movie production, used to denote the person tasked with applying sonic effects to actions on the screen. But in a broader sense the mixing board operator is also a designer of sound, especially if we draw on the etymological roots of "design" and its relative word, "designate." We could say that the mixing board operator designates sounds, physically shaping and maneuvering sound in the construction of a mix.

A Pre-History of the Mixing Board

Mixing boards, therefore, were designed for total sound design. In what follows I trace the design and use of the mixing board in three different industries after highlighting the telephonic "pre-history" of the mixer. I explore three genealogies of modern sound through the evolution of mixing devices in different industries. The first genealogy follows the story of the mixer as used in Public Address Systems (P.A. Systems). P.A. Systems were one of the first places where the power of amplification, through the invention of vacuum tubes, was put to demonstrable use. However, the discourse surrounding P.A. sound maintained a "phonographic" mindset, where live sound was supposed to be captured in its purest form – the system was designed to act as an invisible mediator. In the ensuing two genealogies I trace the use of mixing devices in radio and movies where the mixer was increasingly used for artistic effect. Here, I return to a concept I introduced in Chapter 1, that in radio and movie productions the mixing board was utilized to create "Fantasound." To recap briefly, "Fantasound" was the sound system devised for Walt Disney's 1940 movie, *Fantasia*, where he sought to create a spatially aware soundscape. I see in Fantasound a model for a more general way of thinking about sound in the 1950s that promoted a mode of sound representation that moved away from phonographic notions of capturing a live event. In place of the phonographic illusion, electroacoustic technology afforded the immersive, environmental, and supremely modern experience of "fantasy sound." But more on that later.

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[12] Ibid., 61.

An obvious precursor to the mixing board is the switchboard, as pictured in Figures 2.2 and 2.3. The first switchboard, which brought together multiple telephone lines through a central control unit, was put to use in New Haven in 1878.[13] The switchboard operator could connect a caller to their desired line by physically connecting the two lines at the desk, completing the circuit. Switchboards were an integral part of the telephone exchange where the disparate nodes of the communication network came together in a central location. The switchboard introduced to its users the most basic control function in any communication system: channels were either on or off.

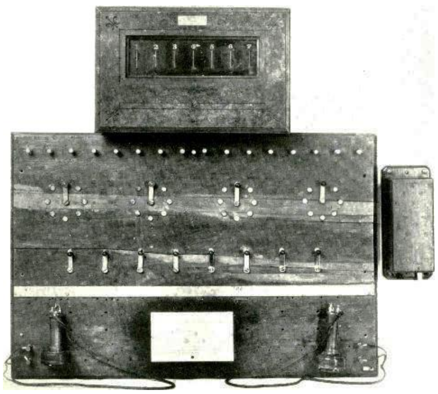

Figure 2.2: 1878 Switchboard. Image from "Telephone Signalling." Bell Laboratories Record 1, no. 6 (February 1926), 242.

Figure 2.3: 1928 Cordless "B" Board. Image from Lacerte, W.J. "Step-By-Step Cordless 'B' Board." Bell Laboratories Record 6, no. 1 (March 1928), 211.

The mixing board occupies the same role as a switchboard in the way that it acts as a central control unit for a larger system. As if to reinforce the organizing power of the switchboard over the potentially messy network of frail transmission lines, these switchboards were designed as solid units of furniture. Early switchboards were boxy in design (Figure 2.2) but as the number of telephone lines increased, switchboards were also manufactured as desks, designed ergonomically for a seated operator (Figure 2.3).[14] The development of switchboards demonstrates an early and important shift in how electronic technologies of sound were being reconfigured in the first decade of the twentieth century. Instead of a wall-mounted instrument panel programmed by technical experts, switchboards were part of the "live" event of human communication conducted through the telephone network. The switchboard operator thus occupied a unique role within the system: unlike the engineers who dealt with issues of technological maintenance, switchboard operators enjoyed a more performative relationship with the

[13] Bell Telephone Laboratories and Fagen, *A History of Engineering and Science in the Bell System*, 20.
[14] "Telephone Signalling," *Bell Laboratories Record* 1, no. 6 (February 1926): 242; W.J. Lacerte, "Step-By-Step Cordless 'B' Board," *Bell Laboratories Record* 6, no. 1 (March 1928): 211.

telephone network.

The evolution of switchboard design reflects the increasing importance of the operator. Numerous features were added to the "boards," as they were colloquially known, to enable smoother operation. One example arrived with the introduction of cordless boards in 1907 by The Western Electric Company.[15] On cordless boards operators could connect calls by pressing various "keys," rather than the previous method of physically plugging and unplugging wires into patches called "jackknife" switches.[16] Key switching introduced a new level of abstraction into the work of the switchboard as the actual switching of telephone calls was now hidden from the operators view and built into the machine. Switching could be achieved with a much easier physical motion and yet it created a dramatic change within the telephone network: a new way of manipulating the functioning of the telephone system.

Many other aspects of control were incorporated into the switchboard as the device became a more centralized node for communication. Switchboard operators could handle multiple "channels" of audio signals, check the functioning of the system through meters, and plug their own voice into the switching network when necessary. An article in the *Bell System Technical Journal* details the multiple affordances of control that were developed in a 1923 switchboard for communication with ships:

> The switchboard provides for four channel telephone or telegraph operation and for the control and monitoring of all channels. In the operation of the system one operator, located at this switchboard, has complete control of the entire transmitting plant.[17]

Monitoring, controlling and switching: designs for the switchboard were oriented towards a central, usually female, operator. The manufacturers of these switchboards were in effect designing an instrument of control that shaped how operators interacted within and upon the larger system. We can see here how the physical space of the switchboard began to function as a miniature model for the space of the network itself, since every nodal possibility of the system was represented on the board.

Switchboards, in short, were an early form of control interface in the telephone system and the controls embedded in the board afforded physical and conceptual relationships between the communication system it was a part of and its operator. Cultural theorist Brandon Hookway has described the interface as "a relation with technology rather than as a technology itself."[18] His focus on "the relation" rather than the thing itself offers a useful way of thinking about how both switchboards and mixing boards function as interfaces. Switchboard designs formalized the kinds of control that

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[15] Bell Telephone Laboratories and Fagen, *A History of Engineering and Science in the Bell System*, 674.
[16] Ibid., 491.
[17] Espenschied Nichols, H.W. Lloyd, "Radio Extension of the Telephone System to Ships at Sea," *Bell System Technical Journal*, July 1923, 152–53.
[18] Branden Hookway, *Interface* (Cambridge, Massachusetts: The MIT Press, 2014), ix.

were possible in a communication system and how an operator could manipulate them. This had conceptual and physical consequences, where the ability to change the quality of sound drastically by the twist of a knob created certain expectations about the malleability of sound. We will see that the kinds of relationships and assumptions that owed to practices of knob-twisting were carried to even further extremes in the interface of the mixing console, where dials of variable shapes and sizes were increasingly featured and fetishized.

Genealogy I: "Modern Sound" by Vacuum Tube and Public Address System

Figure 2.4, taken from an issue of the Bell Laboratories' in-house publication in 1926, presents a man at the controls of an early Public Address (P.A.) System. The dapper-looking man at the amplifier was already exerting a level of control over sound that was incommensurate with that of recordists of acoustic phonographs. Even with the affordances of electroacoustic control, the kind of sound privileged by P.A. operators was still a "natural" and "pure" sound, mirroring the sonic values esteemed in phonography. However, the electrification of sound in the P.A. system generated new questions about how best to represent sound. The proto-mixing devices of the P.A. System still required volume levels to be set, introducing controls that were absent in the art of phonographic recording. The concern for our man at the control desk, throughout the development of the P.A. System, was how to reconcile two opposing views. On one hand was the need to achieve untouched "pure" sound; on the other, was the desire for electronically "enhanced" sound.

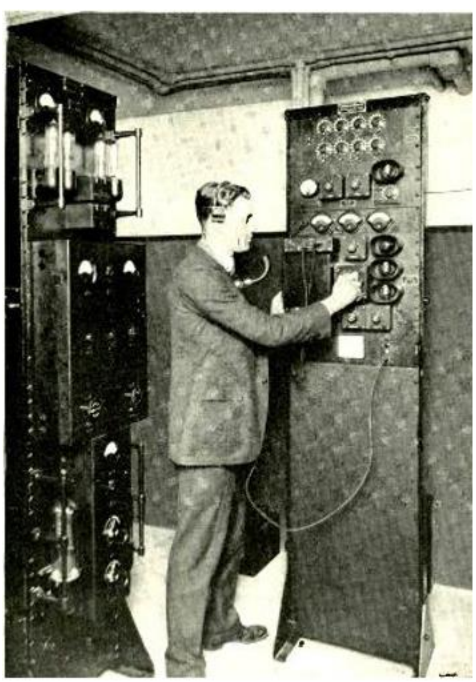

Figure 2.4: At the controls of a Public Address System amplifier. Image from Dowey, T.I. "Public-Address Systems," *Bell Laboratories Record* 3, no. 2 (October 1926), 52.

At the turn of the twentieth century, famously, American Telephone and Telegraph Company (AT&T) explored ways to extend their telephone system across the vast American continent, as they aimed to provide coast-to-coast services. American inventor Lee de Forest patented his triode "audion" tube in 1908, a device that had the potential to amplify audio signals. After a 1912 meeting with De Forest, AT&T bought partial rights to audion technology and immediately began developing the invention for use in telephone amplifiers.[19] However, in the minds of Bell researchers it was clear that de Forest had not fully comprehended what exactly made the audion work as an amplifier. In the standard historical account, Harold D. Arnold at Bell's manufacturing wing, Western Electric, and Irving Langmuir of General Electric helped turn the audion into a vacuum tube capable of practical amplification in the telephone system.[20] On the back of their achievements, at the 1915 Panama Pacific Exposition in San Francisco, AT&T reached its goal of a communication system that through wires and tubes, united the coasts of the United States.

The transcontinental line was performatively demonstrated at the Exposition, accompanied by a booklet distributed from the AT&T stall titled "The Story of a Great Achievement." Whilst the names of many contributors to telephone technology were recognized in the booklet, Lee de Forest's was not among them.[21] This exclusion from Ma Bell's narrative of progress was particularly grating for de Forest who had to witness this snub in person. De Forest had his own company stall at the exposition, as did the Napa-based Californian company Magnavox, which showcased a crude amplified music system using a phonograph, a battery and a loudspeaker.[22] If the San Francisco Exposition had been driven by a city's desire to overcome the catastrophic movement of earth it had experienced nine years earlier, it contained within its stucco walls all the means to move sound indefinitely across it.

Whereas Magnavox tapped into the demand for amplified music systems, it was Bell Telephone's research and developments in vacuum tubes that would eventually provide the practical means to achieve practical sound amplification. The vacuum tube was the kickstart that revolutionized the sound experience of Public Address Systems, radio and movie productions. The first step had been to convert audio waves into electrical waves, as per the principal discovery of telephony. The invention of the vacuum tube made it possible to amplify these electrical waves to usable levels in a variety of applications. It also introduced the idea that in its electrical form, the sound wave could

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[19] Hugh G. J. Aitken, *The Continuous Wave: Technology and American Radio, 1900-1932* (Princeton University Press, 2014), 243.
[20] McGinn, "Stokowski and the Bell Telephone Laboratories: Collaboration in the Development of High-Fidelity Sound Reproduction," 39.
[21] Mike Adams, *Lee de Forest: King of Radio, Television, and Film* (Springer Science & Business Media, 2011), 152.
[22] Michael Crow and Barry Bozeman, *Limited by Design: R&D Laboratories in the U.S. National Innovation System* (Columbia University Press, 1998), 145.

be altered and manipulated. Amplification was a crucial first step, but only one aspect of the numerous ways in which electrified sound could be controlled.

P.A. Systems had always been described and conceptualized as self-contained systems. To the Telephone Company they were a miniature phone network made up of individual elements that were connected by wires. In their 1923 paper on the P.A. system developed within the Bell Telephone System, engineers I.W. Green and J.P. Maxfield included a schematic of the network to show the ways in which all the individual components formed an integrated whole (Figure 2.5). In Figure 2.5, the top row of boxes guide the flow of sound from the input at the transmitters (microphones) to the output at the sound projectors (speakers). In between we can see the various amplifiers boosting the signal before being fed into a volume control panel that includes a volume indicator and monitoring projector. At this stage the affordances of sonic manipulation are limited, with the volume control panel being the main interface for control. This 1923 system had two microphones, with the transmitter control panel capable of switching between the two or sending both channels to the amplifier.[23] The schematic betrays that the idea of control in the early P.A. System was still associated with the individual devices within it.

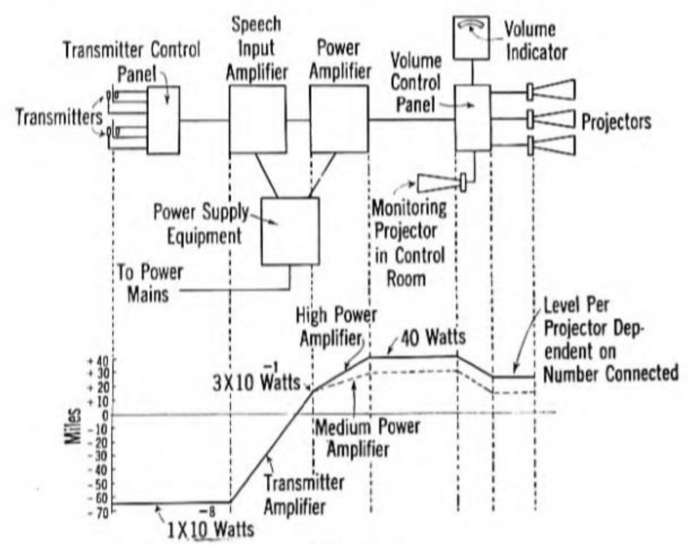

Figure 2.5. P.A. schematic Green, I.W., and J. P. Maxfield. “Public Address Systems.” *Bell System Technical Journal*, April 1923, 124.

This Bell-designed P.A. System was first put to use in 1920, and no drastic amendments were made to it until the Second World War.[24] The individual components of the system were swapped out for newer ones but its organizing principle remained intact. An article by P.G.A.H. Voigt from a 1936 issue of *Wireless World* dispensed some of the acquired wisdom of a veteran user of this system, who suggested that for any P.A.

[23] I.W. Green and J. P. Maxfield, “Public Address Systems,” *Bell System Technical Journal*, April 1923, 128.
[24] Emily Thompson, “Dead Rooms and Live Wires: Harvard, Hollywood, and the Deconstruction of Architectural Acoustics, 1900-1930,” *Isis* 88, no. 4 (1997): 615.

operator faced with a lack of room acoustic data, “the most valuable quick test is to turn the volume control until the system starts howling.”[25] Again, according to this account, the main option for control was still volume, although the article hints that some amplifiers in use at that time may have had the capacity to manipulate the frequency response of the sound. “If the amplifier is provided with the necessary controls,” Voigt explained, “it should be possible to adjust the frequency response so as to suit the hall.”[26] On the whole, mixing boards and control devices for P.A. Systems were never developed to the same extent as they were in other media, despite the fact that they supplied a pre-echo of the electrically amplified sound later cultivated for radio and talking movies.

Whilst early radio broadcasts were prized for their iconic and desirable sound, the P.A. System was instead assessed according to its ability to function as an invisible mediator. Its medial transparency was a feature highlighted by Maxfield and Green in their original paper on the P.A. System. The authors made it a special point to mention that whilst the sound projectors could be placed quite far away from the speaker, hearers tended to perceive that the source of the dislocated sound was the feeble acoustic voice of the human orator. So convincing was the illusion that the authors stated that audiences would only believe it was the loudspeaker sound they were hearing once the system had been turned off, since at this point “their inability to hear made them realize how successfully the system could operate.”[27]

The notion of the P.A. System as a transparent index of a sonic event has its counterpart in the history and narratives of the phonograph. It is interesting that in both phonography and P.A. practice, the development of mixing boards and other devices for sound control occurred much later than in radio and movie industries. Progress on P.A. Systems and phonographs was geared towards preserving “natural” sound, perhaps because of their association with the voice and the functions in which they were employed. The aesthetic developed for radio and movies, as we shall see, was instead marked by the creation of fantasy soundscapes. It is striking that these latter industries so readily embraced the electrical manipulation of sonic qualities, whereas cultures of audio preservation did not.

The divergent aesthetic concerns of P.A. and radio were brought into sharp contrast in an article published in *The Sibley Journal of Engineering* in 1931. Here, the author began, ironically, by noting the similarities of the radio and P.A. System musing that “a P. A. System is nothing but an overgrown radio set, dealing with only the audible frequencies.”[28] Switching tack, he dramatized key differences in each sound ideal:

> The general tendency of the radio public is to suppress the top frequencies and accent the heavy base [sic]. This appears to “enrichen" the music, but

[25] P.G.A.H. Voigt, “Sound Distribution in PA Work,” *Wireless World* 38, no. 12 (March 20, 1936): 295.
[26] Ibid.
[27] Green and Maxfield, “Public Address Systems,” 117.
[28] A.C. Stallman, “Public Address Systems,” *The Sibley Journal of Engineering* 45, no. 3 (March 1931): 85.

> greatly cuts down the intelligibility of the voice. For Public Address work this is just the opposite of what is required of course, because here we want the voice to sound as natural as possible and to be clearly understood.[29]

The author drew a distinction, in other words, between the pure, natural sound of the voice and the enrichened musical tones of the radio. For him, it was exactly the suppressing and accenting of frequencies, the manipulation of the sonic event, that made radio a kind of "fantasy sound machine." The P.A. system, by contrast, was a functional device useful to sonic distribution.

One person who did approach the P.A. System with a radio mindset was Leopold Stokowski. Stokowski conducted experiments with Bell Laboratories throughout the 1930s. As mentioned earlier, Stokowski was keenly interested in the affordances of electroacoustic technology to render sound more "plastic." At one concert in 1933, at the Philadelphia Academy of Music, Stokowski was able to demonstrate these electroacoustic techniques through the use of a P.A. System. This system was specially designed by Bell Labs for this event. The music that was to be performed had already been recorded onto a roll of film, and so the event itself was masquerading as a live orchestral concert in ways reminiscent of Edison's tone tests with the phonograph. The conductor, Stokowski, performed the one live element of the entire concert. He had been equipped with a mixing device that controlled the loudness of the recorded orchestra. During recording, the dynamic range of the orchestra was squashed in order to be contained on the film strip. At the 1933 concert Stokowski reintroduced the dynamic range to his own taste which were often governed by a desire for the extreme. "In his effort to build huge climaxes he twisted a knob off one of his dials," noted one reviewer, "the audience was none the wiser.'[30] In 1933, apparently, Stokowski hadn't quite learned how to master the sonic forces at his disposal.

A later demonstration, at Carnegie Hall in 1940, advertised the spectacle of Stokowski's on-stage "mixing" as a concert of "enhanced music." The headline of an article in *The New York Times* described the concert evocatively: "Sound Waves 'Rock' Carnegie Hall as 'Enhanced Music' is Played." "The loudest musical sounds ever created crashed and echoed through venerable Carnegie Hall last night," wrote the *New York Times* reporter, "as a specially invited audience listened, spellbound, and at times not a little terrified."[31] One of the specially invited audience members was composer-pianist Sergei Rachmaninoff, who was asked to share his views. He expressed his opinion that enhanced music was admittedly "a marvelous thing, considered from the standpoint of demonstration," but that there were issues that obviated a dismissal of the entire project and a return to "non-enhanced" music:

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[29] Ibid.
[30] Waldemar Kaempffert, "New Tone Quality By Wire Achieved," *The New York Times*, April 13, 1933, 14.
[31] "Sound Waves 'Rock' Carnegie Hall As 'Enhanced Music' Ls Played," 25.

> Take that *Pictures at an Exhibition* [by Mussorgsky-Ravel] Why, I didn't know what it was until they got well into the piece. Too much "enhancing," too much Stokowski. I would like to hear more music without enhancement, perhaps some of the things I know well. Then I might be able to say something.[32]

As Rachmaninoff's tirade suggests, the ability to "enrich" or "enhance" music was unsettling for many listeners exposed to early P.A. Systems, although it is interesting to note that commercial exposure was limited to the transmission of voice and classical music. As a mediator of orchestral music and vocal tone, the P.A. System was supposed to dispense clear, pure sound "as it occurred in reality," the concern being that mixing devices could just as easily degrade this "real sound" as enhance it. It is unsurprising then that the need for more complex mixing boards and devices that could exploit the affordances of electroacoustic control took hold in radio and film. These, after all, were the industries where sonic dreams were made.

<u>Genealogy II: "Modern Sound" by Radio Drama</u>

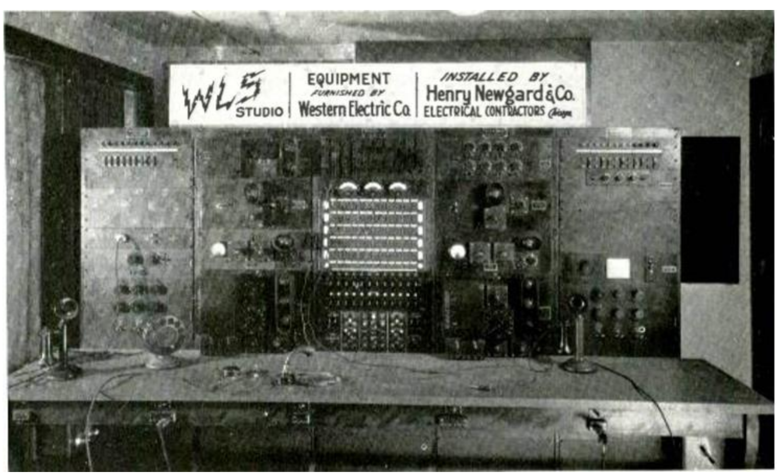

Figure 2.6: Early radio desk. Image from Evans, P.H. "Installing Radio Broadcasting Equipment." *Bell Laboratories Record* 1, no. 6 (February 1926), 233.

From the earliest days in the history of broadcasting, radio studio installations boasted the capacity to combine multiple sources of sound into a single mix. A report on radio installations by the Bell System subsidiary, Western Electric, notes the incorporation of "mixing panels" which were used to combine the inputs of a radio host's microphone and two other microphones in 1926.[33] In Figure 2.6, we see that in the control room of the studio, these mixing panels were mounted above and to the side of a microphone-laden desk. This image reveals a transitionary phase of design, where a telephonic style of wall-mounted control panel was beginning to look more like the mixing console synonymous

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[32] Ibid.
[33] P.H. Evans, "Installing Radio Broadcasting Equipment," *Bell Laboratories Record* 1, no. 6 (February 1926): 232.

with modern radio broadcasting. As yet, however, all the necessary controls were not yet accessible from a single desktop surface.

The architects of radio broadcasting studios were among the first to grapple with the actual design of electroacoustic technologies like the mixer. Manufacturers of the 1936 Collins 12H Speech Input Assembly, designed for radio broadcasting in the U.S., paid special attention to the needs of the expanding radio studio, creating a mixing device that arrayed the instruments of amplification across a distributed control surface.[34] This unit could mix four microphone channels and was designed in compact form. A period brochure for the unit relates the desire to unify and miniaturize the mixing unit. "Collin's engineers," it states, "have felt for some time that a complete studio input system could be wrapped up in a small, compact package which could be placed on the control operators' desk."[35] Evidence suggests, indeed, that manufacturers of radio mixing equipment in the 1930s were beginning to view the broadcasting studio as a special space: one with its own technical and aesthetic needs.

The design principle of the Collins mixing device was necessitated in part by a desire to break away from the telephone technologies that enabled radio broadcasting. The determination was to imagine an interface from the perspective of the radio broadcaster rather than from the technical viewpoint of another industry. The company was horrified by tales of telephone repeaters being used as amplifiers in radio stations, and it made clear in its publicity that "the Collins Radio Company was one the first equipment manufactures to temper telephone tradition with practical ideas which were related only to radio broadcasting."[36] This disaffection for telephony represented a substantial shift in how mixing devices were conceptualized, as radio executives shunned the utilitarian methods of rack mounted telephone technology in favor of designs that embraced the possibilities for total control over sound.

The Collins speech input devices were still considered technical instruments, but in the BBC's Dramatic Control Panel, first installed across the Atlantic in 1928, a mixing device was created to explore all the aesthetic potentials of sound design. Public radio in Britain devoted considerable financial resources to the production and broadcasting of radio plays, and to this end, they innovated uniquely complex procedures in their studios. A 1932 article in *Telegraph and Telephone*, written with a not-so-subtle air of British superiority, revealed the logic behind their innovative practices:

> In practically all other countries plays are not produced on the same lines as in the B.B.C., where each incident in a play is enacted in a different studio,

[34] Ben Bengler, *The Audio Mixer as Creative Tool in Musical Composition and Performance*, Beitrage Zur Elektronischen Musik (Graz, Austria: Institut fur Elektronische Musik und Akustik, 2011), 9.
[35] "Collins 12H Speech Input Assembly," n.d.
[36] Ibid.

> the transition from one incident to the next being by means of electrical fading devices operated by the producer.[37]

According to this article, the desire for aesthetic enhancement, as much as technical control, explained the use of multiple studios and those electrical fading devices that merged the audio from each recording space into a syncretic whole. This early mixing system was specifically designed to shape the dramatic effect of radio-plays and the possibilities of auditory illusion afforded by electroacoustic technology. The power of the "Dramatic Control Panel" as an aesthetic tool emerged in many aspects of its construction. It could accommodate a wide range of audio inputs: eleven separate channels with built-in control of artificial reverberation effects.

The Dramatic Control Panel's growing prestige was reaffirmed with the creation of a new design in 1932, as part of the BBC's transition to the newly designed Broadcasting House in central London. This second control panel was influenced by high modernist architectural values. Indeed, these values were passed on to radio producers themselves, who began to describe their mixing techniques in the language of environmental design.

In what follows, I unpack the work of the architect, Wells Coates, designer of the 1932 Dramatic Control Panel and Lance Sieveking, a radio producer at the BBC and one of its inventors. Both drew upon modernist, environmental concepts in their work with the mixing device.

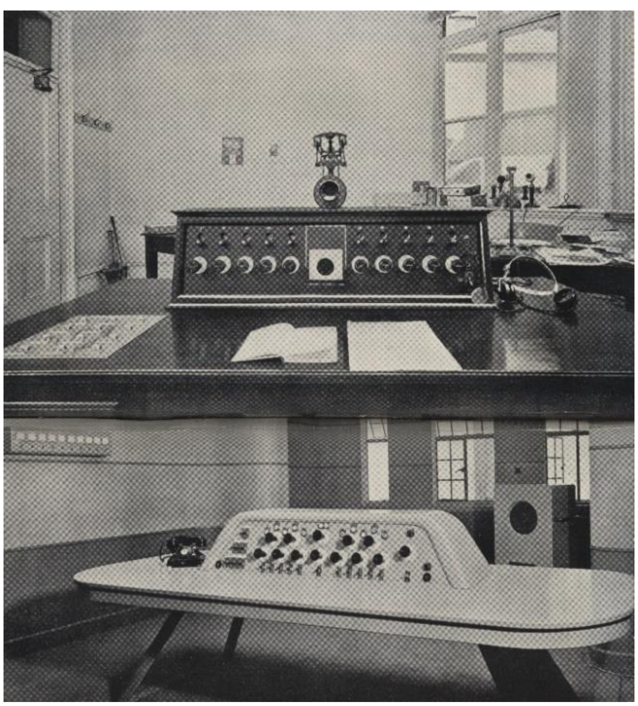

Figure 2.7: A comparative photograph of the original Dramatic Control Panel from 1928 on top, and the Wells Coates 1932 design below. Image from Sieveking, Lancelot de Giberne. *The Stuff of Radio*. London: Cassell and Company Limited, 1934.

[37] N. Ashbridge, "Broadcasting Developments," *The Telegraph and Telephone Journal*, June 1932, 184.

The 1932 Dramatic Control Panel pictured at Figure 2.7 was living equipment, an item of furniture seamlessly integrated into the stylish architectural design of Broadcasting House. A modernist through and through, Coates made his allegiances plain in articles such as "Furniture Today – Furniture Tomorrow" (1932) and "A Response to Tradition" (1933) both published in *The Architectural Review*. Coates borrowed from the language of environmental design, his 1932 article being a case in point:

> The architect is not concerned with architectural "styles" or fashions at all, but with the organization of a new service, which he alone of all "experts" can provide. The natural starting-place for this new service must be the scene in which the daily drama of personal life takes place; the interior of the dwelling – the PLAN – and its living-equipment, the furniture.[38]

Here, Coates reimagined the decorative objects of a house as equipment for a more functional environment. Where Coates recast furniture as equipment in this article, for the BBC's new Dramatic Control Panels, he turned equipment into furniture.

In general, Coates may have believed that his artistic philosophy was concerned with overcoming style in the name of functional progress. However, in his design for the Dramatic Control Panel, Coates gave technological, "functional" control a powerful aesthetic style all of its own. Coates described the dramatic functions of the Control Panel in these terms:

> When dramatic effects like rain, wind, or the hoofs of a horse are required, a switch will give the cue to the dramatic effects studio on another floor, and the turning of a control handle will increase the sound or diminish it until the producer cuts it out by turning the handle back.[39]

That the artistry of the producer at the Control Panel should be deemed worthy of poetic attention at all reveals the increased prestige given to practices of mixing. The control handle described here functioned as a tool for dramatic effect, not technical control. Coates's words were a clear demonstration of the fact that the Dramatic Control Panel had separated the technical work of the amplifiers and electronic circuitry from the aesthetic work of the panel controller, freed to shape the sound for dramatic rather than mere technical effect.

In 1934, Sieveking noted that the Dramatic Control Panel "was born when certain electric instruments made it possible, just as modern architecture was born when certain new materials were invented that made new shapes and methods of construction possible."[40] Electroacoustic sound was a "new material" for Sieveking, a resource that offered the same kind of potential for acoustic design that poured concrete brought to

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[38] Wells Coates, "Furniture Today - Furniture Tomorrow," *The Architectural Review*, July 1932, 31.
[39] Wells Coates, "The Dramatic Control Room No. 1," *The Architectural Review*, August 1932, Plate IV.
[40] Lancelot de Giberne Sieveking, *The Stuff of Radio* (London: Cassell and Company Limited, 1934), 102.

modernist architecture. The title of Sieveking's 1934 treatise on radio drama, *The Stuff of Radio*, gets to the heart of the way electrified sound was now treated as "material." For Sieveking the "stuff of radio" was specifically the plasticity afforded by electroacoustics, and this malleability made sound a workable material. The ability to both manipulate sound quality and trick the listener's ear came together in the "sound effect," a concept that indexed the apex of the radio artform:

> The sound effect, I repeat, is most truly the *stuff* of radio, because, whereas everything else that is broadcast existed before wireless was invented … the art of painting with pure sound is a new thing, peculiar to radio. And when great painting can be done with sound we shall one day know when a great artist shall use the medium.[41]

Surveying the radio practices established in the 1920s and 30s, Sieveking accounted for the ways in which the mixing engineer manipulated aesthetic effects within auditory mises-en-scènes. He categorized six types of sound effect, in order to demonstrate how psychology, cultural conventions and symbolism shaped sonic perception.[42] The radio producer, he implied, had been given a dynamic palette for artistic expression, informed by perceptual technics.

Sieveking saw the Dramatic Control Panel as a musical instrument, describing the manipulations of sound at the Control Panel as musical "movings." "All the world of sound is at your beck and call," he raved, "when you sit down at that beautiful instrument the dramatic control-panel."[43] In one passage in particular, which I shall quote at length, Sieveking poetically describes the thrill of auditory control and the aesthetic pleasure he attributes to the sound mixer:

> The moment comes, in the process of producing a radio-play, when you leave the cast and all the others, completely, and go up to the D.C. Panel room. It is then that you begin to hear with your actual ear what you had previously heard only with your mind's ear. The last part of the process is now. All the studios, banks of gramophones, and so on, are centralized here and you can weave them together, listening to what you are doing as it comes out of the loud speaker. Now you can begin to make those patterns and those pictures which melt as you listen. Here is your iridescent vapour, and you may paint with it on the underside of the clouds. Now here is poem, bee-hum, geese-cackle, woman-cry, and dynamite. Gather them together, feeling as you weave, the rhythm and tempo of the whole play. For a sense of rhythm and

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[41] Ibid., 73.
[42] Ibid., 65–66.
[43] Ibid., 100.

> tempo is the primary qualification of the good producer; and a sense too of what Hilda Matheson calls '*the general fluidity of time and space*.'[44]

The Dramatic Control Panel was thus construed as an artistic device, capable of sculpting sound in ways previously unimaginable.

Mixing devices for radio contributed several elements to the notion of "modern sound." The first relates to a growing desire for aesthetic control. We have seen that mixing devices in radio settings were designed not just for technical control but aesthetic control as well. A new relationship between operator and system thus emerged, as designers directed attention to dials in view of the artistic demands of radio drama. An organological history of those "linear" faders that Tom Dowd famously brought to recording consoles in the 1950s would recognize their indebtedness to radio drama control panels, where the move to associate vertical distance with sound intensity was a welcome advancement for artistically minded producers. An example of another early mixing console fitted with a vertical fader is presented in a 1936 article in *Wireless World*. The article describes the design of new studios for radio drama in Berlin, and notes that with the linear fader design operators could be given more artistic control over loudness (Figure 2.8).[45] Radio mixing catalyzed this need for a design-consciousness that took the performative aspects of electroacoustic technology seriously.

Figure 2.8: Linear faders. Image from Braunmühl, Hans J. von. "Acoustic 'Scenery' In Radio Drama." *The Wireless World* 38, no. 11 (March 13, 1936), 256.

So far, it has been my argument that just as the mixing board was radically redesigned to suit the needs of radio broadcasting, so producers themselves reconceived their craft as a form of environmental design. A new attitude towards sound challenged

[44] Ibid., 102–3.
[45] Hans J. von Braunmühl, "Acoustic 'Scenery' In Radio Drama," *The Wireless World* 38, no. 11 (March 13, 1936): 257.

received understandings of auditory realism. For radio producers like Sieveking, the ability to mix and enhance sound in complex ways seemed to restore the allusive musicality that made realistic drama sensuous and appealing. The mindset of the radio dramatist was markedly different to that of the men who engineered Public Address Systems. In the world of radio, sonic manipulation was geared toward the creative reinvigoration of reality rather than its phonographic capture. The only realism Sieveking was interested in was dramatic purity. In Edison's famous ca. 1915 listening tests for the phonograph, realism was defined by the level of fidelity to a performance; in Sieveking's radio conception by contrast, realism was defined by the impact of reproduced sound on the listeners perceptual capacities. In ways similar to the discourse around "high-fidelity" recordings seen in Chapter 1, radio producers targeted experiential saturation. The ideal was environmental, as the radio producer aimed for an all-encompassing fantasy sound experience.

Genealogy III: "Modern Sound" by Film

I have already alluded to the importance of movie sound on high-fidelity music recording in Chapter 1. There, I argued that the idea that recorded sound functioned as an environmental experience could be traced to developments in the film industry, specifically citing the 1940 movie, *Fantasia*. The Fantasound system, developed for the recording and presentation of the movie, represented a leap in audio technology for film, bringing numerous technical and aesthetic ideas to recorded sound. In what follows, I draw on several alternate examples from the movie industry to unpack the ways in which film productions approached sound as an environmental phenomenon. My third and final genealogy for modern sound takes account of two important factors that played a significant role in the historical crystallization of what we now think of as the mixing board. The first was the affordances of the movie theatre, a space that was especially designed to achieve optimal acoustics. Radio producers were at a disadvantage here: regardless of the control afforded by mixing devices in the studio, they had no control over the acoustic properties of their listeners' living rooms. Second, since movies were not a live medium, film producers had power to re-engineer sound after shooting had been completed. Movie productions developed re-recording methods that exploited this fact, constructing mixing boards that could bring together in one place all the different sonic elements of a movie.

The introduction and success of "talking movies" in the second half of the 1920s generated lively public debate about the relative merits of movie sound. As sound techniques developed within this industry it became common to compare the craft of radio with that of film. In a lecture series from 1938 published by the Research Council of the Academy of Motion Picture Arts and Sciences, for example, Wesley Miller contended that "the sound technique for motion pictures is quite different from that of radio." The radio listener, he observed, "adjusts the volume to his immediate pleasure with no reference to the probable original volume or to any illusion of the source having been in the room."[46] Miller went on to argue that radio was often used as background sound, resulting in "a lowered concentration demand upon the listener."[47] Movie producers, he claimed, were engaged in feats of illusion, the movie-goer being both a captive listener and a captivated one. Unable to control their auditory experience, they were also forced to be more attentive to every aspect of it. The ideal aesthetic for movie sound, presented by Miller, corresponded to two themes that recur throughout this dissertation: the quest for spatial control and perceptual saturation. These quests informed both the acoustic design of movie-theatres and the technological design of audiovisual machines for presenting sound and image.

The advent of the "talking movie" instigated reviews and analysis of movie theatres' acoustic properties. In a 1930 article for *Projection Engineering* the authors described the movie theatre "as a patient in need of acoustical diagnosis."[48] Advertisements for companies offering architectural remedy filled the pages of this journal. Take Figure 2.9, for example, where Celotex, a manufacturer of acoustic tiles, treated issues of unwanted reverberation. Not only echo, but electrical interference and "dead spots" were prevalent in theatre auditoriums.[49] Considerable attention was paid to the acoustics of movie theatres throughout the 1930s, such that by 1940, C.C. Potwin, an employee of Western Electric's motion picture division, could claim that the final resistance to audio control had been subdued. "A principal unit of the sound transmission system in motion pictures can now be efficiently controlled," he proclaimed, "this unit is the path through which sound travels from the loud speakers to the ears of an audience – in other words, the auditorium – the most expensive single unit of the sound transmission system."[50] For Potwin, the least manipulable component of the movie sound system had now been triumphantly incorporated into it.

[46] Wesley C. Miller, "Basis of Motion Picture Sound," in *Motion Picture Sound Engineering* (New York: D. Van Nostrand Company, 1938), 4.
[47] Ibid.
[48] R.L. Lindahl and Wallace Waterfall, "Important Factors in Theatre Acoustics," *Projection Engineering*, September 1930, 16.
[49] Paul R. Heyl, "Architectural Acoustics," *Projection Engineering*, May 1930, 17.
[50] C.C. Potwin, "The Control of Sound in Theaters and Preview Rooms," *Journal of the SMPE* 35, no. 8 (August 1940): 111.

Figure 2.9: Celotex Advertisement. Image from "How Acousti-Celotex Provides Ideal Hearing Conditions for Sound Pictures." *Projection Engineering*, April 1930.), 6.

In the 1950s, the development of three-dimensional film and stereophonic soundtracks extended the environmentality of the movie-going experience. The surprise success of the 1952 3D film, *Bwana Devil*, generated a tide of interest in stereoscopic movies, despite poor critical reviews. Movies like *Man in the Dark* (1953) and *It Came from Outer Space* (1953) capitalized on the craze as producers hoped that the technical innovations of three-dimensional visuals would revitalize dwindling ticket sales.[51] Efforts to exploit an extra dimension of movie visuals coincided with similar attempts in audio. The 1953 3D feature film, *House of Wax*, showcased stereophonic sound, a technique also incorporated into the experimental system, Cinerama. Cinerama was a unique project that debuted in New York in 1952 with a presentation titled *This Is Cinerama*. It featured three projectors and a curved screen that was much larger than those found in standard movie theaters. The sound system offered "six-track stereophonic sound," with speakers

[51] Ray Zone, *3-D Revolution: The History of Modern Stereoscopic Cinema* (University Press of Kentucky, 2012), 11.

located behind the screen and within the auditorium.[52] This was a level of audience immersion not attempted since Disney's *Fantasia* twelve years earlier. Whilst Cinerama did not offer a three-dimensional experience, it reinvigorated interest in the illusion of perspective, both auditory and visual. The limiting factor for Cinerama's success was the need for special technologies and auditoriums that could handle the complexities of the system. New movie theaters were required – the proof-of-concept being the Cinerama Dome in Los Angeles.

The Cinerama Dome represented the apex of cinematic control that we have explored so far. The dome was built in 1963 by Welton Becket and Associates, the same architectural firm that designed the Capitol Records Tower. The Dome was purpose-built for the Cinerama system, offering controlled conditions for the reception of movies that sought to ensure the virtuality of an audiences' sensory experience. Pictured in Figure 2.10, Cinerama's flagship building was constructed as a concrete geodesic dome that showcased its advanced design. In the Dome, not only had the technics of presenting a "full-dimensional" movie been mastered, but the space of reception had been designed to match the vision of the film's makers. In environments like these, mixed sound was key to feelings of aesthetic escape.

Figure 2.10: Cinerama Dome. Image from Rand, Marvin. *California Captured: Mid-Century Modern Architecture*. New York, NY: Phaidon Press Limited, 2018.

The concept of "mixing" in the post-production film studio was more complex than in other industries and could mean many different things.[53] An article in *Wireless*

[52] Ibid., 68.
[53] Mixing boards appeared on film sets as early as the 1920s, though they gained more aesthetic prominence in editing studios, especially as sound systems improved. Mixers were first employed on set to combine the

World from 1932 explained that the actual mixing of different sound sources occurred during dubbing and re-recording:

> Dubbing means recording sound while a picture of the event to which eventually it will be wedded is being projected on the screen. The practice is nowadays almost exclusively confined to music and effects, as the difficulty of obtaining accurate lip synchronisation on dialogue makes it unsatisfactory for that purpose. Sequences in a film to which there is to be only a musical accompaniment and effects are shot "silent" and dubbed.[54]

Mixing, according to the author of this article, was a practice beholden to filmic techniques of dubbing and re-recording, where sound was synthesized into the final product. The mixing board in post-production thus functioned like a musical instrument, working to shape and mold sounds.

The level of complexity involved in these mixing techniques can be gauged from a 1947 article published in the *Journal of the Society of Motion Picture Engineers* that described the design of a postproduction suite at Republic Studios in Hollywood. Amongst the authors of this article was Michael Rettinger, acoustic consultant for the Capitol Records Tower. The suite, according to the article, contained three different mixing consoles for scoring, dubbing and previewing film. The dubbing console alone furnished twelve channels with space for three mixing engineers, as Figure 2.11 shows.[55] This particular console was equipped with faders for volume control, variable equalization that could adjust specific frequencies, as well as channels devoted to the audio input from the reverberation chamber and other effects. Dynamic range compressors and audio limiters, whose controls were also accessible from the mixing console, allowed for regulation of relative loudness.[56] In short, the mixing board at the Republic Studios was capable of advanced control over the shape of sound itself – or at least, this was the fantasy. Sound, that is, reached its fullest potential for plasticity and control when subjected to the mixing practices of the movie industry.

inputs of the multiple microphones that were eventually fed to the recorder. Generally, this role for the mixing board was equivalent to the technical function seen in radio and public address systems, making sure the sound fit within the limits of the technical instruments and recording format. However, in the process of film re-recording, the mixer was geared for aesthetic expression, since it facilitated more nuanced control over the relative loudness levels of audio sources. Edward W. Kellogg, "History of Sound Motion Pictures," *Journal of the SMPTE* 64 (August 1955): 194.

[54] "Sound Films of To-Day," *The Wireless World*, March 2, 1932, 277.

[55] D.J. Bloomberg, Waldon O. Watson, and Michael Rettinger, "A Combination Scoring, Rerecording, and Preview Studio," *Journal of the SMPE* 49 (1947): 20.

[56] Ibid., 24.

Figure 2.11: Dubbing console at Republic Studios. Image from Bloomberg, D.J., Waldon O. Watson, and Michael Rettinger. "A Combination Scoring, Rerecording, and Preview Studio." *Journal of the SMPE* 49 (1947), 20.

Conclusion

When mixing boards and consoles were designed and utilized for music recording in the 1950s and 60s, they drew on a long history of both technical and dramatic control. As we have seen, this history had its roots in P.A. Systems and the industries of radio and film where producers constructed sound worlds for dramatic effect. In their use as creative tools, mixers became musical instruments in their own right, eschewing their heritage in fidelity culture and phonographic capture. The mixer-as-instrument could "play" sound in certain ways, utilizing audio effects and other sonic manipulations. Mixing consoles embodied many of the fantasy elements of electroacoustic sound. More than this, they became immersive creative environments wherein artists exploited the plastic malleability of electric audio.

Philosopher Gilbert Simondon coins the term "techno-aesthetics" to theorize objects that have both technical utility and aesthetic value. Against the tendency to analyze objects along these two lines, Simondon argues for more integrated readings, claiming that "there is a continuous spectrum that connects aesthetics to technics."[57] This chapter has shown how the design of the mixing board moved along this spectrum at various stages in its multifarious history, as it was transformed from a technical object into an aesthetic instrument, and back again. I have argued that there are deep connections to be drawn here between the kinds of aesthetic control championed by mixers in radio drama, movies and recording studio consoles, and the technical control of early mixing devices and switchboards. In fact, the concept of "aesthetic control" itself has its technical roots in panel-based systems. The mixing board, that is, afforded "aesthetic control," in ways that were spatially mapped onto a scientific understanding of the electric sound system.

A very different musical experience was constructed as a byproduct of the control afforded by electroacoustic technology. Sound itself was transformed – spatialized into a moldable and alchemical substance. Simondon describes this transformation of substance

[57] Gilbert Simondon, "On Techno-Aesthetics," trans. Arne De Boever, *Parrhesia* 14 (2012): 3.

through technical objects in a way this has a clear relation to the study of mixing consoles:

> Aesthetics is not only, nor first and foremost, the sensation of the "consumer" of the work of art. It is also, and more originally so, the set of sensations, more or less rich, of the artists themselves: it's about a certain contact with matter that is being transformed through work.[58]

The mixing board, in short, was the medium by which electroacoustic sound was made plastic. Malleable sound, that is, emerged, not so much as the product of technology itself, as in physical experience of using interfaces: of moving dials and faders in ways that allowed for total control of the sonic experience.

A further consequence of the transformative interaction with sound at the mixing board was the development of an environmental approach to sound design. As we saw in my genealogy of movie sound, mixing boards were often used to conjure virtual sonic environments for movie theatres that had themselves been designed to showcase advanced electroacoustic technology. In the space of the auditorium, audience members were treated as attentive listeners in ways that recall the clichéd, quality-conscious listener of "high-fidelity" music recordings that we explored in Chapter 1. The increasing affordances of sound design at the mixing board raise questions about the virtual, sonic experience they were creating. How exactly did listeners perceive "mixed-sound" spatially? What, in fact, was their experience? It is to these psychoacoustic questions – ones that have to do with the nature of perceptual space itself – to which I now turn.

[58] Ibid., 2.

Chapter 3

Mixing in the Mind: Do Androids Dream in Stereo?

> Reality, to me, is not so much something you perceive,
> but something you make.
> - Philip K. Dick, *The Android and the Human* (1972)

I. Mixing Auditory Space

In Chapter 2 I claimed that an important aspect of "modern sound," is that it is often "mixed sound." Through three different places of audio control – public address systems, radio and movies – I showed how mixing devices were designed to offer increasingly more aesthetic and technical control over sound. For users of these mixing devices sound was treated as a substance that took on plastic qualities, able to be shaped and molded by the flick of a button or the turn of a dial. In each of the previous chapters I have also suggested that the discourse around "high-fidelity" music recordings that arose in the 1950s was marked by a new sense of what audio fidelity meant. I argued that technologies of sound reproduction were described in terms of perceptual saturation. This perceptual manipulation, as I understand it, was the belief that audio technologies should reflect and manipulate sonic phenomena based on how humans perceived them. For electroacoustic technologies then, auditory perspective and the knowledge of human perceptual capabilities was essential.

Having explored the history of the mixing board and its development as an instrument for "playing" sound, the central aim in this chapter is to explore some of the historical roots of mapping sound and human perception. What follows is, in effect, an attempt to explore where exactly all this "playing of sound" was thought to occur – the space of sonic perception. As we shall see, this space was a confusing one. To take one example I have mentioned previously, the fader is an integral part of the mixing board; electronically, it is a variable resistor, but perceptually it fades sound in and out. The mixing board operator only ever manipulates an electrical property – the resistance – but it has been designed for its perceptual effect, hence the term "fader." This overlapping of technical and perceptual understanding of sound is clearly betrayed in electroacoustic devices like the mixer. The merging of acoustic and electronic knowledge within electroacoustic science brought spatial qualities of sound to the forefront even as they added another layer of complexity.

Leopold Stokowski recognized the interchangeable nature of technician and performer at the very beginning of the era of radio broadcasting. It was a phenomenon that disturbed him. Stokowski's wife, Evangeline, recalled one event from the conductor's first radio broadcast with the Philadelphia Orchestra in 1929. When Stokowski discovered a mixer at the first rehearsal, he asked what its purpose was. This explained, and gesturing at the "sound man," the musician complained, "then you're paying the wrong man. He's the conductor and I'm not. I don't want this to be broadcast under my name if

I'm not controlling the *pianissimo,* the *mezzo forte*, and the *fortissimo*."[1] Stokowski noted that the mixer operator was not just a technician of a transparent instrument but an active participant in the aesthetic product of the orchestra. That the conductor used musical terms for loudness to describe the mixer's impact only further illustrates my point that technological, perceptual and even musical understandings of sound collided in significant ways at the controls of the mixing console.

Critical theorist Theodor Adorno shared Stokowski's alarm and described the technical deficiencies of radio sound in spatial terms. In his 1941 article "The Radio Symphony," Adorno drew a parallel between the experience of dynamic range at the radio receiver and the proportions of architectural structures. He maintained that radio produced the equivalent of a miniaturized model of the music it was attempting to reproduce, totally destroying the proportional dimensions that made a symphony what it was. "Absolute symphonic dimensions," Adorno wrote, "carry with them the existence of an experience which it is difficult to render even in rough terms, but which is, nonetheless, fundamental in the apperception of symphony and is the true musical objective of technical discussion of auditory perspective: the experience of symphonic space."[2] As we've seen in Chapter 2, electroacoustic technologies conjured an environmental sense of sound. Some, like Stokowski learned the tools of electroacoustic technologies in attempts to construct fantastical sonic environments; others, like Adorno, were convinced that electronic sound could not be redeemed. In either case, this electroacoustic experience was often conceived and understood in geometric terms.

In what follows, I treat the mixing board as a technology for framing sonic experience. I focus on historic conceptions of the sonic space produced by the mind – the arranging of sound in a listener's head – that creates an auditory perspective. In many ways the mixing board has been designed to control and creatively manipulate sound within this sonic space. We have already explored a variety of audio effects throughout this chapter, some containing more obvious "spatial" qualities. Artificial reverberation conjures an echoic space in our minds that can make sound seem larger, whilst panning specific sounds to the left or right of a stereophonic system creates an equivalent illusion that a band or orchestra might be spatially arranged from left to right in our living room. In this chapter, however, I limit my study to the control over frequency and loudness, the two main tools of the mixing console that also contribute to our spatial experience of sound. First, I will establish what "auditory space" could mean, briefly covering different conceptions of this idea. Second, I trace this concept in studies of perception, specifically the cybernetics-influenced work of Donald Broadbent from the late 1950s. The bulk of this chapter will then trace the deeper histories of perceptual science that informed the functions of frequency and loudness control embedded in the mixer and how they were used to shape auditory perspective.

Spatializing Sound

[1] Oliver Daniel, *Stokowski: A Counterpoint of View* (Dodd, Mead & Company, 1982), 306.

[2] Theodor W. Adorno and Robert Hullot-Kentor, "The Radio Symphony," in *Current of Music: Elements of a Radio Theory*, English ed (Cambridge, UK ; Malden, MA: Polity, 2009), 150.

In the 1950s and 60s the process of combining and recording sound – "the mix" – was often described as one of painting sound within a two-dimensional field.[3] But what exactly was this supposedly empty auditory space? The very opening-out of this perceptual geography developed from a long history of psychological and physical experiments, ones that first mapped an acoustic terrain physically, and then theorized that terrain psychologically from the perspective of an idealized listener. This 3D space was always a confusing space because it has been constructed from scientific investigations into both the nature of sound and into the nature of perception. It was confusing because sound perception does not always match up to the physical properties of sound in the world. The cartography of this "space" was obscure, as evidenced, for example, when considering the perception of loudness where a sound whose amplitude is doubled does not necessarily sound twice as loud to a listener. Rules that applied to the physical nature of sound did not always correlate to the perceptual experience of it.

Historically, audiophiles, engineers, and producers alike have struggled to find words to describe this "space" of perceived sound. The producer, Brian Eno, likened mixing to the art of painting sound onto a canvas, which was to evoke the image of a blank slate of audio perception waiting for content.[4] The rise of stereophonic recording in the 1960s introduced the term, the "stereo field," to designate the space occupied between the extremes of the left and right speaker. It is also common to describe the way that we perceive the positions of instruments in a music track as "imaging" in a more general sense. Writing in the 1990s, David Gibson, recording engineer and sound therapist, claimed that the perception of sound worked in two different ways: on one hand were the physical sound waves; on the other was the virtual placement of these sounds in our minds that are imagined.[5] No matter the vocabulary used, engineers found it useful, when constructing their mixes, to posit an ideal listener's "auditory space," even if that space was impossible to fully describe.

As far back as the 1950s, radio was conceived as the "theatre of the mind." That dramatic phrase is sometimes attributed to voice actor, Joseph Julian, though, as scholar of early American radio drama Neil Verma points out his original phrase was "theatre in the mind."[6] Verma argues that the preposition "in" qualifies a more accurate description of that field of experience, since it "names one medium (radio) by its capacity to nest a second medium (theater or pictures) in a third (mind or imagination)."[7] Later music producers in sound recording clearly drew from this radiophonic idea when using the language of vision and cognition to describe their craft. Yet the third medium in Verma's

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[3] Sieveking, *The Stuff of Radio*, 102–3.

[4] Stuart Dredge, "Brian Eno and Peter Chilvers Talk Scape, iPad Apps and Generative Music," *The Guardian*, September 26, 2012, sec. Music, https://www.theguardian.com/music/appsblog/2012/sep/26/brian-eno-scape-ipad-apps.

[5] David Gibson and Maestro B. Curtis, *The Art of Producing: How to Create Great Audio Projects* (Routledge, 2019), 63.

[6] Neil Verma, *Theater of the Mind: Imagination, Aesthetics, and American Radio Drama* (University of Chicago Press, 2012), 2.

[7] Ibid.

scheme is hard to fully determine, raising difficult philosophical questions about the very nature of human consciousness. The brain may process audio information from the ear in certain ways, but it is unclear how the conscious mind imagines and spatializes sound.

By the 1960s, the idea of "sonic space" was fully ascendant in academic and cultural discourse. Media theorist Marshal McLuhan, notoriously, used the concept of the "sensorium" to describe the collective effect of the five senses on the mind. McLuhan theorized an empowered and generalized idea of "auditory space," created by the ear as a countereffect to the tyranny of visual space created by the eye. McLuhan declared in 1961 that "the auditory forbids perspective," endowing sound with revolutionary potency in his sensory-media theories.[8] Yet this statement ran against the grain of contemporaneous psychologists and audio engineers who were exploring the specific role of auditory perspective in studies of perception and the development of surround sound systems. One notable example was the "Vortex" series of concerts produced in 1957 in San Francisco and recreated for the 1958 Brussels World Exposition. These concerts featured an early surround sound system explicitly designed to manipulate auditory perspective. One reviewer for *High Fidelity* described the experience as the "conquest of spatial and aural infinity."[9] So whilst McLuhan may have maintained that auditory perspective was still less didactic in its spatial configuring than visual media, developments in audio technology were attempting to erode that very distinction of aural experience.

Twentieth-century composers have also expressed their work in relation to a spatial concept for sound. R. Murray Schafer famously used the term "soundscape" in the late 1960s to describe and encourage the listening experience of the external, physical existence of sounds in space.[10] Many of Schafer's ideas were shaped by his concern for the lived sonic environment, specifically the impact and growth of noise pollution in urban life.[11] Drawing attention to the environment his theories nevertheless continued to betray a spatial understanding of sound. As in other concepts for describing the experiential space of sound, the relationship between external sound and the internal perception of sound was never fully clear, despite the fact that many users understood that there was a difference.

In this brief survey of spatial understandings of sound, I have highlighted some of the more distinct examples that seemed to offer radically new ways of thinking about sonic space. However, contrary to attempts to trace defined movements that interacted with auditory space in different ways, I would argue that the history of sonic spatialization is rife with contradictions and fusions.[12] My argument is that such

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[8] Marshall McLuhan, "Inside the Five-Sense Sensorium," in *Empire of the Senses: The Sensual Culture Reader*, ed. David Howes, Sensory Formations Series (Oxford ; New York: Berg, 2005), 49.
[9] Alfred Frankenstein, "The Music of the Hemispheres," *High Fidelity*, May 1959, 46.
[10] Yvette Janine Jackson, "Narrative Soundscape Composition: Approaching Jacqueline George's Same Sun," in *Between the Tracks: Musicians on Selected Electronic Music*, ed. Miller Puckette and Kerry L. Hagan (MIT Press, 2020), 2.
[11] Barry Truax, "Soundscape, Acoustic Communication and Environmental Sound Composition," *Contemporary Music Review* 15, no. 1–2 (July 1, 1996): 54, https://doi.org/10.1080/07494469608629688.
[12] Georgina Born, "Introduction - Music, Sound and Space: Transformations of Public and Private Experience," in *Music, Sound and Space: Transformations of Public and Private Experience* (Cambridge University Press, 2013).

perceptual confusion – indeed the apprehension of the spatial nature of sound itself – was catalyzed by the affordances of electroacoustics, in particularly by practices of "mixing" at the mixing board. The ideas of sonic and musical space were present, not simply in the exceptional cases of vast sound systems and directional audio effects, but in the mundane use of electroacoustic technology in general. The electroacoustic system itself, as soon as it gave practitioners the option of where to send audio signals, contributed to a spatial sense of sound.

Cybernetics, Perception and Mixing

The illusory qualities of electroacoustic sound also made it a perfect tool for the study of the mind. In 1958, the British psychologist Donald Broadbent published his first major work exploring human cognition, *Perception and Communication*. In this book, which warrants extended discussion here, Broadbent proposed a theoretical model for how humans processed information, drawing on ideas from the nascent disciplines of communication theory and cybernetics. Broadbent's entry in *The MIT Encyclopedia of the Cognitive Sciences* notes that his method had a revolutionary impact on the history of psychology in the United States.[13] The dominant method in U.S. psychology at that time was "behaviorism," a methodological framework that limited the objects of study to the environmental factors that could be shown to produce observable changes in its subjects. Broadbent, by contrast, explored the interior processes of the brain; he focused on "the hypothetical internal mechanisms by which present input was brought into contact with past knowledge."[14] He encouraged speculative attempts towards understanding the brain's inner processes.

Broadbent's research in *Perception and Communication* perpetuated his famous "filter theory" of human cognition. The filter theory developed out of real issues that Broadbent had experienced during his time in the Royal Airforce as a pilot. He sought a way to determine the relationship between attention and its impact on communication, a difficulty he had witnessed as a life-and-death problem in the cockpit. His filter theory asserted that the perceptual system (P-system) of hearing was fundamentally limited in its capacity to process all the information it received, and as such, "access to the P-system is controlled by a selective filter."[15] In this work, Broadbent drew on the language of cybernetics and computing to describe the functioning of the brain, particularly as he illustrated the operation of auditory perception or human hearing.[16] In these situations, human hearing and attention were the weak link in an otherwise efficient communications system.

Cybernetics, significantly, developed in the wake of practical problems encountered in communication systems during World War Two. The field of cybernetics has deep roots in engineering cultures of the early twentieth century, but was formalized

[13] Robert Andrew Wilson and Frank C. Keil, *The MIT Encyclopedia of the Cognitive Sciences* (MIT Press, 2001), 95.
[14] Neville Moray, "Donald E. Broadbent: 1926-1993," *The American Journal of Psychology* 108, no. 1 (1995): 118.
[15] Wilson and Keil, *The MIT Encyclopedia of the Cognitive Sciences*, 96.
[16] William Sims Bainbridge, *Leadership in Science and Technology: A Reference Handbook* (SAGE, 2012), 14.

by Norbert Wiener in his important 1948 work, *Cybernetics: Or Control and Communication in the Animal and the Machine*. Wiener borrowed the Greek word for steersman, *kubernētēs*, to characterize the emerging systems of control and communications, referring to a central tenant of this discipline – the maintenance of stability whilst navigating hazardous perceptual fields.[17] The book was unexpectedly popular, as many scholars have recognized.[18] It catalyzed the discussion and development of rich intellectual concepts such as systems, feedback, information, and homeostasis.[19]

Like Broadbent, Wiener, a mathematician at MIT, engineered systems for military aircraft. Wiener worked as part of the National Defense Research Committee's work on anti-aircraft fire control during the 1940s, using his knowledge of probability theory to determine and simulate the future movements of enemy targets in order to shoot them down. Influenced by his government work, Wiener gave some of the practical problems faced by control engineers a theoretical grounding and a more universal scope. Speculation in "systems theory," as such, extended beyond mere mechanics, to questions impinging on nothing less than the survival of life itself. Ronald Kline, author of *The Cybernetics Moment*, writes that "the allure of cybernetics rested on its promise to model mathematically the purposeful behavior of all organisms, as well as inanimate systems."[20] This allure meant that during the 1950s many theories influenced by cybernetics tended to view a wide range of situations as "systems" dogged by problems of control and communication.

Of all the objects that could be modelled, the brain was privileged as an area of study; this "control center" was a focus point for theories of control and communication then being advanced by cybernetics.[21] Numerous studies focused on the brain and nervous system in this period, such as W. Ross Ashby's *Design for a Brain* (1952), and John von Neumann's *The Computer and the Brain* (1958). In 1960 Manfred Clynes designed a computer that could effectively measure electrical activity of brain activity.[22] Wiener had long maintained the connection between cybernetics and the modelling of the human nervous system. His 1948 article in *Scientific American* mentioned the cybernetic task in the subtitle: "[cybernetics] looks into the processes common to nervous systems and mathematical machines."[23] Donald Broadbent, in other words, was swept up in wider intellectual trends when he wrote *Communication and Perception* and introduced his filter theory for human cognition. His novel approach relied on the analogy of computer-brain processes established by cybernetics. Only by treating the human perceptual system as a computer model could Broadbent theorize the internal mechanisms of the brain.

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[17] Mindell, *Between Human and Machine*, 4.
[18] Flo Conway and Jim Siegelman, *Dark Hero of the Information Age: In Search of Norbert Wiener, the Father of Cybernetics* (New York: Basic Books, 2005), vii; Kline, *The Cybernetics Moment*, 68; Mindell, *Between Human and Machine*, 439.
[19] John Lechte, *Key Contemporary Concepts: From Abjection to Zeno's Paradox* (SAGE, 2003), 48.
[20] Kline, *The Cybernetics Moment*, 4.
[21] Andrew Pickering, *The Cybernetic Brain: Sketches of Another Future* (University of Chicago Press, 2010).
[22] Patrick Kilian, "Participant Evolution: Cold War Space Medicine and the Militarization of the Cyborg Self," in *Militarizing Outer Space: Astroculture, Dystopia and the Cold War* (London: Springer Nature, 2020), 214.
[23] Norbert Wiener, "CYBERNETICS," *Scientific American* 179, no. 5 (1948): 14.

In *Perception and Communication*, Broadbent reviewed many of the experiments of contemporaneous researchers through the lens of his filter theory. If there was one thing his book sought to do, it was to uncover the mysteries of attention; the matter at hand was the comprehension of a message from a multitude of messages. Broadbent cited cognitive scientist Colin Cherry's concept of the "cocktail party effect," where subjects were found to select one message from a loudspeaker emitting multiple sources of speech. Broadbent drew on the idea of "mixed" sound when reviewing this concept, writing that "a listener is likely to understand only one message in the complex jumble of sounds made up by mixing two messages."[24] In cocktail-party situations, the former pilot claimed, an "auditory perspective" forms in the mind of the listener:

> The relation of figure and ground in visual perception is clearly similar to that between selected and rejected speech messages: in both cases the former is reacted to in detail, while the latter receives only a general and undifferentiated response.[25]

The project, for him, was to explain the way in which the mind or perceptual system constructed what was experienced as an auditory reality by the listener. Broadbent's filter theory, that is, intended to shed light on why certain sounds were perceived in the foreground whilst others receded into the background. He aimed to map the internal perspective or geometric proportions of auditory space.

We could read Broadbent as having made psychological experiments out of the basic electroacoustic principle of mixing. He was questioning what mixer operators had been exploiting in movies, radio, and sound recording – namely: what were the co-ordinates of the listener's attention when presented with multiple sources of sound? What operators had been doing for decades on the mixing board was being used as the basis for analyzing human cognition. Admittedly, Broadbent was interested in the comprehension of speech, rather than the mixing of sound. But the language and concepts adopted for speech psychology and sound mixing were closely linked, as we have seen; both were concerned with the effect of "multi-channel listening" on the brain.[26] To describe the brain as having multiple channels and filtering the signals it received, after all, was essentially to describe a mid-century mixing console.

No wonder, then, that the mixing board itself was frequently referred to in neurological terms by sound engineers, especially towards the 1950s. A review of trade journals printed in the decade reveals that writers increasingly imagined the mixing board at the center of a media nervous system. In a 1949 issue of *Radio-Electronics*, for example, an instructional article for a DIY mixer assured its readers that "in a more expanded form, a console such as [the one featured] is the nerve center in every broadcast studio."[27] Similarly, the inaugural issue of *High Fidelity* in 1951 printed an article claiming

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[24] Donald E. Broadbent, *Perception and Communication* (New York: Pergamon Press, 1958), 60, http://catalog.hathitrust.org/Record/000579913.

[25] Ibid.

[26] Ibid., 210.

[27] Richard H. Dorf, "Audio Console Controls Sound," *Radio-Electronics*, February 1949, 34.

that "in the modern high-fidelity installation, preamplifiers and control units are the audio nerve center."[28] Alec Nisbett's *The Technique of the Sound Studio for Radio, Television, and Film,* first published in 1962, cemented this metaphor in his textbook on BBC broadcasting operations. "The nerve centre of any broadcast or recording," Nisbett insisted, "is the control desk."[29] For many mid-century engineers, the mixing console was the brain of the sound system.

In other words, mixing boards were designed to control perception, at least from the perspective of those who adopted a cybernetic understanding of communication systems. Mixer operators used the interface to modulate the attention of their listeners, controlling what form of information they were receiving. The producer – constructing a mix at the console for aesthetic effect – shaped attention, bringing some sounds into the foreground and others into the background, much in the way that Broadbent identified. On one hand, Broadbent looked to model the human brain as a kind of computer; on the other, the mixing board itself appeared to function in a similar way to the human perception of hearing. It was no accident. Sound mixing and sound perception share a similar history. To understand the nuances of the mixing board's relationship with the mind we have to go back in time, tracing historical attempts to map the human perception of frequency and loudness. The historical interplay between mapping sound and controlling sound reveals an embedded computational theme, the assumption being that the mixing board operator "programs" the listener's auditory space. As the science fiction writer, Philip K. Dick observed in the opening epigram to this chapter, with the mixing board, sonic reality was really "something you make."

II. Equalizers: A History of Frequency Mapping

In what follows, I treat the mixing board as a technology that physically modelled the ranges, limits and gradients of auditory experience. The mixer's two main functions of loudness and frequency control were connected to experiments that probed the characteristics of human hearing. This historical project can be viewed as an attempt to chart the perceptual space of human experience, to determine the ranges and boundaries of what sounds can be heard. It is within this perceptual space that the mixing console was designed to operate. Through the control of loudness and frequency I view the mixing console as a tool of audio geometry. Frequency control manipulates the "hearing space" of auditory perspective, whilst volume control draws on perceived gradients of loudness. The mixing console reconfigured sonic relations through its controls, in ways that psychologists like Broadbent identified with the internal processes of the brain. The mixing board, therefore, is more anthropometrically designed in its operation than its sterile rows of knobs and faders would have us believe.

In this first section I explore the numerous attempts to establish the upper and

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[28] Alan C. Macy, "Audio Nerve Center," *High Fidelity*, Summer 1951, 18.
[29] Alec Nisbett, *The Technique of the Sound Studio: Radio, Record Production, Television, and Film*, 2d ed. rev. and enl., The Library of Communication Techniques (New York: Hastings House, 1970), 50.

lower hearing limits of frequency. Mixing boards manipulate the frequency characteristics of sound through the controls of an equalizer (EQ). Using EQ, the mixer can, for example, add and subtract bass frequencies or flatten higher ones, shaping the overall timbre of sound. EQ works within a range of frequencies that are determined by the construction of the mixer, the standard design being 20Hz to 20kHz – the average range of human hearing. The manipulation of frequency through this form of control afforded a kind of panorama of sound – a horizontal landscape of frequency. However, this landscape had to be constructed. By exploring the historical attempts at defining the limits of hearing frequency we can see how this range of control, afforded by EQ, was determined. There is a rich history to be told about how this topography came to be, one that sheds light on the way knowledge of that aural spectrum was arrayed by electroacoustic technology.

Figure 3.1: Advert for Cinema Engineering Equalizers. Image from "Troubled with the Sponsor's Falsse Teeth Whisstle?" *Audio Engineering*, May 1953, 13.

On Aural Limits

In 1820, English natural philosopher William Hyde Wollaston described the frequency range of human hearing, the lowest and highest pitches that could be perceived, as a space "comprised between the lowest notes of the organ and the highest known cry of insects." For Wollaston, such a range extended across "more than nine octaves."[30] His paper *On Sounds Inaudible by Certain Ears,* presented to the Royal Society in London, resurrected strange antiquarian speculations that had been neglected since the acoustic experiments of Joseph Sauveur in 1700.[31] (The nineteenth-century naturalist was better known for his work on chemistry and physics.) Wollaston himself professed that his foray into the limits of hearing was sparked by the realization that a friend – whilst possessing perfect hearing and perceiving "musical pitch as correct as that of any ordinary ears" – could not hear an F four octaves above middle C.[32]

For Wollaston, the big scientific takeaway from so casual an observation was that deafness was not entirely dependent on intensity. Rather, "certain" ears appeared "dull" to certain frequencies and pitches. The implication, moreover, was that every species or person had their own distinctive hearing range. Such observations led Wollaston to speculate about ultrasonics – sounds that may exist beyond human perception. If his friend could not hear beyond the F note, then perhaps other animals could hear beyond Wollaston's own upper hearing limit, measured using chirping insects.[33] Human hearing, in Wollaston's conception, was confined to a range, delimited by the mechanical workings of the organ in the bass and the natural sonorities of insects in the treble. He had laid before history, in other words, the space of aural experience, a bounded vista opened between machine and animal.[34]

Writing fifty years before the telephone, Wollaston's words reflect a time when the range of human hearing and the nature of sound had not yet been apprehended as modern objects of knowledge. The space of hearing had not been mapped and surveyed by those researchers seeking the imperious powers of discrete sonic measurement. But this situation would not last for long. In 1830, French physicist Felix Savart constructed a siren that generated frequencies up to 24,000Hz.[35] His successor as chair of physics at the French Academy of Sciences, César-Mansuète Despretz, determined in 1845 that the upper limit was 30,000 cycles per second. However, this data was obtained, "not by actual measurement of the frequency, but by estimates made by musicians with trained ears who claimed to be able to recognize the number of octaves which they could follow into the regions of high frequency vibrations."[36] For Savart as for Despretz, the range of

[30] William Hyde Wollaston, "On Sound Inaudible by Certain Ears," *Philosophical Transactions of the Royal Society of London* 110 (1820): 313, https://www.jstor.org/stable/107561.
[31] Edwin Garrigues Boring, *Sensation and Perception in the History of Experimental Psychology* (New York: Appleton-Century-Crofts, 1950), 332.
[32] Wollaston, "On Sound Inaudible by Certain Ears," 311.
[33] Ibid., 314.
[34] John M. Picker, *Victorian Soundscapes* (Oxford University Press, USA, 2003), 8.
[35] Karl F. Graff, "1 - A History of Ultrasonics," in *Physical Acoustics*, ed. Warren P. Mason and R. N. Thurston, vol. 15, Physical Acoustics (Academic Press, 1981), 5, https://doi.org/10.1016/B978-0-12-477915-0.50006-3.
[36] Robert Williams Wood, *Supersonics, the Science of Inaudible Sounds* (Providence, R.I.: Brown university, 1939), 8, https://catalog.hathitrust.org/Record/001484314.

human hearing was tabulated by an uncertain process of subjective induction.

The search for the upper limit of human hearing was no easy task for mid-nineteenth-century scientists, and something more than the mere estimations of musicians was needed. American physicist and inventor Robert Williams Woods notes that early attempts to define the upper limits of hearing were beset with wild inconsistencies. Woods complains that "limits [were] found varying from 20,000 to 50,000 [cycles per second],"[37] highlighting that even if instruments could be made to create high frequencies, devices were still needed to determine what those frequencies actually were.[38] The frequency approximations of trained musicians were not enough, and there was a concerted effort to replace such subjective methods with hard research and measuring technologies.

Some years after Despretz's speculations, Francis Galton's 1883 *Inquiries into Human Faculty and Its Development*, presented the Galton Whistle, an instrument capable of generating audio frequencies beyond human hearing. In his investigations with the whistle, Galton concluded that "the power of hearing shrill notes has nothing to do with sharpness of hearing, any more than a wide range of the key-board of a piano has to do with the sound of the individual strings."[39] Just as the keyboard physically bracketed the range of sounds that could be played, in Galton's conception, so was the ear confined to a discrete hearing range. The issue was not so much the perception of a distinct tone as the true determination of the limits of sound perception. The Galton whistle was used for exactly that purpose, paired with various tuning forks in the Bezold-Edelmann continuous tone test, introduced around 1898.[40] This was a comprehensive test that measured the full spectrum of human hearing and generated a method for determining the levels of deafness amongst different patients.

Instruments that could generate consistent high frequencies and devices that could measure them continued to be invented into the twentieth century. In 1899, Rudolph Koenig developed tuning forks capable of producing frequencies beyond human hearing. (Koenig's study of "supersonic waves" was enabled using "dust figures," a method invented by August Kundt where dust in a tube produced visual representations of the sound waves.) These dust figures became the basis by which F.A. Schultze, working in 1907, measured the upper limits of hearing high frequencies, a limit he determined to exist at 20,000Hz.[41] That round number – 20,000 – is still cited as a general reference for the "outer edge," indicating the supposed upper limit of human audibility. Here it is

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[37] Ibid., 10.

[38] Graff, "1 - A History of Ultrasonics," 9. 'The task of detecting, visualizing, and measuring sound was a far more formidable task in the 19th century than that of producing sounds.' Also relevant was the task of creating simple tones without overtones distorting the perceived sound. See Boring, *Sensation and Perception in the History of Experimental Psychology*, 332.

[39] Francis Galton, *Inquiries into the Human Faculty & Its Development.* (London, 1883), 377, https://hdl.handle.net/2027/uiug.30112000723335?urlappend=%3Bseq=395.

[40] *Pacific Record of Medicine and Surgery*, 1898, 238.

[41] Wood, *Supersonics, the Science of Inaudible Sounds*, 12.

important to highlight that it was only by translating sound waves into a visual medium that "proper" measurements could be made.

Over the course of the nineteenth century, the poetics of Wollaston's organ notes and chirping insects were replaced with a host of instruments designed to probe the human hearing range in defined cycles per second. Yet those who studied hearing and the function of the ear still felt that despite ascertaining the upper and lower limits of frequency perception, objective analysis of hearing was still elusive. Writing in 1903, Paul Ostmann, a prominent ear, nose and throat specialist working in Marburg complained that all previous research into the state of hearing had proven only "that up to the present no objective measurement of hearing has been found."[42] As late as 1929, T.A. Clarke, of the Ferens Institute of Otolaryngology in London, was still able to write that despite the ongoing desire for objective measurement, "otology [the medical study of the ear] is never likely to become an exact science."[43] The field was in flux, and the researchers knew it.

Whilst attempts to define an objective means to measure hearing across the frequency range seemed less than satisfactory, few argued with the logic of auxiliary research projects on the limits of hearing. In fact, nineteenth-century studies of the senses in general were marked by an increasing realization of the extraordinarily narrow range of human perception. In this respect, vision was no better off than audibility, one writer commenting that "the optic nerve does not respond to rays of very short or very long wave-length. Hence we do not see either end of the spectrum. All our senses are in like manner limited; for instance, sound waves of very high or very low pitch are inaudible."[44] Humans, it turned out, were more sensorially restricted than they could have imagined.

Anxieties about the limited function of the senses and comparisons of sound against sight became ubiquitous. The American neurologist George Miller Beard for example, was another who weighed in on the limited function of the senses and the comparison of sound against sight. In an article from 1878 titled, "The Scientific Study of Human Testimony," he began by stating that "the senses, which have hitherto been regarded as infallible, are even more narrowly defined than the memory or the higher qualities of intellect."[45] Beard lamented even the deficiencies of sight, despite his belief that "sight is certainly the best of the five senses."[46] Beard was unsettled by scientific realizations of the narrow range of the senses. Not only were the senses severely limited, but they could also be deceptive. Beard noted with alarm that "sounds and smells, taste and touch, can be subjectively created, even in a sane and healthy brain."[47] That the

[42] *The Journal of Laryngology, Rhinology, and Otology* (Adlard & Son and West Newman, Limited, 1903), 561.
[43] T. A. Clarke, "On Hearing Tests," *Proceedings of the Royal Society of Medicine* 22, no. 3 (January 1, 1929): 13, https://doi.org/10.1177/003591572902200328.
[44] *Harper's New Monthly Magazine* (Sampson Low, Marston, Searle & Rivington, 1883), 85.
[45] George M. Beard, "The Scientific Study of Human Testimony," *Popular Science*, June 1878, 173.
[46] Ibid.
[47] Ibid., 178.

senses were manipulable implied problems not only for any individual invested in separating subjective and objective reality, but also for the fate of larger groups, it being "possible and easy to cause a large number of individuals, of intelligence and in good health, to see simultaneously the *same* subjective visions without any of them being able to detect the deception."[48] Ultimately perception could not be trusted; if vision was king of the senses for Beard, how much easier to deceive the ear.

So far, we could describe the history of the mapping of frequency limits in human hearing as the search for positive limits. In experiments seeking to define the human hearing range, as we have seen, work on the perception of sound was largely marked by attempts to find the maximum frequencies that could be heard. The irony is that many of these experiments were actually interested in sound waves that did not sound, in ways that were true both for the study of supersonic waves and the study of deafness. In the search for the limits of hearing, what had been created was bounded space between two extremes. The area between the highest and lowest frequencies was considered the space of auditory experience where most people could hear. It was a space occupied by a phantom: the model listener.

On In Between

Having explored how a multitude of different methods and technologies were deployed to ascertain the boundaries of human hearing, I will now turn to the ways in which this knowledge was instrumentalized for controlling the perception of frequency. The scientific knowledge of hearing ranges would be used for a very different agenda by the American Telephone and Telegraph (AT&T) company. We could describe the general use of this knowledge by researchers at AT&T's Bell Laboratories as the search for minimum ranges rather than maximum ranges. The analysis of hearing limits in the telephone system was directed towards finding the smallest frequency ranges that could be transmitted efficiently and still understood as speech. It is within this context of telephone communication that equalization was developed, as a tool to manipulate and control the frequency of sound.

Up until the introduction of the vacuum tube in 1913, the problem of signal strength loss, known as "attenuation," was the primary concern of AT&T's engineers.[49] The early telephone system was completely passive, receiving power beyond that of the voice into a phone receiver. Vocal power determined how far a phone call could travel, but it was discovered that the power-loss of a voice being transmitted down a long-distance telephone wire was unevenly spread across the frequency range. Higher frequencies experienced greater attenuation than lower frequencies, and so the problem of distance was intrinsically linked to frequency. Around the turn of the century, the telephone company introduced, loading coils (doughnut-shaped iron cores that

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[48] Ibid., 177.

[49] Bell Telephone Laboratories and Fagen, *A History of Engineering and Science in the Bell System*, 61.

telephone wires were wrapped around) to counteract this frequency-sensitive attenuation.[50] The coils provided greater stability to the electrical properties of long-distance telephone lines, preventing the high frequency loss that was experienced on non-loaded lines. However, it was found that the impact of loading coils was dependent on their distribution. Continuous "loading" maintained the frequency response of the soundwave but when loading coils were distributed less frequently, they created a "cut-off frequency." Frequencies lower than the cut-off frequency would pass through, but frequencies above it would be attenuated. Loading coils, in other words, were filtering frequencies.

Whilst the economic benefits of loading coil technology were obvious for long distance communication, it was their secondary effect as frequency filters that contributed to future developments in sound control.[51] Loading coils concretely showed that audible frequencies were impacted by the electrical properties of inductance and capacitance. The Bell engineer George Ashley Campbell would enhance the capacity to manipulate frequency further, with the invention of electronic wave filters around 1903.[52] These wave filters took the control of frequency as their starting point and provided a way to design circuits that could isolate and filter specific frequency bands.[53] Coupled with vacuum tubes, wave filters were designed to "equalize" the frequency characteristics of amplified telephone signals, counteracting the distortions that occurred as a result of the various processes within the electroacoustic system.[54]

Equalizer circuits soon appeared in many other sound technologies, used to balance the frequency characteristics of sound in a variety of places. An article from 1923 described Bell engineers using equalizers in public address systems and RCA engineer, John Volkmann, developed a separate, self-contained equalizer unit to make up for the poor acoustics of movie theatres in 1930.[55] In 1926, to maximize the frequency response of electronic phonographs, engineers cut bass frequencies in the recording process using wave filters that were built into the recording machines. Compensation of these cut frequencies during playback was originally attained mechanically, before equalizers were embedded within turntable preamplifiers.[56] EQ followed a similar trajectory to the mixing board as a whole, transitioning from a functional, technical tool made to balance sound "correctly," to one that had more creative use and aesthetic impact. In a recurring pattern, this transition was catalyzed by the movie industry, where equalizers were designed for

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[50] Ibid., 99.

[51] One scholar estimates that they saved Bell Telephones one hundred million dollars in costs up to 1925 alone. James E. Brittain, "The Introduction of the Loading Coil: George A. Campbell and Michael I. Pupin," *Technology and Culture* 11, no. 1 (1970): 36, https://doi.org/10.2307/3102809.

[52] J. E. Brittain, "Electrical Engineering Hall of Fame: George A. Campbell," *Proceedings of the IEEE* 95, no. 5 (May 2007): 1135, https://doi.org/10.1109/JPROC.2007.893254.

[53] G. A. Campbell, "Physical Theory of the Electric Wave-Filter," *The Bell System Technical Journal* 1, no. 2 (November 1922): 2, https://doi.org/10.1002/j.1538-7305.1922.tb00386.x.

[54] Bell Telephone Laboratories and Fagen, *A History of Engineering and Science in the Bell System*, 272.

[55] W. H. Martin and A.B. Clark, "Use of Public Address System with Telephone Lines," *Bell System Technical Journal*, April 1923, 146; Howard M. Tremaine, *Audio Cyclopedia*, 1757 p. (Indianapolis: H. W. Sams, 1969), 83, //catalog.hathitrust.org/Record/001617997.

[56] H.H. Scott, "The Philosophy of Amplifier Equalization," *Journal of the AES* 2, no. 1 (January 1954): 46.

use as an audio effect in post-production.[57] By the 1950s, EQ was so integral to the creative process of mixing sound it was embedded in mixing consoles for recording.

Electronic wave filters also found use in auditory experiments. For acousticians and researchers of sound, the ability to filter unwanted frequencies solved a long-running problem in hearing studies. The traditional tools of tuning forks and whistles were always liable to produce overtones and resonant frequencies, which distorted the purity of the fundamental tone desired by experimenters. The introduction of electronic wave filters meant that such a "pure tone" could be manufactured from a set frequency, and used for more effective hearing measurement.[58] I would argue, in fact, that the refinement of frequency filters marked the end of a long line of attempts to strip away sound to its supposed core, to create an untarnished tone free from distortion. Filtering technology, as such, represented the final phase in a long Euro-American project to experience frequency itself without distraction – to see sound waves denuded, or uncontaminated by the dirty contingencies of culture or mediation.

The history of the mapping of frequency in human hearing, then, reveals a continual process of defining and refining perceptual limits. As we have seen, the estimations of these frequency ranges of human hearing were intrinsically tied to the instruments used to generate and detect wave cycles per second. The search for frequency limits in human perception were themselves limited by the technologies used to discover them. The introduction of an electronic means for generating specific frequencies situated telephonic knowledge – the science of electroacoustics – at the center of human hearing research. The vibrating metal of crafted tuning forks, as such, were replaced, at the moment when sound was electrically transduced, by the alternating current of telephonic circuitry.

The story of the development of frequency ranges in the Bell Telephone System, can be told as two simultaneous narratives: one of discovering and conquering the "outer" limits of auditory space and another of exploiting the "inner" limits of human perception. Jonathan Sterne has suggested that wider frequency ranges were in effect "surplus value" when it was discovered that intelligibility of speech could be preserved with narrower frequency ranges.[59] Bell Telephones created frequency ranges on their own terms for their own needs. AT&T's aim of controlling necessary frequency ranges represented a shift in research goals, where attempts to fully understand how sound behaved and how it was altered by telephone technology gave way to research into how it was perceived and reconstructed by an average or ideal listener.

Sterne argues that research into human hearing was moving farther inwards: from studies of the vibrating ear drum to exploring how the ear created and sent audio signals to the brain:

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[57] Dennis A. Bohn, "Operator Adjustable Equalizers: An Overview," in *Audio Engineering Society Conference: 6th International Conference: Sound Reinforcement*, 1988, 370, http://www.aes.org/e-lib/browse.cfm?elib=4628.
[58] Mills, "The Dead Room: Deafness and Communication Engineering," 53.
[59] Sterne, *MP3*, 45.

> The interchange between ears and machines extends from the middle ear to the inner ear. This shift is paradigmatic, because it literally places sound-reproduction technology *inside* the mind's ear.[60]

Thus did the receiver of the telephone call implicitly become the privileged object of study. It became essential for Bell Telephones to understand how listening subjects reconstructed audio information, which meant researching the inner workings of the mind.

An investigation that had begun as an observation of listening subjects in space had, by the 1920s, turned to probing the internal space of those listening subjects. The emerging imperative was to uncover how the human mind itself generated and perceived an "auditory space." Telephonic technologies were developed as interventions, ones that responded to studies in perception which then in turn spawned new forms of research based on psychoacoustic findings. It was in effect a feedback loop of research spiraling out of the multitude of connections between two auditory systems, one human and the other, non-human. Research into human hearing informed telephone developments; telephonic technology in turn shaped further experiments in human hearing. Returning to Wollaston's initial enquiries into the frequency range of human hearing and comparing it with telephonic approaches to frequency range suggests a slow transition, from an attitude of measurement to one of control. Wollaston mooted the idea that human hearing was only one range amongst many; his proposal – that hearing had serious limits – was increasingly confirmed by various studies into the ever-stultifying senses.[61] Yet, where the discovery of sensory limits alarmed some physicists of the nineteenth century, as we have seen, telephone researchers saw limited ranges in a more positive light. The rise of telephony had made it possible to manipulate frequency range and control specific properties of sound.

<u>III. Faders: A History of Mapping Loudness</u>

Control of amplitude is often equated with the control of loudness in sound engineering, even if this relationship is not as directly proportional as often thought. On the mixing board, the "fader" or "attenuator" is the tool used to control the loudness of different channels. The amplification panels developed by Bell Telephones used rotary knobs to control loudness, and this design passed on to amplifiers and mixers for P.A. systems, radio and movies. Arthur Davis, founder of Cinema Engineering, patented the "straight-line attenuator" in 1950 and towards the end of that decade producer Tom Dowd is thought to have installed them on audio mixers for recording.[62] This straight-line fader is

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[60] Ibid., 63.
[61] Edward Wheeler Scripture, *Thinking, Feeling, Doing* (Flood and Vincent, 1897), 148.
[62] Arthur C. Davis, Straight-line attenuator, United States US2517180A, filed May 15, 1950, and issued August 1, 1950,

the now classic slider control normally found in the bottom half of a typical mixing console.

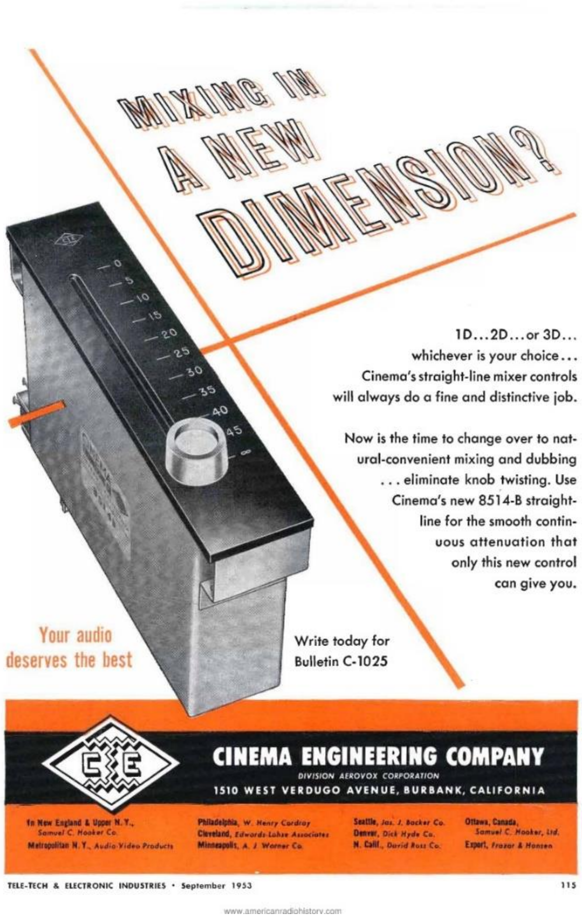

Figure 3.2: Advert for Cinema Engineering's "straight-line attenuator." Image from "Mixing in a New Dimension." *Tele-Tech*, September 1953, 115.

Whereas the term "equalizing" refers to the act of evening out frequencies in a wave form, "fading" refers to the perceptual sense of sound diminishing. Any such diminution has little to do with the physical properties of the sound wave. This detail reveals a lot about how sound intensity has been understood. Unlike the history of mapping frequency, research into sonic intensity was rooted in human perception from very early on. To fully appreciate the functional nuances of the fader, in this subsection, I will sketch another brief history, this time tracing the genealogy of cultural techniques that mapped the physical phenomena of sonic intensity and the psychological phenomena of loudness.

Psychophysical loudness

What is loudness? Experiments into amplitude and how humans experience this physical

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https://patents.google.com/patent/US2517180A/en?q=straight+line+attenuator&before=priority:19580101&after=priority:19480101; Izhaki, *Mixing Audio*, 174.

aspect of a waveform as "loudness" both intersect and diverge from the history of frequency ranges. Gustav Fechner, writing in 1860, identified the work of Karl Emil von Schafhäutl as the beginnings of research into "the limits of audibility."[63] Fechner, the so-called "father of psychophysics" and a thinker that I will concentrate upon most in this section, described how the Munich-based naturalist and musicologist positioned his subject's ear over a glass plate before dropping a small ball on said plate. Schafhäutl's control over the sonic variables of this very quiet experiment rested on the experimenter's ability to keep that distance between the ear opening and the point of impact on the glass constant. The weight of the ball and the distance from which it would be dropped having been determined, Schafhäutl concluded that "the limit of audibility was the sound of a cork ball of 1mg, falling a distance of 1mm at midnight, when no wind was blowing."[64] This experiment had many weaknesses. Fechner himself noted that the experiment was limited to the monophony of a single ear.[65] The more pressing concern was that Schafhäutl in his attempt to find the minimum acoustic intensity that could be detected by the ear, lacked the benefit of a unit of measurement to describe his findings. The Bavarian could only provide details of the weight of the ball, the distance it was dropped, and the meteorological conditions in which the experiment took place. It wasn't much to go on.

As yet, there were no universally accepted methods for producing reliable and consistent loud sounds. This made any attempt to measure human response to loudness or sonic intensity a difficult task. As late as 1887, Galton revealed the lack of progress towards loudness measurements in a review of new designs for anthropometric instruments, tools designed for the measurement of human faculties. Galton published a response from James McKeen Cattell of Wilhelm Wundt's laboratory in Leipzig on the issue of loudness tests. Cattell, who became the first professor of psychology in the United States, kept his appraisal of the situation brief. "As far as I know," lamented Cattell, "no sound of standard loudness has been agreed upon."[66] It would be a while before anyone could make sense of the phenomenon.

Similarly, Fechner did not dwell on this aspect of perceiving sound for very long, immediately turning his attention to the more extensive experiments on frequency range. *Elements of Psychophysics* (1860) was Fechner's illustrious attempt to bring together mind and matter, to quantify the relationship between physical sensation and psychological perception. It was a project that anticipated later explorations into the perception of "sonic intensity" and "loudness." "Psychophysics should be understood here as an exact theory," Fechner insisted, "of the material and the mental, of the physical and the

[63] Gustav Theodor Fechner et al., *Elements of Psychophysics*, A Henry Holt Edition in Psychology (New York: Holt, Rinehart and Winston, 1966), 214.
[64] Alexandra Hui, *The Psychophysical Ear: Musical Experiments, Experimental Sounds, 1840-1910* (MIT Press, 2013), 18.
[65] Fechner et al., *Elements of Psychophysics*, 215.
[66] Francis Galton, "On Recent Designs for Anthropometric Instruments," *The Journal of the Anthropological Institute of Great Britain and Ireland* 16 (1887): 7.

psychological worlds."[67] A rigorous science beckoned on the horizon, one that reconciled the relationship between perceived events and their physical stimuli.

Fechner hailed Ernst Weber as the father of psychophysics, the same Weber whose work, most notably the 1834 publication *The Sense of Touch*, had made initial enquires into the rules governing the perception of various senses. In his research, Weber noted that whilst systems of measurements had been created for numerous physical properties like length and weight, human subjects did not necessarily perceive these differences according to the diktats of pure scientific measurement. The kind of scales often used in the physical sciences were linear scales; they subdivided values equally. Weber noticed a different logic at work in his studies of perception. "When noting a difference between things that have been compared," Weber wrote, "we do not perceive the difference between the things, but the ratio of the difference to their magnitude."[68] As Fechner discerned, this was to suggest that perception did not scale in an arithmetic series (1,2,3,4, etc.), but in a geometric series, where the next value is always a product of the previous value and a constant value (2,4,8,16 etc.).[69] These insights were foundational to Fechner's science of psychophysics. They established the idea that perception could be measured, and that the relationship between perceived sensation and physical stimulus needed more research.

We could summarize Fechner's contributions to the study of loudness as an attempt to utilize Weberian principles towards the formation of a standardized, linear scale for loudness sensitivity. For such a scale, Fechner needed to establish three things. First, he had to establish the minimum sound intensity that could be perceived, what Weber called the "absolute" or "stimulus threshold."[70] This would mark the beginning of the scale, the zero point. Second, Fechner needed to know the smallest difference between two stimuli that could be sensed. This could be used to create a standard unit of measurement for sensation. Again, Fechner borrowed one of Weber's ideas, the "just-noticeable difference," to establish such a unit, arguing that it was "the smallest detectable increment in a sensation and therefore always psychologically the same size."[71] Finally, Fechner wanted to mathematically describe the relationship between changes in physical stimuli and psychological sensation, to provide a formula for how a just noticeable difference corresponded to the level of stimulus change. This last idea, to discover the link between perception and the physical environment, was crucial.

In his analysis of Weber's data, Fechner believed he had discovered a mathematical law that determined the relationship between physical stimulus and perceived sensation. Weber's research had shown that increasingly larger magnitudes of stimulus were required to register successive noticeable differences in sensation. Fechner gave this phenomenon a mathematical formula: sensation equaled a constant scaling factor (that varied depending on the sense being tested) multiplied by the logarithm of a

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[67] Fechner et al., *Elements of Psychophysics*, 7.
[68] Ernst Heinrich Weber, *E.H. Weber on the Tactile Senses* (Psychology Press, 1996), 126.
[69] George A. Gescheider, *Psychophysics: Method, Theory, and Application*, 2nd ed (Hillsdale, N.J: L. Erlbaum, 1985), 8.
[70] Ibid., 1.
[71] Ibid., 8.

stimulus. In short, sensation had a logarithmic relationship to stimulus. Fechner called this formula "Weber's Law." The logarithmic scale produced by Weber's Law could be used to predict how much change in physical stimulus would be required to create a just-noticeable difference. The link between physics and psychology had been found. All that was left to do was to collect more data that could confirm Weber's Law.

Back in the laboratory the problem of creating reliable ways to generate defined gradients of sonic intensity resurfaced. Fechner, as was his want, assessed other researchers' methods; he urged that any experiment would have to limit the possible variables that could influence the production of sound. The desire was to establish only one variable that could be used to incarnate one true scale of sonic intensity. To this end, Fechner and his colleague Alfred Volkmann decided to construct a simple "sound pendulum," which consisted of a "strong knitting needle" as the axis, a plate and a hammer. Somewhat embarrassed, Fechner would later note that his loudness apparatus had been improvised – built on the same day it was conceived. Yet, he and Volkmann professed themselves unperturbed:

> While apparatus and experiment were crude in certain respects, … the results were so conclusive that it could be foreseen that a more exact execution with a carefully constructed apparatus would not lead to any other results.[72]

Fechner could only temper his methodological reservations so readily because the results of the experiment had backed up the principle claim of his psychophysics treatise: that loudness perception, like many of the senses he had studied, was consistent with Weber's Law.

This is not to say that the perception of loudness was no longer a mysterious phenomenon – notwithstanding such confidence in the validity of Weber's Law when applied to the perceived magnitude of sound. Fechner's work to define and mathematically quantify this sensation was still deficient in two important ways. First, he lacked reliable equipment for testing, and, second, he lacked an official unit of measurement to register the physical magnitude of a sound wave. Perhaps it is no surprise, then, that a musician's knowledge could still be applied to an otherwise scientific problem. "I found it very interesting to hear the statement made by a musician (the violin virtuoso von Wasilewski) about the Rhine choral festival," Fechner admitted, "that a choir of 400 male voices did not cause a significantly stronger impression than one of 200."[73] This statement, significantly, was the one Fechner chose to conclude his discussion of loudness in *Elements of Psychophysics*.

However, Fechner's psychophysical research into loudness contained several important elements that had a lasting impact. Fechner reoriented the search for loudness measurements as the search for gradients of sensitivity. As the American psychologist, Edwin Boring, noted, Fechner believed that "you cannot measure sensation directly, but

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[72] Fechner et al., *Elements of Psychophysics*, 148.
[73] Ibid., 152.

only sensitivity."[74] Following Weber's methodology, Fechner also contributed to the construction of an "average listener." Both Weber and Fechner determined their psychological measurements statistically, and so their conclusions, which would be used as general references, reflected the mercurial traits of an imaginary "average" test subject. Finally, Fechner had introduced a radical idea by grounding scientific measurement phenomenologically. He had, in essence, reversed the usual order of experimental science. Rather than testing the psyche according to material phenomena, Fechner assessed physical phenomena according to the internal logic of perception. In this act, Fechner was asserting that the mind could be measured with the same empirical rigor as physical space. Which was to also suggest that the mind, the perceptual system of human consciousness, had a space all of its own.

Telephonic loudness

Telephonic loudness drew upon the research of psychophysics in numerous ways. At first, loudness was still treated as a spatial phenomenon. Just as Fechner could only use the height of a falling pendulum to determine varying sonic intensities, telephone engineers could only define loudness as a distance. Before vacuum tube amplification and repeaters, a telephone call could only travel as far as its natural power would allow. As such, loudness became a category that was often intermingled with the concept of "efficiency." The more efficient a telephone line, the further sound could travel and therefore from the perspective of communication engineers, the signal had been made louder. Again, there was no precise measurement to determine the relative efficiency of one line over another. Early tests developed by AT&T involved comparative listening tests, where the relative quality of a line was determined by the ear alone.[75]

In their listening tests, the engineers at Bell Telephones essentially "black boxed" loudness. The concept of the black box became an important idea in cybernetic theory.[76] Black boxes were components that acted upon a system in measurable ways, but their internal functioning could not be measured. In a 1924 article the Bell engineer, W.H. Martin, revealed the extent to which the problem of loudness had been effectively cordoned off within the system. "The input and output of the circuit are in the form of sound," wrote Martin, "and its efficiency as a transmission system may be expressed as the ratio of the sound power output to the sound power input."[77] Statements such as these highlight that telephone researchers could only compare the loudness of a transmission at inputs and outputs of the network, and note the gradual loss of power over larger distances.

Unsurprisingly, the first attempts to establish a standard measurement for loudness relied on spatial logic. "Loss in miles of standard cable" was the first unit made by AT&T around the turn of the century. To create this measurement, engineers set up an

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[74] Boring, *Sensation and Perception in the History of Experimental Psychology*, 36.
[75] Bell Telephone Laboratories and Fagen, *A History of Engineering and Science in the Bell System*, 303.
[76] Pickering, *The Cybernetic Brain*, 20.
[77] W. H. Martin, "The Transmission Unit and Telephone Transmission Reference Systems," *The Bell System Technical Journal* 3, no. 3 (July 1924): 400, https://doi.org/10.1002/j.1538-7305.1924.tb00010.x.

ideal telephone circuit with the best equipment available at the time. Other telephone circuits would be compared with the reference circuit. As the most "efficient" line, the reference system would always transmit sound the loudest and so miles of cable would be added to it until it had the same loudness as the telephone line under examination.[78] The number of miles of cable added to the reference system constituted a known, quantifiable measurement of loudness: the loss of power per mile in a telephone connection. In strict terms, this was a measurement of attenuation, not of loudness gained, but loudness lost.

Subsequent developments in loudness measurement by AT&T relied on the older, spatial conception of power-loss per mile but were increasingly expressed in more abstract, mathematical terms. The process of simplifying and generalizing attenuation began with an update to the reference system. In the 1920s a new "ideal" cable was established that had fixed quantities of resistance and impedance when transmitting sound at 800 cycles per second (an "800-cycle mile" as it was known).[79] This reference system added an extra level of precision, defining more parameters and therefore limiting the variable factors that contributed to power loss over the telephone line. Furthermore, engineers noticed that the attenuating properties of such a line could be expressed in a logarithmic formula, as they had discovered that sound power-loss per mile increased at a constant ratio. Thus, the older process of physically adding lengths of telephone cable had been replaced, attenuation was now grounded within a mathematical framework.

At this stage of development in the telephone system, the loudness measurements of Fechner and telephonic enquiries into attenuation began to converge in significant ways. The function of the ear and the functioning of the telephone network in regards to sonic intensity became interchangeable concepts in engineer's description of sonic power. The 800-cycle mile was given a mathematical formula; attenuation equaled $10.56 \log_{10} P_1/P_2$ (P_1 represented input power, P_2, output power). This formula was remarkably similar to Weber's Law and the equivalence was not lost on telephone engineers. The mathematical formula for the 800-cycle mile formed the basis of a new unit of measurement in 1924, the transmission unit (TU). In an article describing the TU, Bell engineer, W.H. Martin, proclaimed that just-noticeable differences of loudness had a mirror image in the properties of telephone lines. "The sound power changes which can be detected by an ear," wrote Martin, "are of the order of that corresponding to a mile of standard cable."[80] The implication was clear. Telephonic sound, prior to amplification, was literally sound as far as the ear could hear.

If the telephone system seemed to function like the human ear it was also treated like the body of a psychophysical test subject. The introduction of vacuum tube amplification and electronic wave filters that we explored earlier, afforded new methods and technologies for testing the telephone network. The 1917 "thermophone" gave electroacoustic researchers an instrument that could produce sound with precise control of amplitude based on heat being applied to a conductor.[81] This invention allowed for

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[78] Bell Telephone Laboratories and Fagen, *A History of Engineering and Science in the Bell System*, 305.
[79] Ibid.
[80] Martin, "The Transmission Unit and Telephone Transmission Reference Systems," 406.
[81] H. D. Arnold and I. B. Crandall., "The Thermophone as a Precision Source of Sound," *Physical Review* 10, no. 1 (July 1, 1917): 22, https://doi.org/10.1103/PhysRev.10.22.

much greater control over sound intensity levels. Alongside the controlled production of sound, new transmitter designs offered the possibility of detecting even smaller gradients of sound levels. The 1916 condenser microphone was designed to be equally sensitive to soundwaves of every frequency, and therefore a more accurate instrument for measuring loudness.[82] This condenser microphone would be used to create a new and improved reference system for the telephone network following the introduction of the "transmission unit."[83] Human ears were no longer needed to assess the quality of two different lines, now that electroacoustic technologies could quantify sound in discrete metrics.

Technologies like the thermophone and electronic generators of sound proved equally useful instruments for measuring human hearing response. Prominent researchers at Bell Laboratories like Harvey Fletcher used electronic sound generators, amplifiers, wave filters and speakers to produce measured sounds at specific frequencies. These developments revolutionized testing of loudness sensitivity, as the founder of Harvard's Psycho-Acoustic Laboratory, S.S. Stevens attested:

> The invention of electrical oscillating circuits and telephone receivers injected a new order of precision and convenience into auditory experiments. Beginning in the 1930s physicists and psychologists utilized the new instruments to elicit ratio judgements of loudness.[84]

At Bell Laboratories Fletcher became known for his research into frequency-based sensitivity for loudness. Fletcher and his colleague, Wilden Munson, tested loudness perception at specific frequencies across the human hearing range.[85] Fletcher and Munson created a graph with one axis for frequency and the other for sound pressure to demonstrate the loudness "curve" of the ear. Their findings, published in 1933, revealed that loudness sensitivity varied at different frequencies. It appeared that the ear itself was not a neutral receiver of sound. In Fletcher and Munson's project, the separate historical investigations into frequency and loudness perception finally come together. However, telephonic science also contributed to separating these two aspects of sound. As we have seen telephone engineers consistently sought methods to isolate and control these integral properties of sound independent from one another. Frequency and loudness could only be "mixed" once they had been separated apart.

Telephone technology has profoundly shaped our conceptual understanding of loudness. The configurations of loudness within the telephone system have contributed

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[82] E. C. Wente, "A Condenser Transmitter as a Uniformly Sensitive Instrument for the Absolute Measurement of Sound Intensity," *Physical Review* 10, no. 1 (July 1, 1917): 39, https://doi.org/10.1103/PhysRev.10.39.
[83] Martin, "The Transmission Unit and Telephone Transmission Reference Systems," 408.
[84] S. S. Stevens, *Psychophysics: Introduction to Its Perceptual, Neural and Social Prospects* (Routledge, 2017), 20.
[85] Harvey Fletcher and W. A. Munson, "Loudness, Its Definition, Measurement and Calculation*," *Bell System Technical Journal* 12, no. 4 (October 1, 1933): 377–430, https://doi.org/10.1002/j.1538-7305.1933.tb00403.x.

to an electrical hegemony in thinking about acoustic phenomena. For example, the acoustic intensity of a sound wave and the power of the electroacoustic wave transmitted on the telephone wire were eventually seen to represent the same thing. W.H. Martin, in his article on the transmission unit clarified the nature of loudness-loss in purely electronic terms. "'The mile of standard cable' corresponds to the ratio of two amounts of sound power," stated Martin, "or as this change in sound power is produced by changing the power delivered to the telephone receiver, to a ratio of two amounts of electrical power.[86] Martin's words betray a subtle historical transformation, one where the "change in sound power" is finally understood in terms of electrical power. The loudness of sound is simply a property of the electrical wave. The distinction between electronic power and acoustic intensity was further eroded by the introduction of the decibel in 1928, an equivalent to the transmission unit. Articles on the decibel referenced attenuation in telephone cables and Weber's Law for loudness perception in the same breath.[87] Telephone engineers intermingled ideas from perceptual science, the physics of acoustic waves and electronic theory.

That acoustic waves would be wholly coopted into an electroacoustic worldview can be traced to the historical development of telephone technology. Telephonic developments contained a circular logic in many instances. M.D. Fagen relates that "the very devices (vacuum tubes and filters) which brought about the need for objective measurements also provided the means for making them."[88] Which is to suggest that electronic problems could always be overcome with electrical solutions. In this brief history of loudness measurements and investigations, we can see that where loudness was endowed with spatial properties in psychophysics, it was spatial control that defined telephonic developments. Through telephone measurement units like the decibel, attenuation was brought into line with Fechner's theories for loudness sensitivity; one decibel representing one just-noticeable difference of loudness. However, unlike the nineteenth-century psychophysicist, the twentieth-century engineer could control the amount of loudness perceived by a listener, through the dial of a telephone amplifier or the fader of a mixing board.

IV. Conclusion: Mixing and Programming

To conclude, I return to the strange hybrid image of auditory space/mixing board with which I began. As we have seen, the history of mapping loudness and frequency is intrinsically linked to the two interface technologies that define the mixing board: the fader and the EQ. By their design, values of loudness and frequency at hand, the mixer embodies the achievement of a historical mapping of sound. It is often said that the mixing board operator has "control over sound," that he – it is always *he* – commands the quality of sound by his mastery of electroacoustic technology. He stands supreme, modifying loudness with faders and frequency with EQ. However, such an order of things

[86] Martin, "The Transmission Unit and Telephone Transmission Reference Systems," 403.
[87] R.V.L. Hartley, "'TU' Becomes 'Decibel,'" *Bell Laboratories Record* 7, no. 4 (December 1928): 137.
[88] Bell Telephone Laboratories and Fagen, *A History of Engineering and Science in the Bell System*, 310–11.

might be reversed, given the telephonic approach to sound control I have sketched. As we have seen, the nonhuman mixer also manifests a system of values that invades human nature, shaping conceptions of the processes by which humans perceive sound internally. No wonder, then – given that the mixer's functions aligned with ideas about auditory space – that mixing boards (as much as control technologies in general) were often portrayed as sinister technologies, in ways reflected in popular culture of the 1950s and 60s.[89]

In the mixer, the nineteenth-century project of mapping human faculties and physical phenomena meets the twentieth-century project of control. The fader, constructed to increase in decibel increments, is designed in the same way our ears perceive "just noticeable differences" of loudness. Similarly, the EQ control is designed to cover the human hearing range for frequency, covering the full spectrum of our perceptual abilities. I might observe, in light of this history of electroacoustic media in general, that the idea of a "theatre in the mind" becomes less of a metaphor and more of a truism. The mixing board was designed to get inside listener's heads, as much as listener's heads were designed to get inside mixing boards. The mechanical sensitivities of the machine were engineered to model the sensitivities of human hearing.

One of the general themes that Donald Broadbent's research on auditory perception highlighted in *Perception and Communication* was the way in which the brain produced conscious reality. Perception was not just a reflection of the sensations people received, but was conjured by the brain from sensory data and memory. The role that memory played in our perception of sound was a key issue, informing the development of Broadbent's filter theory. He asked: to what extent did the brain construct auditory reality from sensory input, and to what extent did it do so from memory? This was a question science fiction writer Philip K. Dick would explore in his fictional work. In Dick's novel *We Can Remember It For You Wholesale* (1966) the protagonist who can't afford a trip to Mars is given the opportunity to purchase the memory of a visit. Weighing up the pros and cons of such a move the character muses, "Was this the answer? After all, an illusion, no matter how convincing, remained nothing more than an illusion. At least objectively. But subjectively – quite the opposite entirely."[90] The character here reaffirms the author's belief that reality was something that was produced, an idea that reverberates with the conclusions of researchers into perception and the controls on a mixing board.

Armed with telephonic technology, researchers not only created an exterior physical map of sound but an interior psychological map of how this sound was processed by the mind. Through developments in the telephone system, hearing and sound – more so than any other perceptual phenomena – were subjected to extensive mapping and attempts at control. In using these technologies of sound, the audio mixing board operator is in more than a metaphorical sense programming the perceptual space of its intended listeners, manipulating the ways in which the mind constructs an auditory

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[89] Miriam R. Levin, "Contexts of Control," in *Cultures of Control*, ed. Miriam R. Levin (Amsterdam : Abingdon: Harwood Academic ; Marston, 2000), 30.
[90] Philip K. Dick, *Selected Stories of Philip K. Dick* (Houghton Mifflin Harcourt, 2013), 327.

reality. The operator administers loudness in logarithmic fashion and manipulates frequency within the human hearing range.

To mix is to program.

Chapter 4

All the Colors of Tone: The Trautonium

In the previous chapters I explored two technologies that have often been overlooked as electroacoustic instruments, the modern recording studio and the mixing board. In this chapter I turn to a more obvious electroacoustic case study – the synthesizer. Unlike the mixing board and recording studio, which as we have seen were rooted in filmmaking practice, electronic instruments developed in musical institutions. Early electronic instruments such as the Theremin (1920) and Ondes Martinot (1928) were initially conceived as concert instruments.[1] They were designed for performance, exploiting the affordances of electroacoustics to create a more expressive instrument. Within movie productions the development of these electronic instruments was reoriented. Instruments that could shape timbre in more complex ways offered more than just the novelty sounds of electronic oscillators.

Miklós Rózsa famously employed the Theremin in his scoring of *Spellbound* (1945) and the instrument became a staple of science-fiction soundtracks of the 1950s. In the United States, figures such as Raymond Scott, Bebe and Louis Barron, and Eric Siday became known for their experiments with electronic sounds in the aftermath of World War Two. The Barrons found success scoring for movies, furnishing *Forbidden Planet* (1956) with "electronic tonalities" that were created with self-designed circuits modelled on cybernetic principles.[2] This particular score highlighted the tension surrounding electronic sound and its role in movies more generally. The musician's union and Composer's Guild both voiced concerns about crediting the Barrons as official composers.[3] It seemed that within the movie industry, electronic instruments were predominantly valued either for their idiosyncratic, other-worldly tones – an exotic addition to the orchestral palette – or for their ability to simulate sound – a mere audio FX device.

I suggested in Chapter 2 that sound was "designed" through technologies like the mixing board. A similar process can be traced in the development of electronic synthesizers. Electronic synthesizers are different to many, early electronic instruments, emphasizing the affordances of electroacoustic technology for timbral control rather than performance. The Trautonium embodies this shift. First built in Berlin in 1929, it was eventually used for performance, sound effects and composition. Like the mixing board, the Trautonium drew upon research that probed the perceptual capabilities of human listeners and, I argue, was designed to function as an instrument for total timbral control.

The Sound of *The Birds*

[1] Albert Glinsky, *Theremin: Ether Music and Espionage* (University of Illinois Press, 2000), 197.
[2] James Eugene Wierzbicki, *Louis and Bebe Barron"s Forbidden Planet: A Film Score Guide*, Scarecrow Film Score Guides, no. 4 (Lanham, Md: Scarecrow Press, 2005), 35.
[3] Ibid., 14.

In April 1963, *New York Times* critic Bosley Crowther reviewed the latest Hollywood blockbuster, a film whose narrative famously revolved around the eponymous birds who inexplicably attack the population of Bodega Bay, a town just north of San Francisco.

> A threat of unspeakable horror is latent in our feathered friends! At least, that is what Alfred Hitchcock is implying in his new film, "The Birds," which is whirring and screeching with deafening uproar at the Palace and Sutton Theaters. Making a terrifying menace out of what is assumed to be one of nature's most innocent creatures and one of man's most melodious friends.[4]

The power of the film Crowther implied, was aural: an effect of the deafening intensity of its use of sound. He was not the only critic to be impressed by the sonic uproar. "There is not a note of music throughout the picture", a reviewer for *TIME Magazine* observed; but rather, "a deafening crescendo of screeching, whistling, chattering, flapping cacophony."[5] A writer for *Film in Review* also argued that the effectiveness of the narrative derived "as much from novel special effects … as from Hitchcock's skill in concocting suspense."[6] The critical consensus was that Hitchcock had given "man's most melodious friends" a disturbing new soundtrack.[7]

If the sound of the birds seemed so unnatural to reviewers and audiences, this was because their sinister tones had been produced, not by a "natural" instrument, but by an electronic machine: the Trautonium. The Trautonium ensured that even when reviewers offered little praise for *The Birds* as a film, they could not escape the alarming force of its soundtrack. After lambasting what it called Hitchcock's ill-conceived "monster movie," the critic for *Newsweek* turned a perceptive ear to the film's treatment of sound:

> One innovation that *is* interesting is the Trautonium, an electronic sound machine invented by Dr. Friedrich Trautwein, which is able to reproduce noises either faithfully or in a deliberately distorted way. The bird's caws on the sound track are, in fact, distorted – harsher, louder, and angrier than the noises of real birds – and the effect is quite frightening, probably because the ears of a moviegoer are less sophisticated than the eyes. He recognizes the sounds as those of birds, but does not notice the subtle changes that the Trautonium has played on them.[8]

The *Newsweek* reviewer, in other words, offered an auditory twist on the "uncanny valley" hypothesis: that when the bird sounds seemed almost real, they actually felt more alien. Particularly disconcerting, for the writer, was the psychological impact of sounds that were perceived as natural and artificial at the same time. Electronic sound, apparently,

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[4] Bosley Crowther, "Screen: "The Birds": Hitchcock"s Feathered Fiends Are Chilling"," *The New York Times*, April 1, 1963.
[5] "They Is Here," *TIME Magazine* 81, no. 14 (April 5, 1963): 103.
[6] Sterling de G Foote, "The Birds," *Films in Review*, May 1963, 309.
[7] For a wider compilation of audio reviews see James Wierzbicki, "Shrieks, Flutters, and Vocal Curtains: Electronic Sound/Electronic Music in Hitchcock"s The Birds," *Music and the Moving Image* 1, no. 2 (2008): 10.
[8] "Hitchcock"s Monster," *Newsweek*, April 8, 1963, 92.

could both mirror sound and deceive listeners in unnerving ways. The Trautonium, with its ability to simulate an approximation of bird sounds, induced unsettling experiential effects.

In this chapter I explore the evolution of the Trautonium, tracing its journey from avant-garde instrument to sound effects generator, a trajectory that takes us from the electroacoustic experiments of Berlin laboratories to the movie productions of Californian studios. The development of the Trautonium provides a unique site to ground explorations into electronic sound synthesis. Neither the first electronically powered instrument, nor the earliest to claim the ability to simulate all sounds, the Trautonium nevertheless drew upon and incorporated a diverse spectrum of ideas. Several recurring narratives framing electronic sound synthesis were in play: the Trautonium was informed by acoustic research into human vocal tracts, the search for a perfect musical interface, and, the development of electroacoustic technology, in this case the neon tubes that could generate the complex wave forms that gave the instrument its signature sound. Furthermore, the Trautonium, as we shall see, was imbricated in debates about the political dimensions of technology and aesthetics during the first half of the twentieth century, particularly in discussions about the power of totalitarian media. Technologies of sound and light were as important to the film industry as they were to the staging of political power.

New Electronic Sounds

Hitchcock was not the first to discover the memorable sounds generated by the Trautonium. The American composer Henry Cowell had in fact come across the instrument thirty years earlier. In 1931 Cowell was awarded a Guggenheim Fellowship that funded a research trip to Berlin. During his two-month stay, Cowell met Georg Schünemann, deputy director of the Hochschule für Musik. Schünemann introduced Cowell to the university's Radio Research Section, a group of laboratory researchers, that were conducting extensive research and experiments in electroacoustics and radio technology. Part of Cowell's tour included a demonstration of the Trautonium that had been invented by Friedrich Trautwein two years earlier. The instrument impressed Cowell with its potential to create new sounds through electronic technology.[9]

Cowell's interest in the Trautonium, and his fascination with Berlin-based acoustic science in general, can be linked to ideas developed in his book, *New Musical Resources*, which was published in New York in 1930. The treatise identified potential areas for musical exploration, specifically new materials and resources made available to composers by recent developments in acoustic science. Berlin was a suitable destination for the musically "progressive," having become a hub for electronic sound and acoustic research. "Contemporary music makes almost universal use of materials formerly considered unusable," Cowell declared, believing that "little is known about the materials of contemporary music, and there are surprisingly few attempts to organize them into a

[9] Joel Sachs, *Henry Cowell: A Man Made of Music* (New York: Oxford University Press, 2012), 190.

unified system."[10] *New Musical Resources* was Cowell's attempt to fill a perceived gap in musical knowledge. He identified three main areas of study – three as-yet untapped "musical resources" – to form the three sections of his book. Part one explored "tone combinations," part two, "rhythm," while part three was devoted to "chord-formation." In this final section of the book, Cowell introduced his most celebrated compositional innovation: a device he called "the tone-cluster."

The bulk of Cowell's 1930 trip was spent at the Berlin Phonogramm-Archiv, Erich Hornbostel's ever-expanding collection of non-western music recordings having been newly relocated to the city's *Museum für Völkerkunde*. Cowell purportedly inspected up to two hundred recordings of music that had been gathered from around the world.[11] His fascination for "ethnic sound" betrayed that the Phonogramm-Archiv and the Hochschule's Radio Research Section shared many overlapping aims. Like Cowell, both Berlin institutions were investing in discovering new musical materials from a scientific perspective. Two shared research interests in particular would shape the development of the Trautonium. The first related to the exploration of new tuning systems that went beyond the twelve tones established in mainstream, European music. The second involved the attempt by researchers of phonetics to explain the acoustic generation of vowel sounds.

Psychologist and philosopher Carl Stumpf represented one clear link between the research of phonetics and tuning systems that both informed the Trautonium. Famously, Stumpf founded the Phonogramm-Archiv in 1900, his interest in collecting the music of "primitive" cultures being directly related to his psychological research. For example, Stumpf used such recordings as Sri Lankan Vedda songs, Papa New Guinea rain spells and the music of Patagonian tribes from the archive to support his theories of the development of pitch and tuning systems in his 1911 book, *The Origins of Music*.[12] Stumpf had also written extensively on the psychological aspects of timbre or "tone color," as it was called. In a 1926 paper he explored a concept taken from research in phonetics: fixed formant positions. "Formant" theories were originally used to explain the production of vowel sounds in human speech, and posited that certain bands of frequencies affected the timbre of a spoken sound. Stumpf applied this theory of speech generation to musical instruments, arguing that formants played an integral role in the perception of timbre.[13] As we shall see, these seemingly separate areas of scientific research – phonetics and tuning systems – were deeply influential for inventors of electronic instruments in Germany.

The Trautonium was constructed amidst a wave of interest in "alternative" or "exotic" tuning systems. Engineer Jörg Mager pioneered the development of electronic

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[10] Henry Cowell and David Nicholls, *New Musical Resources* (Cambridge England ; New York: Cambridge University Press, 1996), ix.
[11] Sachs, *Henry Cowell*, 197.
[12] Carl Stumpf, *The Origins of Music,* trans. David Trippett (Oxford University Press), 107, accessed June 30, 2020, https://www.oxfordscholarship.com/view/10.1093/acprof:oso/9780199695737.001.0001/acprof-9780199695737.
[13] Christopher Reuter and Saleh Siddiq, "The Colourful Life of Timbre Spaces," in *Body, Sound and Space in Music and Beyond: Multimodal Explorations*, ed. Clemens Wöllner (Taylor & Francis, 2017), 152.

instruments that explored non-standard tunings. Before the Trautonium, the Hochschule had been early supporters of his work. Mager had created his first electric tone generator in 1921, an instrument he developed and renamed the "Spherophone" in 1924.[14] The Spherophone was inspired by Mager's interests in microtones, pitch divisions that were smaller than the semitone.[15] One of the affordances of such experimental electronic instruments was their potential to achieve outlandish tunings, their construction purportedly affording the transcendence both of tradition and the physical limits of traditional technologies. Many composers cultivated a strong interest in quarter-tones during the 1920s. Cowell, himself, had visited Alois Hábas's Department of Quarter Tone Music at the Prague Music Conservatory in 1926.[16] Using the Spherophone, performers could play notes that were neither conceivable in terms of European tuning methods nor afforded by European musical instruments.

Mager's interest in microtones illuminated a practical problem with the design of electronic instruments: the interface. Traditional technologies, he complained, had developed with preconceived tuning systems incorporated into their design, such as the twelve chromatic keys of the piano. In the wake of the developments of such electronic instruments as Thaddeus Cahill's Telharmonium (1897) or Léon Theremin's Etherphone (1928) the issue of agency of the interface became urgent: how should a performer interact with a machine that could afford so many types of control? In Mager's earliest prototype of the Spherophone, a rotary hand-crank controlled pitch, in ways that likely resembled an extreme version of "pitch bend."[17] This design had flaws. Moving between pitches meant having to pass through all the frequencies in the interval between two notes. Moreover, this mechanism didn't lend itself well to performance. Instruments with fixed pitches may not have offered infinite flexibility in terms of tuning, but they could be played in ensembles, because they were easier to interact with.

The Trautonium's interface represented a compromise between fixed and continuous pitch control, a combination of discrete and untempered notes, features that amalgamated the keyboard and string interfaces. "In playing the Trautonium, a performer controlled pitch by pressing a finger against a wire at some point along its length, thereby putting the wire in contact with a metal bar, closing a circuit, and producing a note," explained composer Joel Chadabe in his 1997 book *Electric Sound*. Meanwhile, "the performer pressed another bar to control articulation."[18] The full spectrum of frequencies, as afforded by Mager's Spherophone, were made available to the performer; in addition, fixed pitch positions were also possible. By opening a field for both analogue and digital play, Trautwein's instrument captured "continuous tonal space", as he described in a book published in 1930, *Elektrische Musik*, which documented his work on the Trautonium.

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[14] Thomas Patteson, *Instruments for New Music: Sound, Technology, and Modernism* (Oakland, Calif: University of California Press, 2015), 64.
[15] Hans-Joachim Braun, ed., *Music and Technology in the Twentieth Century* (Baltimore: Johns Hopkins University Press, 2002), 201.
[16] Sachs, *Henry Cowell*, 139.
[17] Patteson, *Instruments for New Music*, 61.
[18] Joel Chadabe, *Electric Sound: The Past and Promise of Electronic Music* (Upper Saddle River, N.J: Prentice Hall, 1997), 12.

Figure 4.1 pictures the opening pages of Cowell's personal copy of Trautwein's *Elektrische Musik*, acquired in Berlin, and eventually making its way back to California, where it currently resides in the collections of the UCLA library.[19] A small booklet, the thirty-nine pages of *Elektrische Musik* reveal how the Trautonium was constructed and the principles that went into its design. Included at the end of the main text is a composition sketch by Paul Hindemith who was an early supporter of Trautwein's invention. Cowell, Mager and Trautwein, were each beginning to turn away from the use of electronic instruments as a means for exploiting intonation, as the search for new musical resources took a different turn. Cowell explored new rhythmic possibilities and collaborated with the Russian inventor, Léon Theremin, who had invented the Theremin in 1920 to widespread acclaim. The Theremin project would result in the Rhythmicon, the first electronic drum machine, constructed in 1931. Trautwein and Mager, on the other hand, explored frontiers in the electronic production of tone color. Both went in search of new sounds.

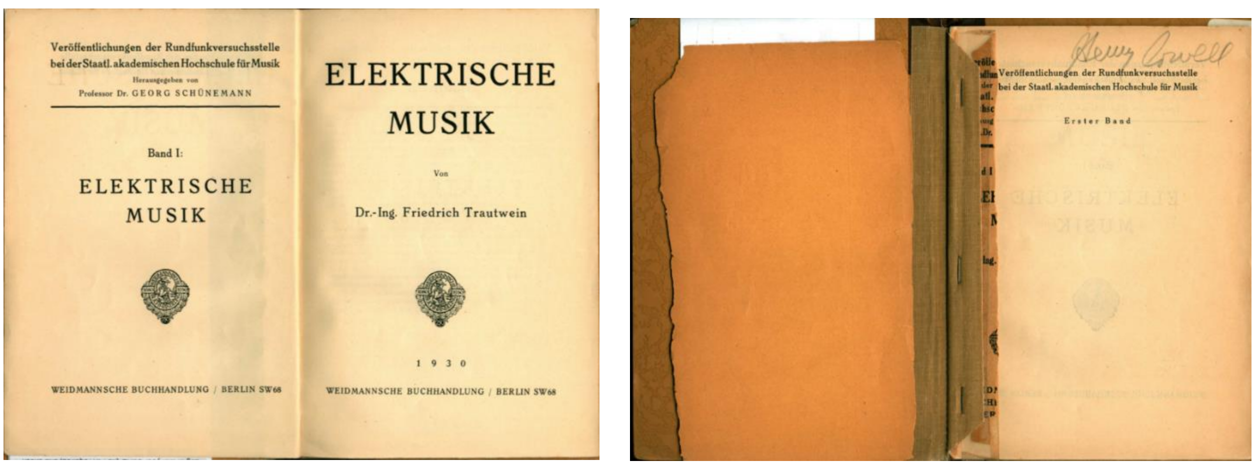

Figure 4.1: Henry Cowell's autographed copy of *Elektrische Musik*, ML3805.T697e in SRLF.

Total Synthesis

The Trautonium's design was shaped by scientific research into timbre, an aspect of sound still clouded in mystery.[20] The magic of tone color was an abiding fascination for this generation of thinkers and inventors. Berlin-based research in acoustics and psychology provided much of the groundwork for instrument designers, keen to apply electrical knowledge to the mysteries of timbre. Studies of tones by such luminaries as

[19] Adrian Freed, former Research Director of UC Berkeley's Center for New Music and Audio Technologies (CNMAT) discovered this detail and sent me looking in the right direction.
[20] Dr Emily I. Dolan, *The Orchestral Revolution: Haydn and the Technologies of Timbre* (Cambridge ; New York: Cambridge University Press, 2013); Emily I. Dolan and Alexander Rehding, eds., *The Oxford Handbook of Timbre* (Oxford University Press, 2018), https://doi.org/10.1093/oxfordhb/9780190637224.001.0001; Robert Fink, Melinda Latour, and Zachary Wallmark, *The Relentless Pursuit of Tone: Timbre in Popular Music* (Oxford University Press, 2018).

Hermann von Helmholtz had pierced the unifying aura traditionally associated with the sonic experience, by stripping sound into separate and measurable parameters. Yet, whilst the amplitude and frequency of soundwaves had obvious connections to a listener's perception of loudness and pitch, how timbre was produced and perceived was less clear. "The third property of tone [timbre] is much the most complicated", wrote Dayton Miller in a collection of lectures published in 1916, "it is that characteristic of sound, produced by some particular instrument or voice, by which they are distinguished from sounds of the same loudness and pitch, produced by other instruments or voices."[21] Even as late as 1965, audiologist Aram Glorig could write in similar terms that "timbre is something of a "wastebasket" attribute: if two tones are judged to be "different," and yet have the same pitch and the same loudness, then they must differ in timbre."[22] The demystifying work of experimental scientists since Helmholtz notwithstanding, the enigma of timbre remained just that: an enigma.

Trautwein made special reference to theories of timbre whenever given the opportunity to publicize the synthesizing properties of his Trautonium. In *Elektrische Musik*, Trautwein drew upon experimental work by physicists that explored tone color, highlighting the work of his compatriots, Helmholtz, Stumpf and Karl Willy Wagner, as well as the American physicist, astronomer, acoustician, and amateur flautist, Dayton Miller. Condensing information from Miller's collection of lectures quoted earlier, *The Science of Musical Sounds*, Trautwein stated that timbre was determined by the relative amplitude of overtones, the sound waves that accompany the fundamental sound perceived as a pitch. "It appears that even proportionally slight variations in these determinant factors can stimulate quite substantial differences in the perception of the sound generated at the physiological level," wrote Trautwein. He concluded thus: "the exact reproduction of specific tone colors would therefore essentially seem difficult to achieve."[23] Here, Trautwein acknowledged that any attempt to reconstruct the wave characteristics of musical instruments electronically would require a device that could produce and control the many variables of a complex wave.

In the face of this acknowledged difficulty of recreating a timbre-manipulating device, Trautwein attempted a total synthesis of the methods available to designers of electronic instruments. First, Trautwein experimented with electronic circuits that drew upon Helmholtz" classic theory of timbre.[24] The "Helmholtz approach" to timbre was the one outlined by Dayton Miller, which understood tone color as a product of the many combinations of overtones that accompanied the fundamental pitch. Any attempt to reproduce timbral effects electronically, according to this theory, would need to provide a way to generate and control overtones. The prestige of this Helmholtzian conception of timbre is obvious in the construction of early electronic instruments like Thaddeus Cahill's 1896 invention, the Telharmonium. The Telharmonium employed tone wheels to generate sound waves electronically. Cahill used these tone wheels to not only produce a

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[21] Dayton Clarence Miller, *The Science of Musical Sounds* (New York: The Macmillan Company, 1916), 58, https://archive.org/details/sciencemusicalso1millgoog/page/n74/mode/2up/search/tone+quality.
[22] Aram Glorig, *Audiometry: Principles and Practices* (Williams & Wilkins Co., 1965), 55.
[23] Friedrich Trautwein, *Elektrische Musik,* (Berlin: Wiedmann, 1930), 8. Translation by Michael Ward
[24] Ibid.

fundamental pitch but also to generate overtones that could be added to the fundamental, a method of manipulating timbre now commonly known as "additive synthesis." Yet, for Trautwein, "additive synthesis" was limited. His experiments led him to believe that this design conception had little to commend itself as a means for the production of timbre. "The musical quality of tone-coloring achieved by these methods is", he complained, "really insignificant."[25] It was clear to Trautwein that a new approach was needed.

Unlike the additive approach that was tried and found wanting, the Trautonium employed a form of synthesis expropriated from research into the production of sound in the human voice. In this approach, timbral control was modelled on the vocal cavity which was known to form specific sounds from an already complex wave form. This subtractive technique imitated the shaping capacities of the human vocal tract, which filtered sound in magical ways. Such filtering represented, in effect, the opposite approach to constructing tone color that was prevalent in additive synthesis and illustrated by instruments like the Telharmonium. Instead of creating complex waveforms one overtone at a time, the Trautonium took a complex waveform and tamed its features using various controls. As such, The Trautonium generated complex wave forms rather than the singular sine waves generated by the Telharmonium's tonewheels. This complex wave form was obtained through the use of a "glimmer lamp", that utilized the electrical properties of the gaseous element, neon.

If the approach to synthesis manifested in the Trautonium was conceptually inspired by the mechanism of the human voice, it was made possible materially by the neon tube. During the 1920s Germany had utilized neon for a variety of functions, developing methods for applying the gas to low voltage lighting as well as to relaxation oscillators for electronic circuits.[26] Unlike the usual vacuum tubes found in other electronic devices, neon tubes generated what Trautwein described as "distorted oscillations", wave forms that did not look, or sound, like the sine waves produced by instruments like the Telharmonium or Theremin.[27] (See Figure 4.2) Pressured into neon tubes the gas becomes ionized once it reaches a threshold, resulting in a glow discharge that generates "sawtooth" waves forms. This method of electronic sound generation produced a fundamental pitch that was accompanied by a range of overtones, in ways that conjured timbral "depth." The sound of the Trautonium was, therefore, distinct from other electronic instruments, especially when compared to the sparse tones of the Theremin – an instrument that generated simple sine waves. "Because of the use of a neon-tube oscillator", writes Thom Holmes, "the sound of the Trautonium was distinctly

[25] Ibid., 10.
[26] Leon Caster, ed., "The Development of Low-Voltage Neon Lamps," *The Illuminating Engineer* 13 (August 1920): 228.
[27] Trautwein, *Elektrische Musik,* 9.

different from that of its predecessors."[28]

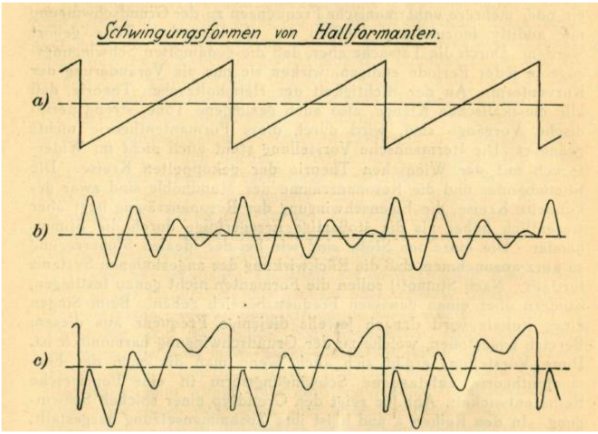

Figure 4.2: Trautwein's diagrams illustrating different waveforms. A, shows the sawtooth waveform produced by the neon lamp. B, shows the overtones generated by the formant circuit filter. C, shows the "galvanic mixing" of the two. Trautwein, Friedrich. *Elektrische Musik,*. Berlin: Wiedmann, 1930, 14.

A second way that the Trautonium was modelled on the human vocal tract was by the incorporation of electronic circuits, which were designed to imitate the production of formant frequencies. As we have seen, formant theory developed out of attempts to understand the acoustic phenomena of vowel sounds in human speech. The theory claimed that within the vocal cavity, specific frequency ranges were amplified, sometimes producing additional resonant frequencies to the fundamental pitch but also filtering the general frequency characteristics of the original sound. Both the filtering and overtone effect contributed to the timbre of the voice. Trautwein used formant theory to design circuits that would simulate formant resonances electronically affording control over which frequencies were affected. In his *Instruments for New Music* (2015) Thomas Patteson describes the formant-circuits" function in these terms:

> On the early models of the Trautonium, the frequency range of the formants could be adjusted continuously by means of rotary capacitors on the instrument's front panel. By moving the formants higher or lower, the player was able to shape the timbre of the electrically generated tone.[29]

The process described by Patteson facilitated the production of a wide variety of timbres. It gave the performer a previously unprecedented amount of control over the tonal color of sound.

The Trautonium, therefore, incorporated an approach to sound design that combined the timbre theories of Helmholtz as well as the formant theories first proposed by German physicist and speech scientist Ludimar Hermann, and expanded upon by Stumpf. Trautwein followed the basic premise of Helmholtz's theory – that tone color was the product of various overtones related to the fundamental pitch – but also incorporated the timbral implications of formant theory. Where instruments like the Telharmonium attained tonal variety through overtone manipulation alone, the Trautonium's sound was

[28] Thom Holmes, *Electronic and Experimental Music*, The Scribner Music Library (New York: Scribner"s, 1985), 49.
[29] Patteson, *Instruments for New Music*, 119.

achieved through the combination of rich harmonic waveforms, produced by the neon tube and the formant circuits, an approach that Trautwein evocatively described as, "a galvanic mixing of excitation-vibrations and resonant formants."[30] This "galvanic mixing" got closer to producing the kind of complex waveforms created by acoustic instruments. The Trautonium was thus a synthesizer on multiple levels. Its very design was the product of a synthesis, of the string and keyboard interfaces, as well through its electronic methods for producing tone color.

The concept of "the synthesizer," in fact, can be traced back to this history of the Trautonium, an instrument that I see as an attempt towards "total synthesis." What informed the project of "total synthesis" was the underlying belief that the timbral properties of sound could be completely mapped and controlled through electronic engineering. One of the first instruments named as a "synthesizer" was the RCA Mark 1 Synthesizer, a machine completed in 1955 by the engineers, Harry Olson and Herbert Belar, for the Radio Corporation of America. In their corporate magazine, *Radio Age*, the instrument is described as "an infinitely versatile system for producing entirely by electronic means any known or imaginable tone or combination of tones."[31] When comparing the claims of the RCA synthesizer with reactions to the Trautonium we find similar descriptions around each instrument's affordances of total timbral control. A reviewer for the trade journal, *Electronics*, wrote in a 1931 article that with Trautwein's instrument, "any tone quality, known or unknown, is available; any pitch can be obtained (and the glorious quality of the low notes must be heard to be appreciated); any desired volume is obtainable; and any desired form of control can be adopted."[32] The conceit of such an "infinitely versatile" system, of course, has infiltrated into understandings of electronic instruments right up to the present, where laptops and digital audio workstations offer a centralized space for generating and shaping the "totality" of universal sounds.

Whilst the Trautonium was not the first instrument to be hailed as a generator of every kind of tone color, it was a new instrument developed, informed and consciously attached to developments in electroacoustic theory. Germany hosted numerous institutions devoted to electroacoustic research and, as we have seen, Trautwein drew upon timbral theories from a variety of sources in the construction and design of his instrument.[33] The instrument was predicated on the affordances of electronic control, and specifically control over complex soundwaves. Unlike instruments that utilized an early form of additive synthesis, like the Telharmonium, where simple waveforms were added to overtone by overtone, the Trautonium took complex waves as the base material from which to sculpt tone. Neither fully influenced by the short-lived interest in quarter tone compositions nor fully swayed by the limited timbres of overtone synthesis, the Trautonium made complex timbral control a central feature of its operation.

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[30] Trautwein, *Elektrische Musik,* 13. and Patteson, *Instruments for New Music*, 61.
[31] "Electronic Music; Electronic Cooling," *Radio Age*, April 1955, 10.
[32] R. Raven-Hart, "Recent Developments in Electronic Musical Instrument," *Electronics*, July 1931, 42.
[33] For a history of German institutions involved in electroacoustics see, Roland Wittje, *The Age of Electroacoustics: Transforming Science and Sound*, Transformations : Studies in the History of Science and Technology (Cambridge, Massachusetts: MIT Press, 2016).

Furthermore, the Trautonium, much like the Phonogramm-Archiv, was invested in the mapping and reproduction of human sonic activity. As we have seen, Trautwein drew on research from speech scientists, creating circuits that simulated the function of the human vocal cavity, and this highlights one of the ways in which the mapping of a sonic phenomenon in a scientific project could then be instrumentalized in the design of a synthesizer. The discoveries of speech scientists were, in effect, used as the basis for electronically reproducing the sonic effect of human speech. The Phonogramm-Archiv was marked by a similar project of reproducibility and mapping. The Archiv's contents were used to map the music of other cultures, relying on the technology of the phonograph to reproduce musical activity from other parts of the world. Stumpf continually promoted the phonograph as an essential tool for comparative music studies to attain appropriate levels of scientific rigor and exactitude. For Stumpf, not only was the phonograph more objective in the act of capturing melodies "in the field" of research, but the recordings made with the machine could also be examined repeatedly back in the safety of the Archiv. Stumpf believed it was not enough to just capture the sources of these different musical cultures, they also needed to be reproduced for analysis, stating, "the ultimate goal is not the collection, but the utilization."[34] The Trautonium and the Phonogramm-Archiv possessed an allure of "exotic", raw sound from beyond the center of European knowledge. These unknown sounds once brought under control – able to be reproduced through the technology of the synthesizer and the phonograph – could then become new musical resources.

Neon Lights/Neon Sound

A visual representation of technology and exoticism was featured in the 1927 film, *Metropolis*, directed by Fritz Lang. In the film, Yoshiwara, a nightclub for the rich, encapsulates the aesthetic world of Weimar Berlin and its famous avenue of entertainment and leisure: the Kurfürstendamm. In the original novel by Lang's then-wife Thea Von Harbou, Yoshiwara captured the audio-visual experience of that street in all of its electricity and novelty:

> Music was in the air, hurled into nocturnal streets by enormous loud-speakers. Wanton was the music, most heated of rhythm, of a shrieking, lashing gaiety.... "No!" panted the man. Blood trickled in drops from his bitten lips. But a hundred multi-coloured rockets wrote in the velvet-black sky of Metropolis, the word: Yoshiwara.... Georgi pushed the window open. The glorious town of Metropolis, dancing in the drunkenness of light, threw itself impetuously towards him, as though he were the only beloved.[35]

[34] Stumpf, *The Origins of Music*, 68.
[35] Thea von Harbou, *Metropolis* (New York, NY: Ace Books, 1963), 46.

In this passage, Harbou draws out the sensory effect of Berlin's most infamous avenue. The critic, Bernard von Brentano noted the Berlin connection in his review of the film, describing the skyscrapers of *Metropolis* as a vertical extension of the Kurfürstendamm.[36]

As is well known, Lang found inspiration for the set-design of *Metropolis* in the city of New York, which he visited in 1924, the United States and its modern cities proving fertile ground for filmic visions of modernity. Architect Erich Mendelsohn, happened to be on the same boat as Lang as they crossed the Atlantic and the two maintained contact throughout their trip.[37] Both were struck by their experience of the city, especially at night with its glamorous displays of neon lights. Mendelsohn returned to Germany and published a photo-book in 1925, *Amerika*, that proved hugely popular. Included in the collection of photos was a solitary entry by Mendelsohn's unexpected travel companion. Taken with a long exposure, Lang's photo evoked the illusion of an electric mirage, the light bulbs of Times Square superimposed on one another (Figure 4.3). Lang's picture not only treated the fantastic effect of lighting technology in the modern city as its thematic subject, but was itself the product of a special effect.

Figure 4.3: Fritz Lang's photograph. Mendelsohn, Erich. *Amerika: Livre D'images D'un Architecte*. 1re éd. française. Morceaux Choisis. Paris: Editions du Demi-Cercle, 1992. Page 131.

The aesthetic possibilities afforded by neon – as a unifying technology for light and sound – were as appealing to filmmakers as they were to political parties. Special effects could underscore political and artistic narratives, a phenomenon explored by Walter Benjamin in his well-known 1935 essay "The Work of Art in the Age of Mechanical Reproduction." In the article, Benjamin traces an "aestheticization of politics" latent in Fascist displays of power, noting how aesthetic force was weaponized by the Nazi Party in Germany. Theodor Adorno, noticed a similar trend in the mass media of the United States.[38] There, movie productions had reached a high level of sophistication, and Lang

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[36] Bernard von Brentano, "Metropolis," *Frankfurter Zeitung Und Handelsblatt*, January 13, 1927, 26.
[37] Jan Wollner, "The Architecture of Metropolis," *Umělec*, 2012.
[38] Theodor W. Adorno and Max Horkheimer, *Dialectic of Enlightenment*, New Ed (New York: Verso Books, 1997); Adorno and Hullot-Kentor, "The Radio Symphony."

also visited Hollywood on his 1924 trip. The production of *Metropolis* has been seen as an attempt to compete with the vast resources of the west coast studios he had witnessed first-hand.[39] Lang filmed *Metropolis* upon his return to Germany using cameras he had bought in New York. In one famous scene where the inventor, Rotwang, gives his robot invention – the Maschnenmensch (Machine-Human) – the appearance of his deceased love, a circle of neon lights was used as a stunning visual effect for this act of artificial resurrection. This scene could be read as a metaphor for the cultural moment of Lang's homeland. Like the character Rotwang, the Nazi Party were committed to an act of revival. The Nazi's political message was centered on a narrative of renewing a broken Germany and, as we shall see, they exploited the aesthetic potential of neon and sound as a totalizing special effect.

Neon was a dreamy substance, the development of neon lighting making the ambiance it conjured evocative of urban modernity and promises of a better future. It was discovered in 1898 by British chemists William Ramsay and Morris Travers, who named the gas after the Greek for "new." The limited availability of neon prevented its widespread use in industrial settings and it only featured as a novelty effect at the beginning of the twentieth century. In 1902, French engineer Georges Claude developed a new system for liquefying air that would later take his name. The "Claude System" was designed to cool air into liquid form so that the various natural gases in the atmosphere could be extracted for industrial use.[40] Claude created a company in 1902, Air Liquide, that produced large quantities of liquid oxygen and nitrogen. In addition, as a byproduct, the company sold a recently-discovered noble gas – neon.

Whilst liquid oxygen and nitrogen had many obvious industrial uses, neon was one of the less functional elements produced by Claude's air liquefaction plants. Despite the minimal need for neon in industrial settings at the time, Claude found a way to profit from the waste material, creating the first neon lighting company in 1923: Claude Neon. Claude Neon would set up numerous franchises in the United States where it became increasingly synonymous with advertising. Claude's own use of neon lighting also carried more performative and political weight. Claude had joined the far-right political party Action Française in 1919 and would later run as a candidate in 1927, deploying his technical innovations throughout his campaign.[41] "At Georges Claude's meetings, the spoken promises which were used to sway the electorate were replaced by experiments", writes Christine Blondel, "he put on the stage the contents of a five ton lorry: air-containers, blackboards, oxygen and acetylene cylinders, transformers and neon tubes."[42] Claude brought the spectacular effects of neon lighting into the growing political darkness of Europe.

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[39] Ward Janet, "Kracauer versus the Weimar Film-City," in *Peripheral Visions: The Hidden Stages of Weimar Cinema* (Wayne State University Press, 2001), 24.
[40] Raymond G. Stokes and Ralf Banken, *Building Upon Air: A History of the International Industrial Gases Industry from the 19th to the 21st Centuries* (Cambridge University Press, 2015), 48.
[41] Frank N. Magill, *The 20th Century A-GI: Dictionary of World Biography* (Routledge, 2013), 701.
[42] Christine Blondel, "Industrial Science as a "Show": A Case-Study of Georges Claude," in *Expository Science: Forms and Functions of Popularisation*, ed. Terry Shin and Richard Whitley (Springer Science & Business Media, 1985), 255.

As we have seen, the "glimmer lamps" used for generating sound in the 1930 Trautonium were repurposed neon tubes that had been originally designed as voltage protectors for radio antennas (Figure 4.4).[43] By the 1920s Germany had developed a special relationship with neon and the technologies that utilized it. The Frankfurt-based company, Griesheim-Elektron, bought the rights to the Claude process of air liquidation in 1907.[44] They started producing neon in 1913 and neon signs appeared in German cities in the following decade.[45] In 1925 the Osram lighting company created a new way of shaping the bulbs used in neon signs, further expanding the creative use of this lighting effect.[46] Both of these technological developments contributed to the popularity of neon signs in Germany. By the end of the 1920s, writes Pamela Swett, author of *Selling Under the Swastika,* "Berlin alone had three thousand lighted advertisements." [47] Also to be noted was the development of neon tubes for use in such electronic devices as surge protectors and instrument panel indicators. In a 1954 manual on electronic music instruments, Alan Douglas noted that when the Trautonium was invented, "neon tubes had reached a considerable state of perfection in Germany."[48] Trautwein was able to experiment with neon tubes because of their popularity in his homeland. This fact only gave the tubes even more of a ritualistic aura. "Early Trautonium players coveted their pet neon tubes just like a bassoonist would his reeds," alleges Greg Armbruster: "they were equally temperamental."[49]

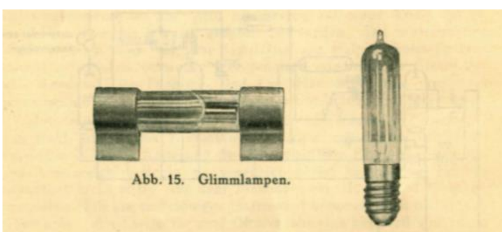

Figure 4.4: The neon tubes used in the original Trautonium. *Elektrische Musik*, 30.

The Nazi Party's accession to power in 1933 left the position of neon technologies in a state of flux. The neon tube in the original Trautonium, whose rich harmonic waveforms had catalyzed Trautwein's approach to synthesis, found itself uniquely connected to the political and cultural vision of the Nazi party. On the one hand, neon was associated with the luminescent advertising and moral deficiencies of the United

[43] Trautwein, *Elektrische Musik,* 29.
[44] Alfred D. Chandler Jr. and Alfred D. Chandler Jr., *Scale and Scope: The Dynamics of Industrial Capitalism* (London, UNITED KINGDOM: Harvard University Press, 1994), 483–84, http://ebookcentral.proquest.com/lib/berkeley-ebooks/detail.action?docID=3300751.
[45] Ebbe Almqvist, *History of Industrial Gases* (Springer Science & Business Media, 2012), 127.
[46] Janet Ward, *Weimar Surfaces: Urban Visual Culture in 1920s Germany* (University of California Press, 2001), 123.
[47] Pamela Swett, *Selling under the Swastika: Advertising and Commercial Culture in Nazi Germany* (Stanford University Press, 2013), 24.
[48] Alan Lockhart Monteith Douglas, *The Electronic Musical Instrument Manual; A Guide to Theory and Design*, 2d ed. (New York [etc.], 1954), 126, http://hdl.handle.net/2027/mdp.39015015424651.
[49] Tom Darter and Greg Armbruster, eds., *The Art of Electronic Music*, 1st Quill ed (New York: Quill, 1984), 41.

States and Weimar Republic. In a 1931 NSDAP meeting, Hitler railed against the deterioration of German cities, linking moral health to flickering lights. "Cities and the mentality associated with them determine and guide our political actions" declared Hitler, "and this big-city mentality is a disaster, poisoned and bestialized, as it is, by a thousand superficial impressions – cheap neon advertising, sham politics everywhere you look."[50] On the other hand, neon had the potential to be recast by the Nazi regime to serve the requirements of totalitarian political spectacle.

The aesthetics of cinema and the use of "special effects" played a significant part in the Nazi's use of neon. *Metropolis* itself, a favourite film of Hitler and Joseph Goebbels, acted as a kind of blueprint as technologies of light and sound were deployed to serve the Nazi vision for Germany, and Berlin in particular. Neon was used both for propagandistic effect (Figure 4.5) and for the staging of political power. William Brevda highlights the Nazi's appropriation of movie aesthetics and set-design for the latter, writing: "after Hitler came to power in 1933, the Nazis made full use of neon display (introduced in Leipzig in 1922) to enhance their "Nationalist Socialist nights" and the *mise-en-scene of Hitler*, a *Film Noire*: night and fog and neon."[51] The British artist and critic, Wyndham Lewis, similarly noted this celluloid approach to politics in his 1939 pamphlet *The Hitler Cult*, stating that "for the Berliner, life has become like a never-ending film of The Life of Adolf Hitler."[52] However, by May 1940 with the beginning of war in Europe a nation-wide blackout would abruptly put an end to Germany's affair with neon.[53]

Figure 4.5. Neon sign in Vienna 1938, encouraging Austrians to vote for annexation with Nazi Germany. Dokumentationsarchiv des Österreichischen, *Austria-Forum*, Inventory number: 6677.

At the end of 1931, whilst Cowell returned to New York (he had offered little evidence of the rising political violence in his correspondences from Germany), Friedrich Trautwein had to confront the new political situation.[54] At first glance, the Trautonium,

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[50] Thomas Friedrich, *Hitler"s Berlin* (Yale University Press, 2012), 204.
[51] William Brevda, "NEON LIGHTS AROUND EVERYTHING: West"s "West," Hitler"s "Empire," Postmodernism"s "Reality,"" *Soundings: An Interdisciplinary Journal* 85, no. 3/4 (2002): 403.
[52] Wyndham Lewis, *The Hitler Cult* (Dent, 1939), 25.
[53] Christoph Ribbat, *Flickering Light: A History of Neon* (Reaktion Books, 2013), 50.
[54] Sachs, *Henry Cowell*, 190.

as an experimental instrument, seemed ill-suited to the "naturalist" theories then espoused by Nazi aestheticians, who railed against those modern artforms they considered "degenerate." The Nazi party removed many figures involved in the development of electronic music from the first half of the 1930s.[55] The Hochschule für Musik's own director, Georg Schünemann, was denounced by the party, becoming one of twenty-seven instructors removed between 1932 and 1933, including many radio researchers and Jewish faculty, as the institution endeared itself to National Socialist values.[56] In an attempt to protect his instrument, Trautwein arranged for a private demonstration of the Trautonium to Nazi officials with his protégé Oskar Sala in 1935. Sala recounted the event in an interview from 1997:

> Luckily, Trautwein knew a general who was on our side and arranged that we could demonstrate the instrument to the minister of propaganda, Joseph Goebbels – Hitler's right hand. I played something by Paganini, and of course he liked it. After that they left us in peace.[57]

Whilst institutions devoted to electronic music and research were systematically shut down, as the meeting described above suggests, there was still room enough in the Nazi cultural apparatus for instruments like the Trautonium.

Where the research aims of the radio laboratory had pushed synthesizer development towards experiments in timbre, Nazi interests in electronic music were motivated by the concerns of public spectacle, and propagandistic display at large events. At the 1935 demonstration of the Trautonium, Goebbels apparently made no attempt to conceal the fact that his interest in the instrument depended on its capacity to furnish mass gatherings with sound.[58] In the context of the political rally, the Trautonium was no longer configured as an experimental instrument. Rather, it was construed as an apparatus for effects, the sonic equivalent of neon lighting. Under the Nazi regime the potential role of the instrument was curtailed, no longer required to probe the intricacies of tone color, it would be limited to underscoring a tightly controlled political image.

The 1936 Olympics in Berlin provided one such mass stage to exhibit the potential power of electronic music. The Nazi party constructed a massive public announcement system for the games, with over 350 microphones employed.[59] Included in this impressive electroacoustic system was the first dynamic range compressor, the mythical Telefunken U3 limiter, designed to protect equipment from the potentially high audio levels captured by all those microphones.[60] Everything was amplified, including the Olympic Stadium's

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[55] Patteson, *Instruments for New Music*, 134.
[56] Elizabeth Janik, *Recomposing German Music: Politics And Musical Tradition in Cold War Berlin* (BRILL, 2005), 70.
[57] Georg Misch, "The Difference Engine," *The Wire*, November 1997, 45.
[58] Patteson, *Instruments for New Music*, 136.
[59] Ward Rennen, *CityEvents: Place Selling in a Media Age* (Amsterdam University Press, 2007), 119.
[60] Karl Pedersen and Mark Grimshaw-Aagaard, *The Recording, Mixing, and Mastering Reference Handbook* (Oxford University Press, 2019), 172.

bell, when officials decided that it was not loud enough in its purely acoustic state.[61] Although the Trautonium was played on the Olympic radio network and featured in a series of programs in the years after, it was never featured in the infamous, mass rally spectacles of the 1930s as Goebbels had imagined. [62] The Nazi's were clearly enamored with the technics of broadcasting. As yet though, they were still working on the National Socialist soundtrack.

After-FX

Trautwein joined the Nazi Party in 1933, and aligned his research interests with the technical needs of the party. Whilst Telefunken collaborated with the inventor to create the "Volkstrautonium" in the same year, an instrument designed for the consumer market, it was a commercial failure.[63] The purpose of the research project, after all, was the development of massive sound systems that would amplify the aesthetic effect of political rallies. After the war Trautwein's contributions to electronic music were limited. He provided a modified version of his instrument, the Monochord, to what would become the hub of post-war electronic art music, the West-Deutscher Rundfunk studios, established in Cologne in 1951.[64] Thomas Patteson notes that Trautwein's support for the Nazi party didn't seemed to have impacted his post-war career.[65] This is all the more surprising considering that another of his other war time projects included work on electrical guidance systems for long distance missiles, a project that would directly connect Trautwein to the inventor of neon lighting.[66]

The life of Georges Claude was more fateful than that of Trautwein, though the two shared a compromised past. Claude was accused of collaborating with the Nazi's during their occupation of France. The extent of his collaboration had serious consequences. Accusers made the link from *Claude Neon*, purveyor of neon lighting, back to his first company, *Air Liquide*, producers of liquid oxygen, a key component of rocket fuel. In a 1944 article for *Life Magazine*, British war historian, Hilary St. George Saunders mapped the extent of V2 "robot rocket" attacks on London. Saunders noted that the German rocket scientists, "were supposedly assisted by Monsieur Georges Claude, a Frenchman and collaborator who claims to have invented the flying bomb."[67] The same plants that extracted neon out of the air had potentially provided the liquid oxygen used for V2 rocket fuel. Claude's final invention would be in the realm of audio. By the time Claude was arrested, he was suffering from deafness and had to listen to the proceedings of his 1945 trial through a "crude hearing device" he had invented for himself.[68] At the

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[61] Siegfried Zielinski, *Audiovisions: Cinema and Television as Entr"actes in History* (Amsterdam University Press, 1999), 170.
[62] Patteson, *Instruments for New Music*, 140.
[63] Ibid., 130.
[64] Chadabe, *Electric Sound*, 38.
[65] Patteson, *Instruments for New Music*, 159.
[66] Fred K. Prieberg, *Handbuch deutsche Musiker 1933-1945* ([Kiel] : Prieberg, 2005), 7233, http://archive.org/details/bib130947_001_001.
[67] Hilary St. George Saunders, "The Flying Bomb," *Life Magazine*, November 20, 1944, 91.
[68] "Georges Claude Imprisoned For Life," *The Advocate*, June 30, 1945, 7.

climax of the trial, listening through this earpiece, Claude received life imprisonment for his propaganda work. The audio device proved his final invention.

Trautwein and Claude's alleged involvement in the construction of long-range missiles connects them to the history of cybernetics. Norbert Wiener was brought into the United States' National Research Defense Committee (NRDC) and tasked with finding a method for predicting the movements of rocket bombs so that anti-aircraft targeting could be improved. Wiener, going far beyond the requested task, ended up writing a general theory of communication. Many of the ideas developed in this work would then feature in his landmark text, *Cybernetics: Or Control and Communication in the Animal and the Machine*, published in 1948.[69] Trautwein and Claude in their own small way were interconnected with developments towards systematic control.

The Trautonium lived on through the developments of Oskar Sala, who had continually modified and improved its synthesizing abilities. Sala's first model, the "Radio-Trautonium", was constructed in 1935 and contained two finger boards, for the generation of two-part harmonies, and two pedals; one for volume, the other for modifying pitch. The instrument incorporated another Trautwein concept in sound synthesis: subharmonics. Subharmonics can be understood as the opposite process of the overtone series; but unlike overtones, subharmonics do not occur naturally. In practice this meant that users of the Radio-Trautonium could not only add the usual overtones to the fundamental pitch but also the undertones below it.[70] In Sala's development of the synthesizer, timbral manipulation was expanded upon in all directions.

Sala's later work re-oriented the history of the instrument away from public demonstrations and performances in order to embrace the ways in which it afforded "perfect" timbral control and produced exotic effects. After the war, in 1952, Sala completed yet another version of the Trautonium, the Mixturtrautonium. This instrument, as its name suggests, represented a mixture of the various forms of synthesis that had been developed throughout the Trautonium's history. It was also a mixture of different technologies, Sala incorporating modern advances in solid-state electronics into the instrument's circuitry. With the Mixturtrautonium, Sala focused on creating soundtracks and sonic effects for movie productions in the 1950s. One project saw Sala working with a figure we have seen before, the *Metropolis* director, Fritz Lang. *Das indische Grabmal*, released in 1959 the second of a double feature, was Lang's penultimate film before his death. Like *Metropolis*, the film was adapted from a novel by his now ex-wife, Thea Von Harbou, and marked Lang's first return to Germany since he fled the Nazis in the 1930s. In this movie the Trautonium underscores the more "exotic" elements, heard before Debra Paget's infamous snake dance and adding strange overtones to cave echoes in a later scene.

The use of electronic audio devices for movie scores and sound effects became increasingly common in the 1950s. The simple electronic sine waves produced by instruments like the Theremin were coopted into the sound-world of science fiction

[69] Nicholas de Monchaux, *Local Code: 3659 Proposals About Data, Design, and the Nature of Cities* (New York: Princeton Architectural Press, 2016), 131.
[70] Patteson, *Instruments for New Music*, 133.

movies.[71] The 1947 record, *Music Out of The Moon*, along with movies like *Rocketship X-M* (1950) and *The Day the Earth Stood Still* (1951), established a long-standing association between electronic sounds, sound control and outer-space.[72] "Mixing instruments" or instruments that existed to synthesize sounds, however, were less common. The soundtrack for the 1956 film, *Forbidden Planet*, composed by Louis and Bebe Barron featured more complex electronic timbres. The Barron's process relied on tape recordings of sounds generated by different electronic circuits. They would then apply various audio effects such as delay and reverberation to the recorded sounds in order to attain the desired timbre.[73] However, none of these technological products came close to the range of centralized control over sound afforded by the Trautonium in all of its iterations. Unlike its rival electronic instruments, the Trautonium was capable of approximating a whole world of synthesized sound, from the Grail bells of Wagner's *Parsifal,* to the birds of Northern California.[74]

All of the material aspects explored in this chapter – the Trautonium, neon and the V2 Rocket – come together in the making of *The Birds.* Legend tells that when Alfred Hitchcock was disappointed by the efforts of his Hollywood sound engineers to fabricate the sounds of his main antagonists, the birds, he turned to Oskar Sala and his Mixturtrautonium to conjure a solution.[75] The American composer, Remi Gassman, provided the connection between Sala and Hitchcock, Gassman having collaborated in 1959 with Sala over the production of an electronic ballet score. According to film theorist Richard Allen, *The Birds* pioneered a new approach to film sound that would eventually become standard: "Hitchcock enthusiastically embraced electronic sound because it allowed him to create the dense layering of sound effects that he wanted for the film, one that anticipates modern sound design."[76] For Hitchcock, in other words, the role of movie sound was not to present "realistic" audio for the events on the screen; rather, it was to embrace the powerful effects of illusion and fantasy afforded by the movie-making process. The Trautonium's success in *The Birds* ultimately stemmed from its value as an instrument of control: the bird sounds could be molded to fit the dramatic fantasies of the screen in a way that recorded samples, not matter how realistic, could not.

We have already explored how neon production in Germany connected the neon tubes in Trautwein's first instrument to the manufacturing of rocket fuel in the Nazi's vengeance weapon. In *The Birds*, the Trautonium was linked to the V2 rocket in a different way. Hitchcock revealed in an interview with the French director, François Truffaut, the heavy emotional reactions he experienced during the filming of the movie.[77] It seemed that memories of a brief stay in London during the Blitz had seeped into the

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[71] Mathew J. Bartkowiak, *Sounds of the Future: Essays on Music in Science Fiction Film* (McFarland, 2010); Trace Reddell, *The Sound of Things to Come: An Audible History of the Science Fiction Film* (Minneapolis: Univ Of Minnesota Press, 2018).
[72] Wierzbicki, *Louis and Bebe Barron"s Forbidden Planet*, 22.
[73] Ibid., 32.
[74] Patteson, *Instruments for New Music*, 158.
[75] Misch, "The Difference Engine," 46.
[76] Richard Allen, "The Sound of "The Birds,"" *October* 146 (2013): 98.
[77] Francois Truffaut, *Hitchcock* (Simon and Schuster, 2015), 290.

portrayal of aerial siege in the movie. Film scholar John Orr, makes a similar connection and suggests that the movie offered a potential atonement of guilt for the English director, who had moved to the United States before the war. Hitchcock's decision to adapt a Daphne du Maurier story provided another link to the homeland he had abandoned. "It was appropriate that du Maurier also provided 'The Birds' feeding Hitchcock's final reckoning with the Blitz, which his family had painfully endured in his absence," Orr writes, "the story itself, though it takes place in post-war Cornwall, may well have been prompted by the war experience and we should note that du Maurier's birds finally descend on London."[78] There is the prospect then, that the birds, underscored by the Trautonium, were symbols of the robot rockets that devastated London. In light of the material connections between the instrument that produced the sound effects of the birds, and the rockets they symbolically represented, Bosley Crowther's review of the movie appears all the more insightful. "There are the usual Hitchcock 'characters' spotted through the film," Crowther writes, "And those birds! Well, you've never seen such actors! They are amazingly malevolent feathered friends."[79]

[78] John Orr, *Hitchcock and Twentieth-Century Cinema* (Wallflower Press, 2005), 88.
[79] Crowther, "Screen: "The Birds": Hitchcock"s Feathered Fiends Are Chilling"."

Epilogue

This dissertation has explored several of the many avenues that extend from the history of electroacoustic sound systems. During my research into electronically mediated sound, I became aware of how little historical and theoretical work has addressed some of the basic elements of sound and music. Concepts like loudness and timbre, and how they have been reconceptualized in an electroacoustic paradigm have received little attention. Whilst historians of electroacoustics, and the majority of research in this dissertation, have uncovered the institutions and techniques that shaped and formed the discipline, few have explored how this figured in the experience of contemporary listeners. There is precious little documentation on how listeners at the time actually experienced many of the electroacoustic effects so celebrated by technicians, engineers and historians. Theodor Adorno's phenomenological study of radio in the 1940s is unique in this regard and his observations and reflections on electronic sound transmission as it happened could form one way to approach a listener-oriented study of electroacoustics.[395]

The electroacoustic systems described in this dissertation were large networks, employed in studios (movie and music) owned by national companies, that were themselves connected to a network of manufacturing plants and media outlets. Yet the continuing development of electroacoustic technology has been towards the miniature. Perhaps the most concrete link between the shared histories of cybernetics and electroacoustics lies in the personal computer. Many historians of cybernetics see the evolution of the modern computer and the internet as having been deeply impacted by ideas within the discipline.[396] Music recording itself has become centralized and miniaturized in the personal computer. Producers in the present can record and manipulate sound exclusively within the machine. All of the technologies physically bolted into the mid-century recording studio can now be implemented virtually. There is even a digital simulation of the famous echo chambers beneath the Capitol Records parking lot (Figure 5.1).

Figure 5.1: Universal Audio's "Capitol Chambers" plug-in, a digital simulation of the sonic characteristics of the reverberation chambers at the Capitol Records Tower. Image from Universal Audio website.

[395] Adorno and Hullot-Kentor, "The Radio Symphony."
[396] Mindell, *Between Human and Machine*, 10; Kline, *The Cybernetics Moment*, 204.

Despite the move from primarily electroacoustic technologies to digital ones in modern recording, traces of the past and their ideas remain. In the Capitol Chambers plug-in shown above, sketches of the Capitol Tower, glimpses of vintage technology and a black and white snapshot of Frank Sinatra are all used by the plug-in developers to tie their purely virtual product to the physical spaces and retro allure of the Tower. The original chambers had been used to simulate the natural effect of reverberation within the more controlled setting of the electroacoustic recording system. The digital version thus forms a chain of simulation, a device attempting to recreate the sonic quality of an old echo chamber which itself was designed to imbue sounds with cathedral-like shimmer. It is interesting to note that despite all the advances and increased affordances of computers and digital sound processing, it is the age of electroacoustic recording that is fetishized. In a sense, systems of the past still haunt those of the future, and in the case of sound systems, for many, they still sound better.

In Chapter 1 I explored the electrification of the phonograph, specifically the Victor Orthophonic Victrola of 1925. This device had managed to win round one of "canned music's" greatest critics, the bandleader and composer, John Philip Sousa. Sousa declared of this phonograph that it was "the first time I have ever heard music with any soul to it produced by a mechanical talking machine."[397] In the transition from purely electroacoustic (analogue) recording to digital recording with computers, Sousa's soul of music has reemerged in the discourse of musicians and engineers. An interview with the musician, Jack White, from 2014 illustrates this point: "when you are recording and producing, you are aiming for something and if you want vibe, warmth, soulfulness, things like that, you will always be drawn back to analogue."[398] Sociologist, Nick Prior, maps the dichotomy in the following terms, "champions of analogue… characterize the analogue world as pure, while digital sounds are deemed to be 'depthless' and 'soulless.'"[399] The spiritualism of electroacoustics, addressed in my introduction, has hung on in the realm of recorded music.

Whilst it is easy to dismiss the desire for pure analogue sound from the halcyon days of recording as simple nostalgia, they point to a real need in music creation that resists the technocratic tendencies of electroacoustic science: magic. The mercurial nature of electronic sound during the mid-century interacted with the elusive qualities that made a music performance special and worth capturing. Now, the development of sound technologies is often oriented towards the elimination of exactly the kind of anomalies that made music recording seem special and alive. If there is a pining for the glory days of electroacoustic recording in the present this could also be attributed to the dire status of music recordings themselves, and not just financially. I am alluding here to another point made throughout my study of electroacoustic science that can be summed up in the title of a 1929 article comparing radio and television: "Radio Eye Harder to Fool than the Radio Ear." The author of this article noted that, "it is far easier to fool the radio

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[397] "New Music Machine Thrills All Hearers At First Test Here," 1.
[398] Paul Tingen, "Inside Track: Jack White," Sound on Sound, October 2014, https://www.soundonsound.com/techniques/inside-track-jack-white.
[399] Nick Prior, *Popular Music, Digital Technology and Society* (London: SAGE, 2018), 61.

ear, with just an approximation of music and speech, than it is to fool the radio eye or television broadcasting, with incorrect pictorial values."[400] By stating that the auditory illusion involved less work, the article seemed to imply that sound media was less of a challenge to the engineer, than visual media. There is a sense that the mysterious qualities of sound had been all too easily extracted and mastered by engineering systems, and that electroacoustic technologies performed, if anything, all too well. In the broader view of electroacoustic developments, the obsession for greater audio fidelity and system performance has risen proportionally to the decline in value and status of recorded music.

Casting the net further still, there is a latent nostalgia towards systems more generally. Where midcentury systems were conceived as a new and improved way of controlling and optimizing large-scale work between humans and machines, their role in the present is different. Our relationship with systems is in flux. In recent times the original concept of systems serving human populations has been turned upside down, even as models and simulations dominate public perception and policy. Many systems that emerged after the second world war, during the "golden age" of cybernetics, are now deemed too big to fail. Whether it is the maintenance of healthcare systems under the strain of a pandemic or the government bailouts provided for financial systems in a global recession; we are increasingly being asked to make sacrifices for our systems, systems that are struggling to maintain control. This has always been the Achilles heel of human designed systems: the possibility of catastrophic failure only increases with complexity. Whilst faith in systems may be wavering, we have become ever more reliant on the stability and control that they seem to offer.

[400] "Radio Eye Harder to Fool than the Radio Ear," *Projection Engineering* 1, no. 2 (October 1929): 16.

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