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Noise Control and Articulated Soundscapes

By

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Thanks to my teachers, colleagues, and family. Thanks especially to my advisor, Ron Kuivila for tirelessly pushing me to diabolical ends, to my Mom, Beverly St. Clair for her grammatical advice, and most of all to Louisa and Gena, for making each day exciting, beautiful, and full of love.

Introduction

What will humanity's urban future sound like? Amidst the tremendous efforts in recent years to re-design and re-imagine the modern city in a future world without oil, very little attention has been paid to sound and acoustics. In sampling the proceedings of a number of recent conferences of architects, designers, and urban planners, I find that sound is rarely, if ever, mentioned.[1] The LEED Standard for Neighborhood Development has sections concerning the visual qualities of a neighborhood, but nothing on acoustics and sound.[2] It is not that sound is an unimportant part of urban experience: noise consistently ranks as one of the top three quality-of-life complaints of residents living in cities around the world [3]. Part of the reason for this disconnect is certainly the visual orientation of modern architectural practice – think of Le Corbusier's statement "I am only eyes."[4] Compared with other sensory issues in the modern city, such as stench, noise has avoided comprehensive control.[5]

My thesis proceeds from the belief that there is tremendous richness in everyday sonic experiences, that these experiences motivate larger patterns of behavior, and that a silent re-imagining of the future is an incomplete one. To that end, it explores moments in the history of ideas of noise and its control in 19th and 20th century North America. The thesis has two main goals. The first is to inform my artistic practice. To an artist working with sound in public spaces, with sound material that might be described culturally as noise, the history of how noise has been conceived, of what makes a sound noise, is extremely interesting.

Also, particular ideas of noise are central to Acoustic Ecology, whose practitioners play a significant role in contemporary Sound Art, the genre in which my work is most often exhibited. The second, related, goal is to provide an historical framework from which the future challenges of sound and urbanity may be addressed. Urban noise is a pressure point on which a variety of yet-unresolved and vital issues related to the way we live now converge. A new set of material and intellectual tools are required to meet these future challenges. This thesis provides a stepping-stone towards working out what those tools might be.

Chapter One investigates the public debates about noise and the attempts at noise abatement in response to the 1878 introduction of the first mass transit system in New York City, the Elevated Railroad. Thomas Edison, fresh from his invention of the phonograph the year before, was called in to diagnose sounds of the railway in operation, sounds which incited public uproar and legal action from the track's neighbors. In what may be the first "environmental" recordings of sound, Edison used the phonautograph, a device that rendered soundwaves visible, to aid in his diagnosis. This episode marks the beginning of modern noise control, of the consultant hired to diagnose a problematic source of sound. Chapter Two covers the evolution of the Articulation Index, a way of measuring how well a communications system transmits speech that was originally developed at Bell Labs in the 1920s to evaluate telephone lines and circuits. This index became the main design criteria used in 20th century noise control. Chapter Three outlines the migration of the articulation index from the discipline of noise control to state and federal guidelines for maximum noise levels in the 1970s. Chapter Four provides a critical look at the work of R. Murray Schafer, the World Soundscape Project, and Acoustic Ecology - work that takes the basic principles of noise control and expands them into comprehensive theories on sound in general. Chapter Five connects the ideas of noise that emerge from this history with my own artistic work. An appendix of documentation of some of my pieces created while at Wesleyan is also included.

The early 20th century saw a radical transformation of the acoustic environment of cities. Using New York City as an example, Emily Thompson has charted the dramatic shift in the public discourse surrounding urban noise from the 1890s, where noise came from mostly human sources such as street vendors and hawkers, to the late 1920s, where noise was portrayed as a mechanical beast. While mechanized and electrical sound sources proliferated in North America throughout that time period - cars, trucks, phonographs, radios - so did the means of controlling and evaluating sound in general - acoustical tiles and insulation, precision microphones, decibel meters, and spectral analyzers. Thompson calls this the “engineered soundscape”: as noise was “engineered” into the environment through cars and other products of engineering disciplines, in order to abate noise it had to be engineered out.[6]

There is a second, more perceptual aspect of the engineered soundscape. Thompson defines the word soundscape as both the sounds present in an environment and the ways of interpreting those sounds, “a world, and a way of making sense of that world."[7] The changing technologies for the transmission and reproduction of sound altered not only the means to control sound, but the general conception of what made for "good" sound. The technology that had the biggest impact on the discipline of acoustics, psychoacoustics, and arguably the American soundscape as a whole was the telephone. According to historian Mara Mills, "The telephone and the ear were measured against one another in the 20th century, the former becoming a psychoacoustic instrument as well as an appliance for communication. A new definition of normal hearing was the result."[8] The models of communication and hearing that emerge from this work on the telephone system are directly incorporated into post-war noise control and remain part of the discipline.

Much of this re-defining of hearing happened at Bell Labs, the research wing of the AT&T telephone company. AT&T funded a vast research program into human speech and hearing in the 1920s, whose results and methods have become part of the canon of acoustical knowledge. This research was almost always performed in relationship to the electronic circuits and electromechanics of the telephone system. By understanding how the human voice and ear "worked," the telephone system could perform as little work as it needed to, becoming more efficient to install and maintain. Increasingly, principles worked out in circuits were applied to the physical and mechanical inputs and outputs of those circuits, the spaces that the telephone connected. Impedance, for example, became a way of describing the movement of sound in general, not just through a circuit. The articulation index, which we will track in Chapters Two and Three, is another one of these principles. By the 1950s the metaphor of the circuit had blossomed into systems analysis, a way of thinking that still permeates many disciplines from corporate management to city and highway planning to ecology and to psychology.

In thinking about the importance of circuits to mid-20th century life, it is helpful to explore the concept of "geometry" as applied by geographer and art historian Denis Cosgrove to Renaissance Italy. Cosgrove sees the concept of Euclidian geometry as vital to many of the practical and spiritual aspects of 16th century Italian life. Geometry was used to survey, drain, and divide up the land outside of cities, was displayed in techniques of perspective in painting and mapmaking, and was at the core of a "neo-platonic cosmology" [9]. I have not explored the connection of circuits to religious thought, but there are at least the beginnings of a comparison to be made, simply as an idea that organizes a significant part of the "speculative and practical" aspects of life [10]. There are certainly Euclidean resonances between the power of surveying in shaping the 16th century Italian landscape, and the laying of miles of long, straight telephone lines across the 20th century American landscape, but circuits themselves are not necessarily "geometrical." Instead, "topology" might be a better term, as it is used in circuit design to describe the network of connections between circuit components; the possible paths for electricity to flow. In cybernetics, an extremely influential mid-century movement, human action is contained within a general circuit topology as another component in the network, one potentially replaceable with an electronic substitute. Post-war cognitive psychology models the brain itself in this way. George Miller, perhaps the most influential cognitive psychologist to advance this idea, started his academic career researching the articulation index at MIT during the final years of World War II, the place and time when the ideas of modern noise control were taking shape.

Thompson's idea of the engineered soundscape impacts music as well. Thompson relates the response to the New York premiere of George Antheil's Ballet Mechanique in 1926, a work whose instrumentation included new urban noises such as sirens and pneumatic drills. While this performance inflamed many, poet William Carlos Williams described gaining a new sensitivity to the sounds of the city on his walk home[11]. The idea of a piece of music giving a listener "new ears" with which to hear the sounds of everyday life is a recurring theme in contemporary music. Sound technologies have played this role as well. The composer Pauline Oliveros has written that "the tape recorder is the most important instrument of the 20th century," not only for its use as an instrument in itself, but for the way that it changes how we listen to the world around us[12]. Oliveros describes her experience as a young composer making recordings of the outdoors through her open window and listening back to these recordings as a kind of ear training: "the microphone was picking up sounds that I had missed"[13]. Oliveros received her first tape recorder in 1953, several years after they became commercially available[14].

For many, magnetic tape and its successors turn the world into a studio. The notion of "acousmatic" listening, of hearing sound without visual referent, is popularized around the use of magnetic tape; of the world as a studio full of sonic richness to be recorded and re-listened to. The word "soundscape," coined in the mid-1960s by R. Murray Schafer, was influenced by the idea of acousmatic sound and no doubt hastened along by the Nagra company's release of the first truly portable battery operated tape recorder in the late 1950s[15]. The practice of world-as-studio continues today in the work of many Acoustic Ecologists, a movement deeply influenced by Schafer, including Gordon Hempton, whose 2009 book *One Square Inch of Silence* chronicles his attempts to record "natural" sounds outdoors without the microphones picking up cars, airplanes, or other man-made sounds. This thesis, in part, explains how we got to this point: where the instruments of sound technology play a vital role in how phenomena like "silence" are measured and defined.

John Cage's *4'33"*, the famous "silent" piece, intersects with the engineered soundscape in a way directly related to the history of noise control. Cage cites a visit to Harvard's anechoic chamber in 1951 as a crucial motivation for the work. Inside the extreme quiet of the chamber, Cage heard two sounds, one high, one low, which the engineer attributed to Cage's nervous and circulatory systems[16]. Physiologically, the absoluteness of "silence," in music or otherwise, was obliterated - life itself was sonorous - and it was this never-ending stream of sound which Cage subsequently focused on. The chamber's original purpose, though, was to test incredibly powerful loudspeakers for use on the battlefields of World War II. The layers of soundproofing around the chamber's interior kept sound from leaking out and "waking the neighbors," according to its designer Leo Beranek. Its anti-reflective surfaces simulated the open battlefield. Beranek, and his firm Bolt, Beranek and Newman, would be at the center of the blossoming post-war noise control industry. Cage inverted the original purpose of the anechoic chamber as a giant noise-controlling muffler, using a space designed to control the extremes of electro-acoustic loudness to explore the extremes of quiet.

These diverse connections between work in acoustics, music, and recording technology are further enriched by placing noise control inside of what Howard Davis has called a "culture of building" [17]. Davis uses this phrase to point to the vital importance of connections between architects, economic structures, zoning laws, religious thought, and the entire domain of culture in creating buildings. One well-known example, which Davis cites, is the effect of zoning regulations that required upper sections of skyscrapers to be set-back from the building footprint on The Empire State Building and other skyscrapers. Applied to noise control, the general concept of a culture of building helps to bring even the most heroic acts of controlling sound into a commercial context. Except in their military research, noise control engineers were almost always consultants, brought in to diagnose and control a problematic sound. They were often hired by the corporations responsible for that sound, to design sound environments for the employees or clients of those corporations. For example, the quieting of civilian jet engines was at first not for the well being of people living underneath a flight path, but for the comfort and safety of airline passengers. Quiet - interior quiet - was the commodity provided by noise control in most cases.

The word "telephonic" appears throughout this paper. Firstly, it refers to a collection of ideas, research practices, and materials that were developed specifically for the telephone system and their diverse use within an acoustic culture of building, following Davis. The use of these materials and concepts verbatim in noise control makes it "telephonic" in this first sense. The second sense is broader, more akin to Cosgrove's "geometry," to the topology of everyday life in the mid-20th century, to an engineered soundscape. The idea of clear, objective distinctions between signal and noise has many origins, but in terms of contemporary practice, this is largely a telephonic concept. The events in Chapter One in some ways stand at odds with the other historical moments in this book, simply because they occur before the widespread use and intense development of the telephone system.

The word "articulation" also deserves a definition, as it is central to in the general context of noise control that I have sketched out. To articulate, in the sense of communication and discourse, is to pronounce clearly. In biology, articulation refers to joints, to the places where the rigid parts of a structure meet. Musical use combines these two meanings, as both the technique used for sounding a note and the way in which successive notes are separated from each other. In crafting the articulation index, a measure of how well their circuits “pronounced” the human voices that they transmitted, telephone engineers also defined clear points of definition between signal and noise, the joints and bones of 20th century sound. The articulated soundscape of R. Murray Schafer and the World Soundscape Project attempts to re-define the crossover point between signal and noise but does not challenge the underlying rigidity of this model. My thesis follows the notion of articulation as it is incorporated in several diverse areas of practice. In tracing a history of noise control and articulated soundscapes, I hope to clear a path for new and more creative approaches to 21st century sound.

1 – Diagnostic Beginnings

In 1878, Manhattan's elevated railway system, the first urban rapid transit in the nation, was expanded from a single line serving the industrial far west side to three lines, connecting uptown residential neighborhoods with downtown workplaces and shopping districts. The train changed the geography of the city, cutting down commute times and enabling a vast expansion of the city northwards, filling in the neighborhoods around Central Park. It also brought an unprecedented number of steam locomotives into the city, spewing smoke, hot embers, and occasionally passengers onto the streets below. While these hazards all provoked substantial complaints, the noise of the railway caused the most public outrage. A number of amateur and professional engineers tried to invent or imagine ways of reducing the noises of the tracks. Thomas Edison, who had invented the phonograph a year before, was called in as a consultant by the company that ran the railway. In the history of urban noise, this episode provides an insight into the techniques of noise control and public perceptions of noise in the second half of the 19th century, a century imagined as "deaf" to these issues by other historians[18].

One widely-used technique to reduce the loudness of street traffic prior to the introduction of motorized transit was filling the street with straw, sand, or other dampening materials. This was only relevant on the paved streets of cities where carriage wheels and horse hooves struck directly against stone or hard packed dirt. And it was only used selectively, mostly around hospitals or homes with sick patients.[19] Steam locomotives presented a different kind of problem, one in which sheer mass and danger made it difficult to intervene. Unlike public streets, the tracks were privately owned, and the mechanics of the train needed to be adjusted in ways that took their complex operation into account. Noise control required a re-engineering of the entire system of train and tracks. The strategies for re-design applied to the elevated train foreshadow in many ways the practices of acoustic noise control that flourished in the 1950s, as well as suggesting alternate approaches.

Emily Thompson and Karin Bijsterveld have both observed that noise was largely considered a problem of efficiency in the period from 1900-1930. Necessary noises were essential to the operations of the city - car horns that signaled danger, car and train engines, industrial activities. Unnecessary noises were extraneous to those operations, and it was these that noise abatement groups targeted. This conception of noise is significantly different from noise as pollution, a concept that was not popularized until the mid 1960s.

Bijsterveld details how these early noise abatement groups were instrumental in reducing the frequency of car horn use by working to establish a visual system of traffic control, mostly stop signs, and thus making the previous habit of signaling at every intersection unnecessary. There was, of course, a significant class dimension to how unnecessary a sound really was. Bijsterveld's analysis of prohibitions on the calls of street vendors in Chicago and Manhattan have shown that the classification of sound as unnecessary, as noise, was used by public officials against the poor. The words “Unnecessary Noise Prohibited” that frequently appear among present-day Manhattan’s nests of street signs are a legacy these classifications. The narrative of the noises of the Elevated Railway and their eventual acceptance is the making of a necessary noise, one that would condition approaches to noise abatement in the early 20th century.

Despite vigorous public protest, including a petition signed by 139 of the city’s doctors, no changes to reduce the sounds of the railway were made. One inventor, Mary Walton, did come up with a working solution, purchased by the railway company operating the Sixth Avenue train line. However, the legal and political incentives for the train company to change the mechanics of the tracks and trains were removed by the State Legislature and Attorney General. Although Walton’s solution is crucial to understanding the events surrounding the introduction of the railway, this paper reviews the ways in which the sound of the train was characterized by the press, the public, the train company, and the engineers attempting to re-design the tracks. In reviewing the ways in which this sound was characterized and treated by the press and the public, three main categories emerge - as an instrument (specifically, a piano), as an object of analysis and storage through early sound reproduction technologies, and as a mechanical system to be re-engineered. These categories often worked in tandem, and they all failed to produce any significant changes in the noises made. The tracks and trains remained unchanged for decades to come, as the service they provided quickly became necessary for many city residents. Instead, New York’s geography changed around the tracks and their sonic envelope. Dwellings within a one block radius of the tracks became less desirable, but dwellings within several blocks in previously inaccessible areas of the city became more desirable. By the early 1900s, those concerned with city noise more often focused on human behavior than mechanical systems, in contrast to the events of 1878, which were primarily focused on designing and diagnosing mechanical systems. These events, perched at a moment of transition between a city powered by horses and one powered by engines, at a moment where sound reproduction technology was just beginning to enter the popular imagination, at a moment of sincere technological optimism, are vital to a history of necessary urban noises, of sounds that cannot be controlled, only negotiated with.

Transit in New York City before 1878

Steam Locomotives had been coming into contact with urban areas for many preceding decades, carrying long distance travelers, freight, and suburban commuters in and out of the city. When they crossed public roads, they were often required to ring a bell or blow a whistle continuously for one quarter mile or more in advance. In lawsuits against railroad companies by the families of people who had been struck and killed at crossings, one common argument was that the train made too little noise: it could not be heard over the sound of horses or it failed to signal altogether.[20] There were also suits that complained of too much noise, and the legal verdict on these noises was that they were necessary "legalized nuisances"[21]. However, the law also stated that railroads must use "best and most improved devices that science has devised" in order to reduce their noise and smoke.[22] Much of the activity in 1878 was directed towards developing or imagining these devices.

While many initial plans for rapid transit within New York City were tested during the 1860s, the elevated railway won the day. While the first railway, whose cars were pulled along by a large cable, was a spectacular failure, the introduction of steam locomotives in 1871 allowed the system to function. The first track ran along Ninth Avenue and bent down along the west side of Manhattan, depositing passengers close to the financial district. In 1874, the Legislature passed a rapid transit bill that authorized private companies to construct roads along Sixth Avenue and Third Avenue, essentially bracketing to the east and west the elite residential area of the period.[23] The rapid transit bill was heavily contested by some of the major businesses on Sixth Avenue and lawsuits stalled construction for three years. Even as the Sixth Avenue tracks were being erected in 1877 and 1878, fisticuffs erupted between construction workers and the employees of a hotel when the digging of track foundations crashed through the hotel's roof. These suits all ended similarly: the streets are the property of the city, and it can do what it wishes with them.[24]

The Sixth Avenue Elevated opened to passengers on June 18th, 1878. The subsequent letters to the editor that flooded the daily papers overwhelmingly emphasized the noise over all other detrimental effects. On July 2nd, a group of

139 doctors who lived or saw patients along the route submitted a petition to the Grand Jury of New York State to begin criminal proceedings against the Metropolitan Elevated, owners of the Sixth Avenue trains. This petition, signed by many prominent members of New York's medical community, claimed that the noise of the trains would cause "perverted mental and moral action," "hysteria, mania, paralysis, meningitis…deafness, or dementia, or death."[25] In the months that followed, the Grand Jury heard testimony from property owners, doctors, streetcar companies, and railway representatives arguing mainly about how bad the noise really was. The report compiled by the Grand Jury three months later described the noise as "the great and overshadowing evil."[26]

In context, it seems surprising that noise overshadowed the other side-effects of the railway, which included the blocking out of light, constant smoke, and all manner of things dropped on the street below - metal parts, oil hot enough to burn, cinders, and even human beings. In its third day of operation, stray cinders torched eight different store awnings within a twenty block section of Sixth Avenue, and a young boy was tossed from the train and crashed through the roof of a horse-drawn streetcar below.[27] Indeed, the complaints of the streetcar companies emphasized these more immediate hazards. The noise complaints came from the upper classes - property owners and residents (including the doctors and their patients), and the offices of prominent companies whose offices abutted the route (for example, the Metropolitan Life Insurance Company). As a contrast, when a reporter from the New York Post asked shopkeepers and residents along the working class south end of Third Avenue if the noise from the elevated trains that had just begun running above them in August of 1878 bothered them, this answer was typical : "Naw, we are used to noises on this avenue."[28]

So how loud were the elevated railways, and, in an age before decibels and Bell Labs, does it matter? Edward Free, who performed the first quantitative noise survey of New York City in 1926, informed readers with considerable surprise that both horse drawn trailers and automobiles measured louder than the by-then electrified elevated trains, as the trains were widely considered to be the loudest sound in the city.[29] However, reports from 1878 describe the trains physically shaking buildings and their contents. What mattered to residents is that the trains sounded loud, regardless of physical measurements. The Sixth and Third Avenue lines were objectionable in their own way. While the Sixth Avenue noises were described as many things, the word “rattle” (modified by a word like “terrible”) comes up most often. This was most likely caused by a number of loosely coupled resonant materials striking against each other - the rails struck the wooden crossties, which vibrated against various pieces of the steel supporting structure below. The Third Avenue noises were different - “a horrible shriek and squeak of metal on metal.”[30] This was most likely caused by friction between the rails and wheels. It is unclear whether these noises could have been predicted or avoided before construction. Both lines were built as cheaply and quickly as possible, which may have been a contributing factor.[31]

The diagnoses and attempted treatments of the railway were often reported by the press in the months following the railway's introduction. These accounts tell us something about how people related to and rationalized urban noise and the sounds of their environment in general. The ways in which railway sounds were described, the metaphors used to describe them, and the failure of techniques borrowed from medicine and science to meaningfully describe or contain them all contributed to their eventual acceptance as a necessary part of urban life.

One way in which people related to the noises and their ability to be contained was through expectations conditioned by the recently invented telephone and phonograph. Less than one month after service began on the Sixth Avenue railway, Edison was brought in as a consultant. His job, as he understood it, was not to make specific recommendations to cure the noise, but to diagnose it. Using his diagnostics, railway engineers would then take appropriate steps.[32] Edison's analytical techniques borrowed from the field of clinical medicine, his own strategies developed to overcome his considerable deafness, and then-contemporary scientific approaches that involved the production and study of graphs. The public's idea of Edison's role seems to have been different from his own. The popular representations of his role show a tremendous optimism at the prospect of technology's ill effects being solved through further invention.

Railway as Instrument

The physical structure of the railway was often described as a musical instrument. The steel supporting structures were compared to the sounding boards and strings of harps and pianos. Inventor Thomas Edison used these metaphors often. One of his recommendations was to insert wooden blocks between two parts of the steel substructure, which would have the effect of a hand damping a vibrating piano string. He also compared the wooden cross-ties to piano keys. While these instrumental metaphors seem like a natural way to relate to acoustics, they also helped to portray the noise of the tracks as an inevitable and even necessary part of their operation. The New York Times wrote "even in its pianissimo passages, when all muffling and sound-reducing experiments are exhausted upon it, it will remain a gigantic iron harp-string stretched across the city, played on plectrums driven by steam, which never tire nor intermit. Of course, the road had to be, and some measure of the noise had and has to be."[33] Others took this suggestion even further, and the science chair of the Ninth Ward Jackson Club, on the assumption that the noise was inevitable part of the railway-as-instrument, suggested a retuning. Edison should work out ways transform the tracks so that they were capable of playing recognizable tunes - Strauss and Offenbach for residential sections, and popular tunes downtown.[34]

Railway as Mechanical System

The only successful method for abating some of the track noise was invented by Mary Walton, a widow who lived in her family's house on 12th Street. Walton's method was less focused on observation and more focused on experimentation. After a single ride on the rear platform of the train, she purchased two steel railroad tracks, set them up on barrels in her family's basement, and began experimenting in secret, afraid that someone would steal her idea. Years before, she had created another invention that had been stolen by one of her husband's friends and published as his own. Her hurt at this dishonesty was part of what motivated her, 25 years later, to "beat" Edison.[35] When news of her $10,000 deal with the railway company to license her technique broke, the story was exactly that - "Woman beats Edison."[36] One year later, Walton would go on to invent a chimney for steam engines that vented the smoke through water, so as to filter it and quench any still burning embers.

Walton attempted to dampen the vibrations at their source by encasing the rails in cotton and sand, covered with a layer of asphalt. This invention largely used the existing structure of the rails, as the two vertical sides of the box were already in place as guards to prevent the train from falling off the tracks in the event of a derailment. Interestingly, both sand and asphalt would have been known insulators of sounds from roads - asphalt as a street surface, and sand for covering cobblestones in front of hospitals and other buildings to muffle the sound of wheels.[37] It is unclear whether Walton applied the asphalt around the tracks in her home, or simple conceptualized it there. No matter - she is the only one to have physically experimented with the tracks.

Edison's highly publicized work on the train would be what spurred Walton to take on her project. Edison approached the railway as a mechanical system as well, but instead of inventing, he saw his role as diagnostic. The railway engineers would take his diagnosis and make the appropriate changes to the track mechanics. Edison's initial analytic techniques, used in his first few days on the job, show parallels with techniques used in medicine at the time. They also relate to his previous uses of bone conduction and touch to overcome his own deafness. A newspaper report from July 4th describes Edison, in a moving train car, biting down on short plank of wood bolted to the windowsill and closing his ears. He also placed his ear directly on the windowsill, and at ground level he touched his ears and hands on the track structure itself. The goal was to receive the "vibrations" of the train "dissociated…with all extraneous sounds."[38] The similarity of these techniques to medical practice at the time, specifically "mediate auscultation", where doctors routinely isolated the internal vibrations of patients to make diagnoses, was not lost on the observing reporters. One wrote: "Mr. Edison has come in a brief time to be looked upon as such a universal genius, capable of inventing anything, and ready and able to cure all of the ills flesh is heir to, that nobody will be surprised to learn that he has been called in as a sort of consulting physician. He felt the pulse of his patient yesterday by a few trips in the cars."[39]

Mediate auscultation was pioneered by René-Théophile-Hyacinthe Lannec, inventor of the stethoscope, with the publication of his Treatise in 1818. Lannec's method involved a set of listening techniques to help physicians isolate individual sounds - sounds which were indices of particular internal conditions and crucial in diagnosis. Jonathan Sterne has charted the profound influence that mediate auscultation had on culture in Europe and America in the 19th century. Edison's various listening techniques, which focus on isolating particular modes of vibration, draw on the empiricism of medical practice that had accompanied the stethescope's rise. While in the 18th century doctors generally thought of the body as a whole system, which could be diagnosed through visual inspection and patient narrative, in the 19th century the body was generally thought of as an "assembly of related organs and functions."[40] Sound was an index into those functions. Without a detailed mechanical understanding of the track, without knowing which organs were which, Edison's diagnostics could have little effect. Edison did make some recommendations, such as hanging blankets down from the track, which were tested sporadically in September and October.

Sound as a stream separate from its source

Edison's next step was to create his own version of the phonautograph, tweaked for the analysis of environmental sound. The phonautograph, invented in 1857 by a Parisian printer, used a piece of straw, attached to a diaphragm, that visually inscribed sound waves onto a piece of lamp-blackened paper. Edison's addition was a telegraph-like key to create a line in parallel with the sound wave when depressed in order to mark specific events. For several days Edison and Batchelor made phonautograms both inside and outside of the train cars in an attempt to create, "an accurate chart of every sound that is now loose on Sixth

Avenue."[41] These would be examined later under microscope. The key to the origins of the noises, then, was not necessarily in the physical acoustic structure of the railway, but in its representation as data. This approach largely follows concurrent scientific practices, where knowledge was produced through a relationship with graphic representations of data derived from scientific instruments. The separation of this process from subjective human observation was essential, especially when applied to the highly contested sounds of the railway. To Edison, the phonautograms were a "permanent record which cannot be contradicted," unlike the subjective opinion of human observers.[42] It is not clear if the phonautograms were ever examined, as Edison left for a cross-country trip out west several days later and was on to new projects when he returned, but it is clear that no substantive information about the railway sound was gleaned from them. This approach foreshadows the statistical approach to sound taken by noise control engineers in the 1950s and beyond.

Edison's involvement with the project was greeted with optimism by the press. A cartoon from the New York Daily Graphic is the most enthusiastic. It shows Edison solving the railway noise problem through inventing a device that bottled up each offensive aspect of the sound, and then proceeding to invent solutions to a number of social problems - dirty city streets, "tramps," offensive smells - to finally earn "an electric halo of glory."[43] The idea of bottling up noise was also advanced by the railway company.[44] While Edison laughed at this idea, it suggests that both Alexander Graham Bell's telephone and Edison's phonograph were already having an influence on a general sense of the malleability of sound – its status as a material that could bottled up, isolated, transmitted and stored. Many authors have stressed the faith in industrial progress that was a feature in American society during the Progressive Era.[45] These accounts are indicative of that faith, that society's ills were curable through continued technological innovation.

Comparison of methods

For all of the energy devoted to it, no part of the acoustics of the elevated tracks was substantially altered for years to come. Both Walton's invention and Edison's limited recommendations were employed over small sections of the tracks to test their effectiveness. However, they were never implemented on a large scale. A 1905 railway manual for the Chicago Elevated explained this lack of action by saying that Walton's invention, while the best option at the time, did not provide enough benefit for its cost.[46] A more likely explanation is both political and geographical. By March of that year, the political football created by the investigation of the Grand Jury had been tossed out of bounds, so to speak, when the State Attorney General decided not to act on the issue and instead to leave it to the Legislature. The Legislature, having passed the issue on to the Attorney General in the first place, was loathe to impede the progress of a transit system. Without the threat of potential litigation hanging over them, the railway companies had no compelling reason to act. The elevated was also proving to be a huge success. Furthermore, the geography of the city was beginning to change, and those residents who objected to the noise were, by and large, moving elsewhere. If anyone was holding out for Edison's sound-bottling apparatus, it seems that, almost a year later, they had either given up hope or lost interest.

Moving day 1879, Necessities

The elevated railway rapidly changed the geography of the city. The avenues that it cut through became less fashionable places to live, but more fashionable places to shop. The elite residential area of the city moved north to Park Avenue along Central Park, served by the Third Avenue elevated a few blocks away. These changes were most visible on May 1st, 1879, the day when most New Yorkers' leases were up. The New York Times summarized the prevailing attitude on Sixth Avenue that day: "Private residences, flats, and even tenements at the lower end, which retained their occupants until a year ago, are now being largely emptied…The prevailing desire is to get as far away from its noise as possible and yet be sufficiently near to make it available for traveling purposes. It is generally found that this can be accomplished by moving the length of a block to the east or west."[47] The wealthiest residents of Sixth Avenue moved to Madison and Lexington Avenues, and also to 59th Street, contributing to the northward expansion of the city's residential areas. While the city had been losing residents to Brooklyn and elsewhere in previous years, May 1879 saw a significant influx of residents, mostly middle-class, attracted by the conveniences of rapid transit. In subsequent years, Sixth Avenue and 23rd Street became a retail mecca. Mona

Domosch, in her analysis of the development of New York's shopping district, has stressed the importance of the elevated trains in allowing women to circulate from their homes in the Upper East side to the stores along Sixth Avenue, often making the round trip twice in one day,[48]

Effect on future abatements

One conclusion that we can draw from the mixture of ways in which the sound of the elevated trains was first characterized is that it set the stage for the proliferation of anti-noise activity that occurred in the early 20th century. If certain city noises could only be negotiated with, rather than controlled, then the only place where control could be exercised was in human behavior. Between 1880 and 1894, the noise of the elevated trains was rarely mentioned in newspapers. When it re-emerged, it became unavoidable. In an 1895 interview, the attorney for the Board of Health attempted to define what made certain noises necessary and others not. Essential services, like milk delivery (their trucks bringing the sound of empty bottles banging against one another) were necessary as long as their noises could not be reduced without significantly hampering their operations. The noise of the trains fit into this category. Unnecessary noises included the cries of street vendors, the late-night transportation of animals to slaughter houses, and the overuse of bells and other signaling devices [49].

As author Emily Thompson has explained in her book *The Soundscape of Modernity*, noise abatement in the early 20th century can be seen as a symptom of the "efficiency craze" that swept through American society at the turn of the century. "Waste, whether of natural resources, human labor, or time, was the enemy" [50]. Noise was not seen as pollution, instead it wasted the time and energy of those who heard it. Noise abaters often lobbied on behalf of those who they thought were affected by the wasteful effects of noise the most: the sick, whose valuable sleep was interrupted, and schoolchildren, whose lessons were drowned out. The distinction between necessary and unnecessary noises was also defined politically and socially, according to "the middle-class vision of a well-ordered city"[51]. Where the economic activities of the poor were too public - street vendors, the transport of animals to slaughter-houses, and the signaling of ferry boat drivers on the Hudson - abatement campaigns found ways to change behavior. The noise of the elevated train makes the most sense in this context. As long as middle-class residents could avoid moving within a one-block radius of the tracks, they could enjoy all of the newfound mobility that the system provided without enduring the noise at home.

It has been argued that the 19th century was a "deaf" century, uncritically accepting the production of new sounds. R. Murray Schafer has tried to explain the general lack of opposition to loud factories and trains with the idea of "Sacred Noise." According to his history, primitive and medieval peoples thought that loud sounds were of divine origin. The culture of the Industrial Revolution simply transferred those associations of power and divinity to the new machines in their environment. But as we see, the 19th century residents of New York City who complained were by no means "deaf;" they were highly sensitive to sound. Words like “terrible” and “cacophony” abound in press accounts – religious language does not. In contrast to Schafer’s sacred noise, I have argued that the soundscape of New York City in the late 19th century was articulated by distinctions between necessary and unnecessary noises. These distinctions were made according to class relationships, the changing geography of the city, and the perceived abilities of modern engineering. In other words, economic and political conditions, rather than hearing ability, ensured the continual resounding of the trains. In the 1920s, the categories of necessary and unnecessary overlapped and blurred with the new concept of signal and noise introduced by the widespread growth of the telephone system.

Chapter 2 – Telephonic Architecture

By 1929, the electronic circuit had become the dominant metaphor in the emerging discipline of acoustics. Principles worked out in circuit design were then applied to sound moving through air and human beings. Impedance, first used to match the input and output requirements of circuit components, became a general theory applied to any electroacoustic system, including the human voice. Telephone circuits, which received by far the most attention, acted metaphorically as well, shaping ideas about interpersonal communication in general as a telephone-like chain of senders, pathways, and receivers. Circuit metaphors informed engineering, psychology, architecture, the armed forces, communications and many other disciplines, especially during World War II and the post-war period. From the 1920s to the 1960s, we see an unfolding of telephone circuits into architectural spaces. These spaces include homes, concert halls, classrooms, movie theaters, office spaces, and the interiors of cars, jets, and trains. Techniques developed for testing and designing circuits would be adopted by architectural acousticians and noise control engineers in their designs.

The Articulation Index, a way of rating sound according to its interference with speech, is an example of a technique developed for circuits that migrated out into the design of acoustic space in general. By the 1970s, the Articulation Index had become so central to noise control that it was the primary factor in federal guidelines on noise. This chapter follows the articulation index and techniques related to it from the 1910s to the mid-1960s, from circuits to architecture, while the next chapter covers the late 1960s and 1970s, from architecture to landscape. The articulation index was central to the "systems approach" to acoustic noise control adopted for military research during World War II and carried into post-war civilian life. Noise control adopted a "source-path-receiver" model and was applied to each element in the system. Thus Leo Beranek's definitive 1952 article on ventilation noise in office buildings first explores the acoustic design of ventilator motors and fans, then the acoustic properties of ductwork, and finally the criteria for the sound that reached the receiver's ears. Systems theory dominated many disciplines during the decades following the war, even shaping our ideas about how brains, bodies, and ecosystems worked. Cognitive Psychology, which understood the brain as a hierarchical information processing machine and by the late 1950s had become the paradigm in that field, is one example. I argue that the systems model adopted by the field of noise control in the 1940s was simply a further unfolding of the telephone circuit into social and architectural space. Hence telephonic architectures - interior spaces as communications channels for the voice.

Articulation testing origins

The concept of articulation has accompanied the telephone from its first commercial origins in the 1870s. In fact, Alexander Graham Bell distinguished his invention from earlier work by calling it the "articulating telephone." While Elisha

Gray and Jacob Reis had used reeds or relays to transmit the voice, giving the listener on the other end a sense of the pitch contour of the voice while losing the consonants, Bell claimed that his invention was the first to transmit all of the sonic information necessary for words to be understood. Various celebrities, many of them British, were publicly enlisted to vouch for the depth of articulation and listener comprehension that Bell's new phone provided. By the 1910s, this "testing" of language by telephone circuits had become standard practice at AT&T, which in 1913 was granted a monopoly over US telephone operations. AT&T pooled its existing researchers into a department of the Western Electric Company, its subsidiary. I.B. Crandall, a researcher for Western Electric, systematically worked from 1910 to 1916 on this question of articulation, performing an analysis of the human voice and the properties of the circuits needed to transmit it. He began developing what he termed "articulation tests", using groups of men and women brought in to the Western Electric Lab who would take turns speaking and listening through telephones with various circuit configurations. Speakers would read lists of words, listeners would write down what they heard, and the results were compared and scored by percentage of words understood. These percentages were averaged and scaled between 0 and 1, so that a circuit with a score of 0.5 would typically render 50% of words understood. By 1916, Crandall had enough data to propose an equation to predict an articulation score, given the distortion and noise of a circuit. This equation first rated particular frequencies in terms of the importance of their contribution to speech comprehension and then summed the differences of the frequency response of the circuit under test with those ideal frequencies

In 1924, AT&T moved its research division from the Western Electric Company to Bell Labs. Harvey Fletcher, who came to work at Western Electric in the late 1910s and became the head of Acoustic Research at Bell Labs in 1926, began to verify and extend Crandall's initial results. His 1929 paper "Articulation Testing Methods," published internally in the lab, detailed a standardized method for performing articulation tests. Test "crews" included five men and five women, who were arranged in various combinations of callers and observers over the duration of the test, which was usually two to four hours per session. Crew members were trained for a period of approximately one month before participating in testing, as they were required to learn a modified version of the International Phonetic Alphabet to mark down their observations and to read the test material. Caller-observer configurations were first tested in one of the lab's soundproof rooms, with the caller facing away from observers to disable the possibility of lip reading or facial cues. Callers and observers then went to separate soundproof rooms, where they spoke into or listened to telephone receivers. For further calibration, reference circuits, whose articulation scores had already been extensively studied, were also used to establish "distortion-free" baseline articulation score for caller-observer configurations. Then, callers would read lists of randomly generated nonsense syllables into a telephone through circuits designed to introduce various levels of distortion and filtering, while observers marked down the sounds that they heard.[52]

By 1933, the methods for articulation testing had become even more streamlined. After 1929, Bell Labs revamped its studio for articulation testing. Every attempt was made to automate the process in order to reduce the time and cost of conducting tests. Observers keyed their observations into modified adding machines that calculated preliminary articulation scores on the spot, scores which had taken hours to calculate by hand. Callers used a modified volume meter to standardize the level of their voice. Automatic volume level detection for noise and the caller's voice allowed for quick calibration and verification of the testing environment. Perhaps the most significant addition, from a contemporary perspective, in the four years since 1929 was the introduction of "room noise" through speakers installed in the observation rooms and through the telephone line itself. Phonograph recordings of ambient sound in a variety of spaces were used to simulate this room noise, and its effects were measured along with the distortion effects of various telephone circuits. This addition of room noise foreshadows the important role that the Articulation Index would play in noise control and regulation from the 1950s to the 1970s. Acoustic space enters into the articulation index as another part of the telephone network, the path from receiver to ear.

Beginning in 1921, Fletcher began channeling various statistical metrics into a single equation that could be used to predict the articulation index. The equation took the form $AI = V * E * F * C$ with the following variables:

V the volume of speech relative to any noise present

E the ear sensitivity factor

F the frequency distortion of the circuit

C the carbon distortion of the microphone

Each was coupled to a particular area of telephone circuit design: V to the telephone line itself, E to the design of telephone receivers, F to the modulation and demodulation circuits used to encode the voice signal, and C to microphone design. This equation remained the intellectual property of AT&T until 1950, when Fletcher first published the results outside of the company journal.

The sound of language itself

While early articulation tests in the early 1910 used complete phrases or sentences as their test material, by 1916 Crandall had shifted to using "nonsense" syllables. Contextual meaning skewed results, introducing a number of uncontrolled variables. Circuits acted on all sounds passed through them independent of meaning. The English language, then, needed to be reduced its basic sonic building blocks in order to more appropriately test that circuit. Phonetics was a well-established discipline by the 1910s, and researchers analyzed English phonemes using the same tools developed for analyzing circuits. They provided their crews with lists of "nonsense" monosyllabic words, constructed from a subset of phonemes whose sonic properties were representative of the language as a whole. By 1929, the method for constructing these nonsense monosyllables had become standardized. 22 Index cards were prepared in the three categories: beginning consonants, vowels, and ending consonants. Each stack of index cards was shuffled and dealt together, creating 22 syllables. The process was repeated three times for a total of 66 syllables. The onset and ending consonant cards were the same with a few exceptions, and there were 11 vowel sounds, with two index cards for each. Thus, with 66 monosyllables, each beginning and ending consonant was repeated three times and each vowel six times. Earlier versions of the index card system used a larger number of cards in each category (52 in one), but it was determined that a sufficient variety of sounds was tested through the subset of 22. Diphthongs, for example, were excluded as researchers felt that their sounds were covered by their individual vowel components. In a way, spoken English needed to be chopped into bite-sized portions in order to be digestible by telephone circuits and the laboratory practices at Bell Labs.[53]

For all the attempts by researchers to remove contextual meaning from the voice, it could not be completely erased. Women's voices were deemed less articulate than men's voices. Researcher John Steinberg tried to explain these lower scores by claiming that the higher fundamental pitch of women's voices produced fewer harmonics, and that these frequencies were more readily distorted by the ear at high amplitudes. "Nature," he claimed "seems to have designed women's voices for soft and smooth speaking."[54] Writing in 1988, Lana Rakow provides other explanations for this claim, citing research showing that men and women adopt the physical capabilities of their voices to fit certain gender types.[55] Men, while capable of speaking higher, tend to speak in a lower register and adopt a tone that emphasizes larger physical size, while women, capable of speaking lower, choose a higher register and a tone emphasizing smaller size. Contradicting Steinberg, culture, rather than nature, was responsible for much of the design of the voice. Rakow cites other studies that have found that facial expressions have a significant effect on the tonal structure and intelligibility of the spoken voice and that women are more likely to smile while speaking during laboratory sessions. Steinberg's findings, only published in the private company journal, were no doubt informed by the public "voice" of the telephone system at that time, the legions of female switchboard operators whose "smooth" voices supposedly had calming effects on potentially rude and uncivil male callers.

This reduction of spoken language to sound alone fit into a culture where self-conscious speaking was encouraged. Fletcher cites George Krapp's 1918 *The Pronunciation of Standard English in America* as a resource in deciding which phonetic sounds should be tested. Krapp's standard was defined negatively, "as the speech which is least likely to attract attention to itself as being peculiar to any class or locality". This speech was practiced and learned through a "self-consciousness" about vocal production and a general interest in phonetics and was motivated in part by the "strange mingling of races" and "shifting social boundaries between class and class" in the United States.[56] Henry James, in a 1905 speech to the graduating class at Bryn Mawr, also encouraged self-conscious speaking: "You don't speak soundly and agreeably…unless you know how you speak."[57] James advocated a "tone standard" for American speech. Articulation testing was a way to trade in all the messiness of the use of language for the sound of language. Instead of a tone standard, we have statistically derived models of average speech and hearing. Fletcher, in a 1925 article, showed the audiograms of 20 women, which vary widely, and commented: "It is evident, then, that in discussing speech and hearing we must deal with statistical averages."[58]

Telephonic architectures in the 1920s

The conception of vocal communication at Bell Labs had a tremendous effect on architectural acoustics, as documented in Emily Thompson's *The Soundscape of Modernity*. Architecture built around the human voice has a long and rich history, though. Richard Cullen Rath, in his discussion of North American church acoustics, has recovered the term "catacoustics" as the 18th century English description of "how sound was instrumentally projected, reflected, dissipated, and otherwise manipulated once it had been produced" [59]. He draws many purposeful correlations between the catacoustics of churches and their belief systems. In European history, one classic example is the difference between the highly reverberant Roman Catholic acoustics, which made intelligibility impossible but enhanced overall vocal presence, and Protestant acoustics, which emphasized intelligibility. When some Catholic churches became Protestant, their stone ceilings were fitted with heavy cloth drapery to dampen reverberations, and "testers" - large, flat wooden sounding boards - were placed behind the minister to help project his voice outward into the congregation. Early North American Quaker meetinghouses show a similar attention to detail, as their octagonal structures create a space where each voice is equally amplified, no matter its position in the room. Mark M. Smith has written that African-American slaves used large ceramic pots in their worship spaces as resonating instruments to decrease the intelligibility of their words to anyone listening from outside. [60]

Thompson has explored in great detail how, during the period from 1900 to 1930, changing conceptions of sound had vast implications for architectural space. One thread of this narrative is that as spaces became more connected with networks of sound reproduction and transmission, architectural space in general became subject to the design criteria of that technology. In other words, space itself became another element in the circuit. In the approximately 15 years between 1915 to 1930, reverberation became the sworn enemy of the acoustician, a form of noise rather than a quality of the sound itself. Though articulation testing and Fletcher's equation were the private intellectual property of AT&T, which prevented their widespread use, they did have a substantial impact on this soundscape. Vern Knudsen, a physicist who spent a year as a researcher at Western Electric but soon moved on to a teaching position at UCLA, applied articulation testing to public school classrooms across the state of California. He took turns with an assistant calling and observing over the length of a 15,000 cubic foot classroom, while tones of varying intensity were played back into the ears of the observer via a modified telephone receiver. Fletcher supplied Knudsen with a list of nonsense syllables for him and his assistant to speak. Knudsen found that in an auditorium of that size, “even a little noise reduces the word articulation considerably,” and called for “extreme reduction of any noises.”.[61] Reverberation itself was one such noise.

Articulation testing also drove the sound of early sound cinema. Western Electric was one of several companies offering a line of services to Hollywood studios and cinemas around the world, innovating in the fields of recording equipment, film stock, and playback techniques. In 1929 Western Electric started a consulting service to optimize the sound of movie theaters that used its systems. Again, articulation testing was used as a design parameter. S.K. Wolf, the head of the consulting service, initially put forward a goal of 96 percent articulation for theaters and found that reverberation was the main opponent to clarity in existing theaters. Consultants descended on the nation’s theaters armed with decibel meters, cap guns, and devices to measure reverberation, recommending a host of treatments such as freshly upholstered seats, acoustic tiling, and wall treatments. In tandem with the “drying out” of reverberation times in Western Electric theaters, a new sound-on-film process released by the company in 1930 significantly lowered the “hiss” coming from the theater speakers. In these quieter theaters, other background sounds, such as the whirl of the projector, soon became evident, and theater managers began placing projectors behind sound-proof glass. The elimination of noises in the theater allowed directors to begin using ambient sounds in their films, and the first film shot on the new Western Electric stock, *The Right To Love*, makes use of many such sounds, such as the rustling of leaves in trees, to dramatic effect. In film, then, the notion of vocal articulation gives way to the articulation of ambience. While beyond the scope of this paper, it does hint at vocally defined spaces opening up to a larger world of sound.

The military articulation index

Beginning in the early 1940s, the Articulation Index was used in the design of communications systems in general, first in design research commissioned by the US Military and then in post-war noise control. These systems often involved combinations of electro-acoustic and acoustic pathways for sound, but were also applied to sound in space generally. In effect, acoustic space became a communications channel like any other. In 1941, the US military heavily funded a joint program of acoustics research at Harvard University's Electro-Acoustic Laboratory (EAL) and MIT's Psycho-Acoustics Laboratory (PAL). The EAL was focused on engineering and design; the PAL on psychoacoustic testing. Military transport and weaponry exposed soldiers to sustained doses of very loud noises that interfered with communications and had unknown psychological effects. Leo Beranek, a junior faculty member at Harvard, having just completed his PhD two years earlier, was chosen to direct the research, which quickly expanded to incorporate other facilities, including Bell Labs. While Harvey Fletcher would pioneer the use of articulation testing applied to telephone circuits, work at the EAL and PAL would take the articulation index further out of the circuit and apply it to communications networks that included acoustic and electronic pathways. After the war ended, the index would be used as one of the primary design criteria in the burgeoning field of noise control, where Leo Beranek and his firm Bolt, Beranek, and Newman played a major role.

While Bell Labs had drawn test subjects from the general population, the PAL's subjects were conscientious objectors from the Boston area who volunteered because of the post-war potential of the lab's work [62]. Initial research found that noise did not significantly impair task performance, even when subjects were exposed eight hours a day for four weeks straight. Communications were severely affected, though, and so the lab focused on reducing noise in the various communications systems at work in combat vehicles. Chief among these systems were radio headsets, which connected crews to command centers and to each other. Speech through the air between crew members inside of the cockpits of these vehicles was extremely problematic – the noise of engines and weaponry all but obliterated meaning.

Following acoustic precedent, PAL turned to articulation testing. The tests used procedures similar to those of Bell Labs, with two noticeable differences. The first was greater attention to acoustic communication through the air between crew members. While "air" had been used a distortion-free medium in the Bell Labs tests, now the air was filled with engine noise. Speakers simulated both cabin noise and crewmembers' voices to test face-to-face communication. The second was the spoken content of the tests themselves. In addition to random monosyllables, a selection of common military commands was tested. Given the reduced vocabulary of military commands, an articulation score of 0.4, or 40% was considered acceptable, a score of 0.3 indicated considerable comprehension difficulty, and a score of 0.6 or higher was preferred. Through the application of newly developed fiberglass sheeting, Beranek and Harvard's EAL were able to engineer an interior environment for the DC-3B bomber that scored 0.44 at a distance of one foot for "an average male voice engaged in loud talking."[63] In addition to fiberglass sound insulation, the EAL produced a number of other material innovations, including substantial improvements to radio microphones and headsets, the "throat microphone" which conducted sound from the skin of the throat, bypassing the exterior air altogether, and the "ear warden" earplugs, which attempted to attenuate the low frequencies of cabin noise and preserve the higher frequencies of speech.

The methods of noise control developed during WWII had a strong influence on noise control in general after the war. A series of papers published in the two years after the war's end abstract the articulation index for general use in noise control. Beranek's 1947 paper recounting his work on the DC-3B bomber research included the two primary components for general use. The first was a graph correlating distance between speaker and listener, vocal effort, and level of speech reaching the listener. The second was a simple calculation for predicting articulation given a spectrum of noise. Combining these two elements allowed Beranek to predict an articulation score, given a particular spatial arrangement of speakers and listeners and a background noise of a given spectrum.[64] Beranek's method for calculating articulation scores was a simplified version of the more elaborate calculation developed by the psychoacousticians at PAL. French and Steinberg, PAL researchers, published the definitive method for calculating the Articulation Index in 1947. This method measured the decibel level of a particular noise in 20 different frequency bandwidths. Those levels were summed and added together, yielding a number that could be scaled to a particular articulation score. Beranek's approach was more field-ready - he used three bands instead of 20. Over the next 20 years the particulars of the number and range of the bandwidths would be tweaked and tested, but the basic principle would remain the same. Contrasted with Fletcher's equation, this new articulation index was simpler and could be applied to any communications situation, whether face-to-face or circuit-to-circuit. It was also more readily appropriated into the consulting work in noise control, architectural acoustics, and product design that proliferated in the years following the end of the war.

Paul Edwards has shown the many other post-war ramifications of the work performed at the EAL and PAL, focusing on the latter. The tanks and airplanes of WWII were a "new cavalry" which can by seen as an early form of cyborg, a combination of mechanical and human components that operated as part of a single system. The noisy pathways between senders and receivers in this system became one of its fundamental limits. Edwards points out that there was unprecedented centralization of the chain of command during the war, made possible by radio communications with front-line forces.[65] This communications model greatly influenced George Miller, a PAL scientist who went on to become one of the founders of cognitive psychology. Cognitive psychology's stress on information processing and model of the mind as a "hierarchically structured information processing machine" made up of "noisy, stressed communications channels," Edwards argues, is a direct inheritance of this work.[66] The articulation index works within this hierarchy, not structuring these channels but simply optimizing them. And this optimization could go both ways, masking speech as well. In fact, Miller's wartime work was to use the articulation index to mask enemy speech by jamming their transmissions with noise and interruptions. Post-war noise control was not unique in its emphasis on communication and its use of systems analysis to structure its work - in fact it mirrored general trends in scientific study that went as far as the workings of the human brain.

Post-war telephonic architectures

Following the end of the war, acousticians were increasingly called upon to control the sounds of air travel, automobile transportation, and office spaces. By the mid-1950s, the discipline had expanded so much that the Journal of the Acoustical Society of America started a second publication called *Noise Control* intended for the general public. Noise control viewed acoustic space as a communications system. The firm of Bolt, Beranek and Newman, which emerged from the EAL and PAL when the war ended, was technically and conceptually at its vanguard. Beranek wrote in a 1960 textbook on noise reduction: “Each noise-control problem was visualized as being a system with three components: the source, the path, and the receiver. No problem could be said to be satisfactorily handled unless the characteristics of the source were known and a criterion, expressing the desired noise levels at the receiver, was established. Only then would one decide how much control need be put in the intervening path.”[67] While systems had the potential to break down complexity into manageable parts, they also ran the risk of not fully describing a situation. Later in that same textbook, Beranek qualified the systems approach with regards to the noise of aircraft interiors: “Actually the criterion chosen for the noise-control design in an aircraft is the result of a management decision that weighs passenger comfort and ability to hear speech vs. accepted standards in competitive aircraft vs. cost and weight considerations.”[68] Richard Bolt, writing in 1952 on airplane noise affecting residential areas, expanded the components of the system beyond sender-path-receiver to include government regulators, aircraft company personnel, the media, and a variety of other structures that shaped not only the presence of sounds from airplanes, but how people interpreted those sounds. Overwhelmed by the density of these interconnections, Bolt wrote, “Somebody, somewhere, should start planning.”[69] The field of noise control, however, was already too fully occupied with responding to current noise problems and developing an acoustical understanding of the sources of those problems - the jet engine, the car motor, and the office ventilation system - to undertake the kind of comprehensive planning that Bolt called for.

Even in Beranek's concept of the noise control system, noise control as a discipline was about specific configurations of sources, paths, and receivers. As consultants, they left implementation of their recommendations up to management, governments, or other organizations. Any noise control situation began with the receiver. Beranek's criteria used three measurements - speech interference level (SIL), loudness level (LL), and noise criterion curve (NC). All three provided different ways of summing together information about a sound's spectrum in order to predict its psychological effects. Extensive testing with human subjects at the PAL and elsewhere informed these correlations. It was found that an acceptable LL varied greatly depending on context, sometimes by a factor of eight. The best predictor of that context was found to be the speech needs of a particular situation or space, so that ventilation noise in a large un-amplified conference room would seem significantly louder than the same sound in a small office or a room full of typewriters. In other words, the spatial and social configuration of a speaking voice and a listening ear determined which sounds were acceptable and which were not. An acceptable articulation score for a particular configuration in turn determined target levels for the noises in that space. In 1952, Beranek and others published a paper on ventilation system noise in offices, which included a chart that determined target noise levels for concert halls, movie theaters, factories, restaurants, conference rooms, libraries, churches, and residences, based on the comprehension needs of music and speech in those spaces.[70] A slightly revised version of this chart would later appear in the 1960s and 70s in seemingly every document related to noise policy, and can still be seen in current Federal Highway Administration guidelines for maximum highway noise levels, as explored in Chapter Four.

1950s noise control was largely concerned with the design of interiors. The acoustic design of offices was already a burgeoning field in the 1920s, and by the mid 1950s it had became increasingly specific through the measurements mentioned above. One important difference was the common use of speech privacy - the blocking out of unwanted speech. Undirected speech - from other offices, other conference rooms, from the hallway, etc. was to be eliminated. While it was possible to add isolation between rooms or floors, it was usually more practical to use the existing noise from fans and air handlers to mask undesired speech. Lab research found that subjects found speech not directed at them annoying when that speech had an articulation score of above 0.1. Optimal speech privacy was found when undesired speech could be masked or attenuated to achieve an articulation score of 0.01, or one in 100 syllables understood. In other words, the noise "jammed" the incoming unwanted speech. Noise criterion (NC) curves represented the preferred frequency spectrum of this all-purpose background noise: obtained, of course, through extensive psychoacoustic tests.

According to Beranek, noise control started at the receiver, but its innovations largely concerned sources and paths. Sources and paths formed the material basis of noise control engineering, the things that engineers were actually called upon to shape and design. Beranek's 1952 paper, mentioned above, is mostly devoted to explaining a series of equations that govern the acoustic properties of ventilators and ductwork. Airflow, fan speed, and duct orientation could all be plugged into these equations to approximate sound output. A similar set of equations was developed for jet engines. The concept of acoustic impedance, the subject of Beranek's 1939 dissertation, was crucial in linking the various physical components of sources and paths. Jet engines proved perhaps the most challenging case, as the engines themselves were tremendously loud and physically complex. Reductions in engine noise usually meant reductions in power. Airplanes needed to be lightweight, which limited the possibilities for noise control. Additionally, the reduced outside air pressure complicated many measurements. A system of floating cabin walls was developed, which inserted fiberglass blankets developed at the EAL during WWII between the outer shell of the fuselage and the interior wall. The interior walls and windows were attached to the exterior by vibration-isolating mounting systems. This "floating" enclosure method of isolation, decoupling source from receiver, was proposed for almost every noise control situation in the 1950s: from rooms in offices to the compartments of passenger trains and even to the foundations of buildings themselves. In the 1950s, noise control held the promise of highly designed acoustic environments, where varieties of articulatory uses could exist side by side, one on top of the other.

Alternatives and refinements to the Articulation Index

While noise control in many ways promised a highly designed sound environment that met its criteria, the reality of the soundscape of the 1950s was much different. Most of the sources of noise that were present were not designed with the criteria of the acoustician in mind. Modern building techniques, as well, were often driven by financial rather than acoustic needs. Thin-skinned office and apartment buildings were more acoustically porous to exterior sounds, and noise control consultants used a variety of methods, including background noise generators, to mask uncontrolled exterior sounds. Jet engines became the most ominous of these exterior sounds. And a series of sensational articles rallied the citizens living around airports to protest the coming introduction of civilian jet aircraft. Responding to these protests and threats of protests, officials for Idlewild Airport contracted Leo Beranek and his firm in 1957 to help control the problem. As the sound of propeller planes had not provoked the same degree of public outrage, Beranek decided to using a rating system based on "perceived noise" to compare propeller engines with jet engines. Crews of laboratory subjects were recruited to rate various shades of airplane noise and develop a satisfactory scale. Beranek then worked with (and against) Boeing to retrofit engines with noise reducing elements. He also worked with FAA officials to adjust takeoff and landing procedures, sharpening the angles of these to minimize the number of houses that the planes flew over. Perceived Noise in Decibels, or PNdB, the scale created through the responses of Beranek's lab subjects, would become the standard for rating airplane noise, and the approach would be taken up in other countries, most notably in England where the "Noise and Number" index was developed in similar fashion in neighborhoods around Heathrow. PNdB and its companions reflect Bolt's conception of a systems approach to noise control, which included social, technical, and political considerations.

The Articulation Index became an American National Standards Institute standard in 1969. Karl Kryter, who had worked at Bolt, Beranek and Newman and at Stanford's Sensory Research Center, was its author. The standard was a refinement of the "wartime" Articulation Index as published by French and Steinberg in 1947. While the 1950s had seen the Articulation Index tweaked and modified as it played a crucial role at the center of a new systems-oriented approach to acoustics, by the 1960s a crop of instruments and methods aimed at creating articulation scores for noise control situations on-site were being developed. In effect, the Articulation Index had proved itself and now the question was how to most efficiently integrate it into acoustic practice. This integration provide messy. Kryter, writing in 1985, recommended a method developed by Tkachenko that involved listening separately to 20 pure tones, their frequencies corresponding with French and Steinberg's 20 frequency bands, and adjusting each tone until it was just barely audible. Those levels, weighted and summed, gave a reasonable approximation of the articulation index.

Unfortunately, this method was relatively impractical and was tuned to only one particular receiver's ears. Other approaches were developed for circuits, including playing loops of speech on magnetic tape into the input of the circuit and measuring the spectrum of the speech received on the other end. Several of the devices were developed during the early 1960s. This method was impractical for noise control, as a sound playback system was required. By far the most successful approach was to attempt to infer Articulation Index scores from the measurements available on most commercially available decibel meters, an approach more fully explored in Chapter Three.

Systems' successes and failures

The systems approach to noise control developed in the 1940s and 1950s emerged from an acoustic culture heavily influenced by the telephone circuits developed in the 1910s and 1920s. Each noise control problem was thought of in terms of a three-part communications chain, from a source, through a path, to a receiver. The criteria used to determine acceptable noise levels for the receiver were in many cases the same criteria that had been used to develop those telephone circuits: the Articulation Index. The Articulation Index was used spatially, connecting desired speakers and listeners while excluding undesired speech. Background noise, such as office ventilating equipment, could be engineered around these requirements. Beranek's work in offices, using this design strategy, was extrapolated to many different types of acoustic use, and as we will see in the next chapter, eventually became federal policy in the US.

Noise control is seen by many as a casualty of the 20th century, a failed project. Noise control in the 1940s and 50s, though, made significant gains, at least in its internal discourse. In a way, the 1950s was the heroic age of noise control, typified by a full page spread in *Life* magazine displaying one of Beranek's projects, the "world's largest muffler" created to quiet a jet engine testing facility in Ohio. Part of noise control's ultimate failure certainly lies in the limitations of the "telephonic" systems approach to sound that reduced acoustic experience to vocal communication. This systems approach operated within a "culture of building," Howard Davis's phrase mentioned in the introduction, where noise control was always on the defensive - called in to diagnose and cure sound environments that had become problematic. Even today, acousticians generally become part of the building process at a late stage. While the designers of the telephone system were building communications channels from the ground up, so to speak, noise control had to work in the opposite direction, reducing, abating, and shaping a communications channel to a satisfactory level.

Chapter 3 – Telephonic Landscapes

In the previous chapter, I have outlined how the concept of "telephonic articulation" migrated out of the telephone network and into a host of acoustic practices in the 1940s and 1950s. My goal in this chapter is to outline how these ideas were written into policy and applied across the American landscape in the 1970s. Between 1960 and 1970, noise became pollution. The phrase "noise pollution" is not used with any regularity in newspapers, magazines, or books, until 1964 when it suddenly becomes the dominant way of characterizing noise. This shift in language is also a shift in emphasis - pollution leaves long-term, permanent traces, while the effects of inefficiency and interference disappear when they have been engineered away. Where efficiency had highlighted operational concerns, such as worker productivity and communications interference, pollution emphasized health impacts. In a 1967 New York Times article, one of many articles in the press giving a general overview of noise-as-pollutant, noise is described as "a slow death." Hearing loss became not just an issue for industrial workers, but for all city-dwellers. One well-publicized study compared hearing tests from nomadic tribes in the Sudan and North American city dwellers, finding that the average 60 year old nomad had roughly the hearing abilities of a 25 year old city dweller, and considerably lower blood pressure as well. Another study, looking at average sound levels in North American cities from the previous 5 to 10 years, found a 1 decibel per year increase, which lead to shocking predictions about future urban sound levels. Chemical pollution had been widely publicized by Rachel Carson's *Silent Spring*, published in 1962, which was serialized in the New Yorker, was a Book-of-the-Month club selection, and the subject of hearings held by John F. Kennedy's administration. This "underside" of progress, the deadly chemicals that not only killed birds but were polluting our water supplies and our blood streams, became a crucial part of the counter-narrative of 1960s culture, and noise was swept up in it.

One important aspect of noise-as-pollution was its change in legal status. Noise control has an interesting, if sporadic, legal history. There are many examples of acoustically focused "zoning" bylaws in the ancient and medieval worlds, including a Roman statute that prohibited blacksmiths from practicing their trade within a certain distance of a professor's residence, and limited their operating hours.[71] Certain cities excluded carriages with iron wheels from streets paved with stones, due to their noise, relegating them to quieter, unpaved, roads.[72] The integration of planning and acoustics in modern cities has been hard to come by. In the early 20th century, common practice for cities in the US was what Karin Bijsterveld has called the "islands of silence" approach, where areas around certain institutions, usually hospitals, churches, and schools, were seen as special, quieter, zones. Though the islands of silence approach occasionally involved action by the city, such as the re-routing of traffic and the paving of adjacent streets, most often it was behavioral strategies such as educating children to be quiet around hospitals that were most effectively implemented. During the post-

WWII building boom, the noise impacts of newly built highways, airport expansion, and construction seem to have been completely off the radar for mainstream planning practices. Where highways cut through existing neighborhoods, they often ran extremely close to existing buildings. Planning in general disregarded acoustics. For example, in 1967, New York City's planning commission approved two high-rise apartment buildings directly underneath one of LaGuardia Airport's jet aircraft approaches, exposing future residents to intense jet engine noise. Noise-as-pollution dramatized how serious these planning oversights were, changing their status from nuisance to life-and-death decisions.

Noise was not easily assimilated into a conservation movement focused on water and air pollution.[73] In 1970, a pivotal year in which many conservation-minded politicians had been elected to congress and President Nixon signed sweeping environmental legislation, the National Environmental Policy Act (NEPA), creating the Environmental Protection Agency, the budget for noise control compared to air pollution was one fifth, and compared to water pollution, one fortieth.[74] What budget was allocated was almost entirely dedicated to jet engine noise. The Office of Noise Control and Abatement, created in 1970, had no staff until 1972, when it received a small staff and budget, and was de-funded and disbanded in the first few months of the Reagan administration in 1981. Its goal, as set forth in the Noise Control Act of 1972, was more focused around study, collating existing state laws into one federal standard, studying noise impacts, and proposing maximum noise exposure levels. However, one area where noise was integrated into the planning process during this period was highway design and planning. NEPA required an Environmental Impact Statement, a document that not only catalogued the predicted impacts of a particular route, but also demanded that highway planners consider alternate routes in order to “minimize harm.”[75] These statements were made available to federal agencies and impacted citizens for public review. While most of the interstate highways had already been completed, some of the planned sections where construction had not yet started were forced to comply with these new requirements.

These new highway-planning requirements resulted in a fusion of noise control and highway design, centered around the production of “noise maps” of highway routes. Their most immediate consequence for the built environment was the construction of noise barriers, although in theory they were meant to inform the route and other parameters of the highway itself. Today, noise maps still represent the most significant intersection of acoustics with regional planning and policy-making. The noise maps produced in the early 1970s, when the disciplines of noise control and acoustics first intersected, mark the beginning of noise mapping as a planning tool with real consequences for the built environment. In other words, this period is an important locus of integrated noise control and planning techniques. This chapter examines several environmental impact statements created during this period for Interstate 66 in Virginia and the Driscoll Expressway in New Jersey. I want to take an expanded view of the noise map as not just a document but a practice that includes setting the maximum noise levels that a highway could produce, constructing noise barriers to meet those guidelines, and translating traffic data to acoustic predictions. This practice drew heavily on post-war noise control. The articulation index was used to set maximum levels for different categories of land use. Noise maps project a telephonic landscape, a continued unfolding of the social topologies of the telephone circuit onto the geometry of the highway system.

A brief history of the noise map

From the introduction of elevated trains in New York City to the present day, the idea of "mapping" noise has been a recurring theme in creating some kind of objective record from the apparently subjective terrain of noise control. Thomas Edison, in using a phonautograph to visually render the sound of the elevated trains in 1878, claimed to be creating a "map of all the sounds now loose on Sixth Avenue," which would serve as an "objective record which cannot be contested."[76] The visualization of sound waves themselves had been of great importance to Acoustician Wallace Sabine and to researchers at Bell Labs. In the late 1920s and early 1930s, teams from Bell Labs, using newly developed instruments for measuring environmental sound levels, were engaged by the New York City Department of Health to aid in production of the *City Noise Report*. Trucks outfitted with decibel meters, frequency analyzers, and questionnaires roamed the city for several years. Almost no sounds went unmeasured - dogs, cats, policemen's whistles, milk trucks, subway turnstiles and myriad others.[77] By the mid-1950s noise control had become an established discipline, one which worked on a particular subset of sounds created by ventilators, electric motors, jet engines, and other mechanical sources. While the *City Noise Report* was attempting to gain a composite portrait of the outdoor sound environment of the city in order to more fully parse the procedures needed to improve it, by the 1950s the set of sounds considered noise had in some ways been settled. And so noise mapping, as employed by acousticians in the 1950s was focused entirely on the sound of jet engines and the sound levels that reached nearby residential areas. During the 1960s some experiments with mapping first-person experience of sound in a particular environment were advanced, most notably by psychologist Michael Southworth. However, the noise maps produced for highways in the early 1970s were less about first-person experience and more about strict compliance with regulations. As the following two case studies demonstrate, while maps were prepared using relatively standardized procedures, there was a high degree of variability in how they were interpreted.

In looking at acoustics and highway planning, it is necessary to briefly review some of the methods used in highway planning. The geography of the United States changed significantly from the late 1950s to the mid 1960s with the building of the interstate highway system, the largest infrastructure project in American history. New roads connected cities to each other and to their surrounding regions, in many cases cutting transit times in half or more. In doing so, they carved through existing neighborhoods, displaced residents, disrupted neighborhood continuity, and subjected remaining residents to the noises and exhaust fumes of cars and trucks. In urban areas, these roads disproportionately cut through poor neighborhoods, often taking advantage of slum clearance incentives to obtain the right-of-way. Highway planners vigorously denied any political motivations in their work, though, instead deferring to the complex models that they used to calculate needed highway capacity and preferred routes. In 1952, the American Association of State Highway Officials published a method for conducting cost-benefit analyses for highways, the first to include potential costs to the highway user - fuel, operating costs, safety, time, and even comfort - rather than simply the cost in concrete and labor of the structure itself. Time spent commuting was accounted for at $1.35 per vehicle hour,[78] $0.55 above the minimum wage.[79] The comfort of the road, measured by smoothness of pavement and lack of potholes, was also included, with the smoothest pavement incurring no costs and the roughest pavement incurring a cost of one cent per mile. Faced with a six percent average increase in vehicle miles per year since 1948 and a similar expansion in suburban communities, these models predicted a huge need for interstate highways to meet the demands of these new commuters. The costs of inaction were huge, with suburban commuters losing small fortunes stuck in local traffic. These predictions fit handily into the aims of the trucking and construction industries, whose powerful lobbying helped pass the Federal Aid Highway Act of 1956, which provided federal dollars to states for completing their portion of the interstate system. Systems theory, then, was crucial to the highway planning of the 1950s, just as it was to noise control. Both were focused on user experience. Unlike noise control, though, highway planning was supported by powerful lobbies.

NEPA attempted to change this process, to force federally funded projects like highways to be planned with consideration for a wide range of consequences and environmental effects. While most of the interstate highways had already been completed, some of the planned sections where construction had not yet started were forced to comply with these new requirements. It is in the preparation of these Environmental Impact Statements that acoustics and highway planning intersected, resulting in extensive maps displaying predicted sound pressure levels over the terrain adjacent to the roadway. According to historian Holly Doremus, the EIS has both an "external function" by informing the public about the effects of a particular action, and an "internal function" affecting the decision-making process inside of an agency both through the information retrieved in preparation of the statement, and through changes in external political conditions.[80] External and internal translate approximately to Howard Davis's terms "interdependence" and "autonomy."[81] Autonomy is that knowledge which is "exclusive to the building culture itself and to the specialists who work within it," while interdependence includes the ways in which a building culture relates to, communicates with, and is influenced by its surrounding cultural context.[82] In this period of intersection between acoustics and highway planning, between two building cultures, this distinction seems highly artificial. Highway planning, indeed all environmental policy making, seemed to absorb without question the language, techniques, and rationale of post-war noise control, including its recommendations for maximum sound levels. At the same time, the conclusions that noise control consultants came to about the need for noise barriers along highways could vary substantially based on who had hired them.

Maximum levels

NEPA instituted many other changes in the integration of environmental concerns with public policy in addition to the creation of the Environmental Protection Agency. Another law signed by Nixon in 1970 was the Occupational Safety and Health Act, which focused on the health of the American workforce and created the Occupational Safety and Health Administration. Both the EPA and OSHA had noise control as part of their mandate. In 1972, the Office of Noise Control and Abatement was established as part of the EPA as a central location to handle these concerns, and its mandate was to protect the public from both hearing loss and general annoyance. In 1974 the office released what is commonly referred to as the "Levels" document, a recommendation of "the levels of environmental noise, the attainment and maintenance of which in defined areas under various conditions are requisite to protect the public health" prepared "without regard to the possible economic costs."[83] The document recommended 55 Ldn as an appropriate maximum sound level in residential areas in order to "assure that speech communication in the home and outdoors is adequate"[84]. In other words, the articulation index formed the main criteria for these guidelines. Ldn was a new sound level rating scale which measured the more-or-less constant sound levels in decibels at a particular site over a 24 hour period. 45 Ldn was considered acceptable for most common indoor articulatory uses - face-to-face conversation, talking on the telephone, and listening to the radio. Given that the exterior of a house provides 10 to 15 decibels of attenuation, a level of 55 Ldn provided a safe margin. The outdoor level of 55 Ldn is mostly an afterthought, as it allowed an articulation score of 0.95 at 2 meters, a calculation that the Office arbitrarily assumed was satisfactory.

The Levels document, prepared without any economic considerations, was simply a recommendation, not policy. Policy was set by individual departments. Harder Rupert, an official at the Federal Highway Administration and later the Department of Transportation, spearheaded the effort to quickly define maximum levels before the Levels document could be completed.[85] Rupert drew on the same noise control literature that the Levels document did, matching criteria to a small set of indoor articulatory needs, but his recommendations were higher - 70db L10 for outdoor noise, 55db L10 for indoor noise. Those indoor sources of articulation were limited to family members, television sets, and radios. Areas where receivers had any sort of articulatory needs outdoors were considered "unique and unusual tracts of land in which serenity and quiet are of extraordinary significance."[86] Their level was set at 60db L10. L10, the average sound level exceeded 10 percent of the time, was a simpler measurement than Ldn, and could be measured by a consultant with the appropriate instrumentation in an hour or less.

While NEPA in theory was about requiring federal policy to account for environmental effects, to turn outwards from the closed systems that had guided previous planning practices, the acoustic model that they incorporated was not interrogated for pre-existing prejudice or deficiency in the same way. In reality, the articulation index excluded a huge percentage of speakers and listeners – children, speakers with foreign accents, the hard of hearing, those with speech impediments, and many more. It was just as restrictive as the 1950s cost-benefit model for highway design. However, these deficiencies were not acknowledged by either the Federal Highway Administration or the Office of Noise Control and Abatement.

Using the articulation index as a guide, a chart displaying maximum noise levels appeared in most EPA documents related to noise control in the early 1970s. This chart had three categories of land use: residential, which included homes, hotels, hospitals, churches, schools, libraries, parks, playgrounds, and other common uses; other developed lands, not included in the residential category; and finally the "unique and unusual" areas mentioned above, which included amphitheaters, specially classified parks, or other specially designated areas. Where noise impacts from highways exceeded these maximum values, barriers were constructed. Where noise already exceeded these maximum values, or barriers were impractical, no barriers were constructed. Where barriers would not provide sufficient attenuation, exceptions could be provided.

Case study: I-66 in Virginia

A section of Interstate 66 in Virginia inside of the Capital Beltway was one of the first highways to be mapped and designed in this way. From the early 1960s until construction began in 1977 the routing of the road, which included the infamous Three Sisters Bridge over the Potomac, became the centerpiece of a larger nationwide struggle over highway planning practices involving protests, court cases, and congressional back-room dealing.[87] After NEPA was passed, the road became a showcase for the new set of planning practices that the law mandated.

In describing the context of planning and noise mapping, it is interesting to review the highly contested history of I-66 through maps and counter-maps. The need for a road heading due west from Washington, DC first appears on national highway plans in 1939's Toll Roads and Free Roads. The "Yellow Book", which served as the template for the nation's interstates after the 1956 passage of the Federal-Aid Highway Act, lays out the road in more detail. The Yellow Book contained a plan for a network of urban interstates criss-crossing the Washington, DC metro area. I-66, as sketched, crossed the Potomac near the Washington Mall and quickly jogged north around Arlington's City Center before heading gradually south, roughly following the right-of-way of the then-failing Old Dominion Railroad. Approximately 10 miles west of the river the route intersected with another proposed highway, the Capital Beltway (I-495) at the southern border of the city of Falls Church, VA.

How did these planned routes make it on to the map? Many were legacies, advocated by small committees in the 1940s. DC's "ring" roads, including the Capital Beltway, were introduced solely through the will of Harland Bartholomew (by his own account), after he was able to convince influential members of a 1944 panel of the importance of this configuration.[88] Subsequent national highway plans, empowered with the newly introduced methods of systems analysis, most often kept these existing routes and added to them, as their models predicted ever-increasing need. A 1959 report by the National Capital Planning Commission, enabled with these new models and also influenced again by Harland Bartholomew, massively embroidered the Yellow Book's recommendation into a 329 mile network of multi-lane freeways and interchanges.[89] Interstate 66, connecting the city of Washington with the wealthy suburban communities of Fairfax County, communities that had grown by almost 150 percent since 1940, was planned to be eight lanes wide and intersecting not only with the Capital Beltway but two other ring roads and three new bridges carrying interstates across the Potomac.[90]

Not everyone bought into these plans, though. In 1962 John F. Kennedy appointed several key administrators who opposed the National Capital Planning Commission's 1959 plan, including Darwin Stolzenbach. Stolzenbach edited the NCPC's map to include mass transit rail lines along many of their proposed routes and eliminated some routes all together. This was a counter-map. While Stolzenbach's staunch anti-freeway position ultimately lead to his removal from office in 1965, the Washington Metropolitan Area Transit Authority, the agency appointed in 1966 to coordinate regional interests in planning Washington's Metro system, adopted many of Stolzenbach's recommendations for the metro routes. The Orange line, which Stolzenbach charted along I-66, was one of these routes. This section of the interstate, then, became tied up with the building of the Washington Metro. Today, the Orange line runs in the median of I-66 for almost five of its 9.6 mile length.[91]

The national conflict between pro- and anti-highway forces at the Federal level came to a head in the final months of 1967 over the comprehensive plan for transportation in Washington DC. Alan Boyd, Secretary of the newly created Department of Transportation, publicly questioned the fairness of highway planning practices, that "take the property of poor people and leave everyone else alone."[92] Boyd's office did all it could to stall construction of The Three Sisters Bridge, which served as the nexus of many of Washington's yet-unbuilt urban interstates by connecting the eastern terminus of Interstate 66 with the Inner Loop. Highway engineers and lobbyists were infuriated, not only calling for Boyd's resignation, but threatening that if Boyd had his way, that "planning everywhere will have to be shared by sociologists, economists, housing officials, and architects," a situation that they predicted would lead to intolerable delays in construction.[93] Perhaps the most telling response was that of Department of

Highways head Thomas Airis, who called Boyd's plan "amateur engineering."[94] The passage of the National Environmental Policy Act on January 1st of 1970, on its surface, dealt a significant blow to this technocratic position by adding environmental effects to the cost-benefit analysis of highway construction. Interstate 66 - held in political limbo until mid-1970, was one of the first highways to be subject to these new requirements.

Three distinct environmental impact statements were prepared for this section of Interstate 66. The first was conducted and completed in early 1972 by the Virginia Department of Highways itself. While this report was released to several federal agencies, it was not released to the public and was soon set aside as it became clear that the Department's techniques were not up to industry standards. The second statement was contracted out to the firm Environmental Planning and Design in November of 1972 after the U.S. Supreme Court upheld a lower Circuit Court decision forcing the Federal Highway Administration and the Virginia Department of Highways and Transportation to prepare an environmental impact statement. Noise analysis was performed by a sub-contractor, Environmental Systems Laboratory. This second statement was released on November 17, 1973 to 75 state and federal agencies and 150 citizens groups for review in anticipation of public hearings, held from December 17th to 24th of that same year.[95] The final draft of the second statement was published on July 9, 1974 after attempts had been made to address concerns raised in the hearings. The second statement proposed an eight-lane highway, branching off near the Potomac into two six-lane segments that crossed the river via the Three Sisters Bridge and the Teddy Roosevelt Bridge. At one point, as it branched off to feed the bridges, it was 14 lanes wide. This statement was amended four months later, reducing the eight highway lanes to six after Volpe's replacement as Secretary of Transportation, William Coleman, asked for an alternative design. However, the six-lane highway was rejected by Secretary Coleman, and VDHT was called upon to draw up an additional plan. This new plan resulted in a third statement, prepared by the Virginia Department of Highways and Transportation and submitted for public review on June 2, 1976.[96] This statement proposed a four-lane highway with carpool and no-truck restrictions, the Washington Metro running in the median, and without the Three Sisters Bridge, which Coleman had taken off the map in 1976. Coleman approved the funds for this design in a noteworthy decision in 1977.

Noise was never explicitly a barrier to the approval of the highway, but it did shape some design features. In the two published statements, there was no significant difference in the noise impacts charted in their noise maps. The Arlington Coalition on Transportation attempted to challenge the noise measurements in the public review of the 1974 eight-lane design, but it did not have the specialized knowledge to challenge the guidelines, and its remarks were easily dismissed. Some attempted to challenge the maximum guidelines based on current conditions. For example, St. Ann's School, a high school whose campus bordered the proposed roadway, found that noise from existing roads was already a serious issue even though levels were nearly half as loud as the maximum. The presence of the road, noise barriers included, would push parts of the campus close to the maximum level, a situation that the principal felt might cause the closing of the school. Undeterred, the authors of the EIS determined that if the school was forced to close due to noise, its students could be absorbed into other schools in the district.[97] Coleman, however, seemed to take these maps and their maximum guidelines with a grain of salt. For example, increased noise motivated his decision to exclude trucks from this section of the road, even if the L10 scale, which omitted short and loud sounds, hid these momentary increases to a certain extent.[98] Occasionally the proximity of a site and/or the incompatibility of a particular section of road meant that the maximum noise level would be exceeded. The 1976 EIS found nine such sites. For example, where the route passed over the Sprout Run Parkway a noise barrier was deemed too expensive to build, even though the road ran in close proximity to a number of apartment buildings.[99]

Another crucial exception to this rule is that no barriers were necessary where pre-existing noise levels from existing roads were higher than predicted noise levels.[100] NEPA was not retroactive, in that an EIS could not be prepared for a project completed before 1970, but this aspect of the law was broadly interpreted to mean that all pre-existing environmental conditions were exempt. For example, no noise barriers were built where I-66 intersected with Lee Highway, because Lee Highway's noise impacts on the houses in that area was predicted to be greater than I-66's.

According to many, the highway's final built form was a "unique compromise" that satisfied many competing interests.[101] In its first six months, many drivers, confused about the carpool restrictions, avoided the road entirely. After several years, the carpool restrictions were lessened from four occupants per vehicle to three, and their hours diminished. While evidence is hard to come by, it seems that those living and working adjacent to the road were able to adapt to their new acoustic conditions. One example is that St. Ann's School is still operational today. Additionally, noise barriers have been added to various sections of the road where they were not initially included. For example, a large undeveloped area to the north of the road just inside of the Beltway was developed in the intervening years, and noise barriers were then erected to protect the inhabitants. Some present day drivers who use the road have a different perspective. One of my Wesleyan colleagues, who commuted on this stretch of road for several years and felt that more lanes were needed to accommodate traffic, was under the impression that politically connected Arlington residents, motivated primarily by their fear of roadway noise, were responsible for the lack of lanes. Indeed, with the Coleman decision repealed by Congress in 1999, the widening of I-66 is currently under discussion.

While the second and third statements calculated the locations of barriers, they did not specify the details of their construction. The Coleman decision stipulated that earthen berms, populated with plants and trees, should be used wherever possible. It seems that where berms were not feasible, or needed supplementing, community groups were called upon to choose the "look" of barriers.[102] The results of these interactions are not publicly available, but they do correspond to the present-day experience of the road with a variety of barrier types and earthen berms adjacent to it. From an acoustic engineer's perspective, many materials could be used for barriers with equal effectiveness. A training manual from a 1973 class for highway designers shows a host of barrier types, materials, and suppliers.[103]

Case study: Alfred Driscoll Expressway

In 1971 the New Jersey Turnpike Authority began to move ahead with plans for a 36 mile "spur" serving the state's Ocean, Monmouth, and Middlesex Counties. The expressway would be named for Alfred Driscoll, the then-current director of the Turnpike Authority and a former New Jersey governor. While the road had been on planning maps since 1964, many in the towns that it cut through mounted significant opposition. In 1972, New Jersey passed its own requirements for Environmental Impact Statements similar to the federal requirements so that while the road received no federal funds, it was still required to undergo the EIS process.[104] The Turnpike Authority, managed by Howard Heydon, chafed at the new requirements. Heydon said, after meeting with mayors from the affected towns, "we are designing this road in a goldfish bowl…engineers used to say 'here is the road, and that's it.' Now we juggle the alignment, have a horticulturalist in a policy-making position, and a community-relations manager."[105] A consultant, John Shadley from Bolt, Beranek and Newman, was hired by the Turnpike Authority to prepare the noise assessment for the EIS. A community group, the Concerned Citizens of New Brunswick, hired its own consultant, C.M. Hogan from Environmental Systems Laboratory in California, as a counter-maneuver.

Over a period of time in 1972, Shadley and Hogan roamed the right-of-way of the proposed route and the existing New Jersey Turnpike, making measurements with decibel meters. While they used similar measurement techniques and even shared measurement data, they came to very different conclusions about where noise barriers should be placed, with Hogan favoring more barriers, Shadley less. These positions seem to simply reflect who their clients were - the Concerned Citizens were thoroughly opposed to the road, the Turnpike Authority felt that it was necessary. But they also could just as easily reflect the lack of practical experience that engineers had had with the creation of noise barriers in the early 1970s. Another important point - New Jersey's EPA had not defined maximum noise levels, and so these levels were open to interpretation. For all the fixity that the noise map implied, there was considerable contingency underneath. Part of this contingency can be attributed to the fact that most noise control was performed by consultants, often hired by companies responsible for the noise.[106]

The Driscoll Expressway was not built in the end, due to a number of factors.

The governor in 1973, Brendan Byrne was opposed to the route, although it had originally been approved by his predecessor. Also, the EIS, once completed, was not distributed to the public in compliance with New Jersey Law. In 1974, South Brunswick won a court case against the Turnpike Authority over this point, and the Authority was forced to restart some aspects of the EIS process.[107] To compound matters, Alfred Driscoll, the road's namesake, passed away in 1975. One week later, the Turnpike Authority dropped the plan.[108]

Highway planning integrated into noise control

The firm of Bolt, Beranek and Newman, so critical to the establishment of standards for maximum noise levels, also created a training course in noise measurement methods, first offered in 1973.[109] Beginning with this course, knowledge of noise control procedures became an evermore standard part of the education of highway planners. In terms of noise control, the most significant difference between the second and third statements prepared for Interstate 66 is that while the measurements and predictions in the second were performed by outside consultants, the same measurements and predictions in the third statement were performed by Virginia Department of Highways and Transportation staff themselves. These training courses were offered by both the Federal Highway Administration and the American Association of State Highway and Transportation Officials. Members of the VDHT staff attended this course sometime before the preparation of the third statement. They were also aided by a computer program developed in Michigan and acquired by the State of Virginia in 1974 that calculated noise levels for various highway conditions and performed other aspects of acoustic prediction.[110]

Computer aided design has become much more widespread in highway planning since the 1970s, and noise prediction has been included in these tools. Acoustic knowledge has been incorporated into highway planning textbooks. Nevertheless, in the United States at least, only slight modifications have been made to the maximum levels and their rationale - the Articulation Index - since they were created. An inquiry into maximum noise levels by the FHWA in 2006 produced almost identical levels to those set in the early 1970s.[111] From the perspective of these maximum levels, the American landscape is a landscape of interiors. Since typical modern buildings reduce sound intensity by almost four times its original amount as it passes from exterior to interior, the maximum level for a particular type of land use can be adjusted upwards by that amount. Places where even "acceptable" speech articulation outdoors is required are, according to the guidelines set in both 1974 and 2006, "unique and unusual tracts of land in which serenity and quiet are of extraordinary significance."[112]

Sender-path-receiver-patron

The intersection of noise control and other acoustic concerns into federal and state highway planning in the 1970s happened at a time when those planning practices were being significantly re-configured through new legislation. The acoustics that they integrated, though, did not undergo a similar re-thinking, but instead were a continued application of communications models that came directly out of the telephone circuits of the 1920s and the work of the Electro-acoustic and Psycho-acoustic laboratories in Cambridge during World War II. In effect, while noise had become pollution in both the popular and political spheres, noise control was applying techniques centered around communications interference. While these techniques seemed to be empirical, honed by decades of study, their application could be quite variable, as is seen in the case of the Driscoll Expressway. The sender-path-receiver model was bent by its patronage; by the social context within which it was applied.

The articulation index of this era, and its application to policy, was directly criticized by the World Health Organization in 1996. The WHO's study is worth relaying, as it adheres to the communications model but makes very different assumptions about the senders and receivers at either end of the model. Although the originators of the articulation index tried not to measure language comprehension but only the sound of language itself, they assumed fluency in English. They also only tested adult speakers. The WHO began its re-evaluation with the premise that all communications are fraught with the possibility for misunderstanding; that the index should be designed for non-fluent speakers and for infants and children who are learning language. Rather than the Federal Highway Administration's recommended levels of 70 L10 outdoors and 55 L10 indoors, or the EPA's recommendation of 55 Ldn outdoors and 45 Ldn indoors, the WHO recommended 30 Ldn indoors and an absolute maximum of 45 Ldn outdoors. Despite this radical revision of the articulation index, the Federal Highway Administration's maximum guidelines are still in effect, and a 2006 department review of those levels found them to still be satisfactory. Nor has the European Union, while taking a comprehensive approach to noise, fully integrated the WHO's lower levels into its guidelines.

Chapter 4 – Telephonic Ecologies

The previous two chapters have explored the Articulation Index as the main design criteria used by acousticians, engineers, and policy-makers from the 1920s to the 1970s. The end of the previous chapter presented a critical re-definition of this model by the World Health Organization, whose members came to very different conclusions by considering a much broader range of speakers and listening abilities than had previously been considered. During the early 1970s, as methods in noise control were being applied to land use and planning, researchers at the World Soundscape Project in Vancouver, Canada were forming their own approach. The WSP was attempting to provide the groundwork for a new discipline of "acoustic design" which would control noise not through engineered solutions, but through comprehensive evaluations of all sounds heard, what R. Murray Schafer, the project's founder, called "soundscape." From 1972 to 1977, when funding ran out, the project published three studies on the soundscape of Vancouver, BC, of Canada as a whole, and of five villages in Europe and built up important libraries of field recordings and descriptions of sound in literature. The influence of the term soundscape, and of Schafer's ideas, is difficult to overstate. Soundscape has become a key concept in aspects of ethnomusicology, history, geography, and the emerging discipline of sound studies in which this paper finds itself. The World Forum for Acoustic Ecology, a contemporary organization which grew directly out of Schafer's work, is one of the only venues where musicians and scholars from many disciplines regularly come together over the topic of environmental sound. Schafer, a composer and author, and the WSP, whose members were also composers and authors, have largely been seen from the perspective of contemporary music. This chapter places them in the history of noise control. While they imagined their activities to be in complete opposition to typical noise control practices, the two share some fundamental assumptions about sound as a communications system and divisions of signal and noise that arise. This chapter explores those similarities, the useful alternatives that the WSP presents, and the pitfalls encountered in a worldview structured around a soundscape of only signals, laundered of all noises.

Soundscape contexts

First though, it is necessary to provide some additional context for Schafer's coining of "soundscape" in the mid-1960s. Three discourses about sound are most important: Pierre Schaeffer's "acousmatic" listening, the idea of noise as a pollutant, and the blurring of music and environmental sound in John Cage's *4'33"*. In addition to the systems models of noise control, these three ideas shape the early uses of the word soundscape. R. Murray Schafer moved to Vancouver in 1965 as a Resident of Music at Simon Fraser University, teaching classes in both the Music and Education departments.[113] Many of the ideas that inform the World Soundscape Project can be first found in various teaching manuals that Schafer published from 1965 to 1969. Soundscape as a term is generally credited to Schafer and these mid-1960s course pamphlets, where it is used ambiguously.

Schafer has cited Pierre Schaeffer's notion of "acousmatic" sound as an important influence on these early ideas. Schaeffer used the term acousmatic beginning in the late 1940s, as "sound that one hears without seeing the causes behind it,"[114] applied to recorded sounds, manipulated artistically, and presented to audiences through speakers without performers on stage. Schafer's statement in 1967 that "there is no 'land' in soundscape" certainly suggests an affinity with Schaeffer.[115] Schafer argued that for too long the eye had dominated the other senses in determining what we valued in our environment. As a counter-measure, he proposed an ears-only, acousmatic experience of the world.

The New Soundscape from 1969 acknowledges John Cage and his 1952 composition *4'33"* as a primary influence on the idea of soundscape.[116] At first glance, there is a curious conflict in sensibility between the two, which might have prevented this influence. Where Cage enjoyed experiencing urban sound environments, in traffic noise, Schafer found "an apex of vulgarity."[117] The point of *4'33"* was not to listen to the environment like a musical composition and judge its aesthetic qualities, but to provide a space where the sonorous nature of life itself could flow unabated. Schafer introduced heavy doses of aesthetic judgment. In 1972, he recorded the words "First we need to listen. Then we need to make judgments."[118] Some of these differences are explained indirectly by George Leonard, who has written a history on either side of *4'33"*. Leonard traces the particular connection between art and daily life in *4'33"* back to William Wordsworth, and forward to Earth Day 1970, which Leonard calls *24'00"*, a day long realization of the piece. Leonard argues that, thanks in large part to the work of artist Allan Kaprow, the idea that everyday experiences could and should be approached with the same conscious attention as an artwork had by the mid-1960s leaked out far beyond contemporary music and art circles into mass culture in the form of happenings, "be-ins," and increased environmental awareness. Schafer's response makes sense in this more general context, as part of a range of responses to *4'33"* that were less concerned with finding beauty in whatever one found in the world and more about trying to improve that world.

In the years between *4'33"* and Schafer's coining of soundscape, the dangers of environmental pollution were widely publicized by Rachel Carson in her 1962 book *Silent Spring*, a book that clearly laid out the dangers of the pesticide DDT. DDT, sprayed on crops, insidiously leached into streams and rivers, poisoning fish and the birds that ate them, and also made its way into human water supplies. The phrase "noise pollution", which as mentioned in Chapter Three was not adopted by print media until 1964, was coined in the wake of Carson's revelations. Schafer, who was a member of Vancouver's Society Promoting Environmental Conservation, a group that lobbied for environmental regulations, saw noise pollution as no less threatening than chemical pollution; not only to our physical health but our sonic culture in general. He argued that noise pollution had crept inside of us, affecting our perceptions of sounds and our approach to music-making. Rock music, Schafer argued, was a symptom of a polluted sense of hearing, both because of the dangerously high decibel levels found at rock concerts and the music's supposedly alienating lyrics and sonic content.

The Dirty Ear

Rock Music was just one example of what might be called the "dirty ear". Schafer doesn't regularly use the term "dirty ear" but I think it is an appropriate characterization of his ideas about the listening habits of 20th century urban people and the effects of the internalized noise pollution described above. Schafer outlined his cure for the dirty ear in the 1967 pamphlet of course notes titled *Ear Cleaning*. The pamphlet outlines nine lectures and homework assignments suitable for high school and University students. Unlike traditional ear training, *Ear Cleaning* focuses the student's attention on environmental sound as well as musical sound. Most chapters include classroom sound-making with simple objects, like the sound of paper being passed through a classroom or the human voice, and compositions for those sounds that involve the members of the class as performers and conductors.[119] Schafer's introduction states his primary goal, "to open ears," to induce students to "listen like mad to the sounds of their own environment and the sounds they themselves inject into their environment."[120] That environment, which was increasingly filled with "insouciant and distracting sounds," was endangering the faculties of the ear, blunting the sensitivities required for music making; for listening to those sounds which "truly matter." Thus, just as "before we train a surgeon to perform delicate operations we first ask him to get into the habit of washing his hands," our always-open ears needed to be cleaned before performing the delicate operations of music and indeed all soundmaking.[121]

Ear cleaning exercises provided the inspiration for members Hildegard Westerkamp and Barry Truax to join the World Soundscape Project in 1973. Similar to the simple prose scores of Fluxus artists created several years before (another Cage inspired movement) the exercises were easily distributed and simple to perform. In the late 1960s and early 1970s they proliferated in master-classes, in Schafer's articles, and in interviews. These exercises, and the dirty ears that they imply, are central to the WSP. Arising as pedagogy, they maintain their instructional force. For example, they form the first unit of instruction for the profession of acoustic design, as imagined by Schafer in 1977. This new profession was to replace noise control's "negative" approach to sound with a "positive study program."[122] The acoustic designer was proposed as a kind of meta-listener, whose clean ears were consulted by the typical clients of noise control and many others, and who also taught ear-cleaning to others, inspiring a collective acoustic consciousness which would, in itself, lead to the elimination of noise and the beautification of the soundscape. Schafer attacked the then-current practices in noise control as yet another symptom of dirty ears. For example, he lampoons the use of adding background noise in offices to obtain speech privacy. Architects were worse, their ears "stuffed with bacon."[123]

While Schafer found the solutions implemented by noise control woefully inadequate, his definition of noise itself was not substantially different. The first lecture of *Ear Cleaning*, titled "Noise," opened with the following: "We can begin anywhere. It is often useful to examine a negative in order to see the positive clearly. The negative of musical sound is noise sound. Noise is an undesirable sound signal. Noise is the static on a telephone or the unwrapping of cellophane candies during Beethoven. There is no other way to define it…Noise is any sound signal which interferes. Noise is the destroyer of things we want to hear."[124] Schafer goes on to argue against defining dissonance as noise, which understandably may have been a sticking point in an early college music class that introduced students to Charles Ives, Anton Webern, and John Cage. In doing so, though, Schafer trades the duality of consonance-dissonance for that of signal-noise. This definition clearly inherits much from the models as developed for the telephone in the 1910s and 20s and incorporated into noise control through military research in World War II as described in Chapter Two. In fact, one of the exercises for this lecture resembled an articulation test, with a student speaking a text and the class, cued by the instructor, interjecting with bursts of applause, laughter, screams, and other sounds that, to the degree to which they masked the speakers voice, were classified as noise.

Along with this "telephonic" conception of signal and noise, systems theory also plays a role in Schafer's idea of soundscape. In 1969, Schafer moved to the Communications department at Simon Fraser, and the WSP's research would occur under that disciplinary umbrella. As we have seen in previous chapters, the idea of sound as a channel for communications was crucial for noise control engineers. While Schafer did not use the language of systems theory, Barry Truax, a WSP member who took over from Schafer in 1975 after Schafer left the department, in 1984 described the soundscape as a “listener environment system.”[125] In this system, environmental sounds directly influence listening behaviors, which in turn inform the sounds that the listener creates. Noise is amplified in this system, as noisy environments create dirty, noise-addled ears that inspire noisy sound-making activities and a noisier environment, a kind of feedback loop that Truax identified as the “noise generator.” While Schafer avoided systems terminology in his own definitions of soundscape, the underlying concept is the same - sound flows from the environment through the listener and back out again. While the source-path-receiver model of noise control was critiqued for being too “linear,” this model was circular. Both, however, identified the reception of sound as the critical control point, working outwards from the listener/receiver. Ear cleaning works on cleansing the flow of sound through the listener environment system. Soundscape, then, in its most comprehensive form, involves both ways of perceiving a sound environment and the sound environment itself - one revolved around the other. Ear cleaning is a form of environmental cleanup.

A new noise control

In Schafer’s funding proposal to the Donner foundation from 1972, he outlines three phases of the project. The first is a study of Vancouver’s soundscape, the second of Canada’s soundscape, and finally of the world’s soundscape. Between 1972 and 1975, on-site research was performed towards each of these goals, resulting in *The Vancouver Soundscape*, a book and LP published in 1973; *Soundscapes of Canada*, a 10 hour CBC radio documentary aired in 1974; *Five Village Soundscapes*, a book and LP published in 1976; and *European Sound Diary*, published that same year. *The Vancouver Soundscape* satisfied the project's first phase. It begins with two chapters of "ear witness" accounts taken from literary sources and interviews with current residents. These quotations tell a story of a silence lost to human activity: logging, railroads, and city-building. They describe a city losing its sonic awareness: where once various street vendors had their own identifiable cries, where boat captains could navigate in the fog by listening to the echoes of their whistles bounce off the shore, where now traffic noise predominated and the captains had switched to electronic radar displays.

All sounds present in Vancouver are potential subjects for *The Vancouver Soundscape*. These sounds are classified in several ways: as keynote sounds, sound signals, and soundmarks. Keynote sounds are generally background sounds, sound signals foreground sounds, and soundmarks, like landmarks, exceptional sounds of historical and social significance. While the book contains Isobel maps similar to those being used concurrently in highway noise mapping in the US, these maps were built up from measurements taken on site rather than inferred from traffic data. A wide range of sounds is also mapped. There is a map of Vancouver's soundmarks - foghorns, church bells, and a cannon fired at 9 p.m. every evening to name a few. Several maps feature the acoustic profile - the spatial range of audibility - over which a particular sound could be heard. Compared to the noise maps used in highways, which present an overlay of compiled statistical techniques, these sound maps show a concern for the local, for directly perceivable phenomena rather than inferred measurement.

By all accounts, Vancouver was a particularly noisy city in the 1960s. The entire inner harbor was used by seaplanes, which could take off and land from any aspect that suited them. In fact, Schafer's anger at the sounds of these seaplanes formed his initial inspiration for his anti-noise work. *The Vancouver Soundscape* contains several surveys of residents' perceptions of these sea-planes. The first survey was performed in 1969 by Schafer and the students in one of his classes in the neighborhoods around Stanley Park at the tip of Vancouver's peninsula. Subsequent surveys were performed in the same neighborhoods and found that residents grossly underestimated the average number of seaplanes per day that flew above their houses; 8 to 65 in 1969 and 16 to 106 in 1973.[126] The WSP asserted that because most of the changes in the soundscape happened at the periphery of the public's attention, dramatic changes could occur over time without notice. After taking measurements of the amount of time that seaplanes were audible over Stanley Park on three different afternoons in the summer of 1973 and correlating the average of 27 minutes with the rising numbers of seaplanes, the WSP predicted that by 1981 the noise of seaplanes would be a constant, uninterrupted presence. By attending to these facts, by closely listening and monitoring sound's periphery, the WSP hoped to avoid that situation. The audio recording accompanying the book, featuring recordings from all around the city, was intended to amplify the same point.

Hi-Fi Lo-Fi, the Articulated Soundscape

Sea-planes, car engines, air conditioning fans, these are all a part of what *The Vancouver Soundscape* called the “lo-fi soundscape”. The book forcefully argues against the presence of these sounds, claiming “Vancouver is slipping steadily into the lo-fi condition.”[127] The hi fi soundscape, on the other hand, is one in which “discrete sounds can be heard.”[128] Schafer began applying these terms to soundscape in *The Music of the Environment*, written in 1971. Though they were used in very different ways, the concept of “fidelity” in environmental sound shares much with the articulation index described in previous chapters. Just as Schafer reproduces noise control’s definition of signal and noise, he also absorbs its design criteria. The distinction between hi-fi and lo-fi soundscapes, while presented as common-sense, is a nuanced one. The hi-fi soundscape has “a low ambient noise level. The country is generally more hi-fi than the city; night more than day; ancient times more than modern. In the hi-fi soundscape, sounds overlap less frequently; there is perspective; foreground and background.”[129] In contrast, “in a lo-fi soundscape individual sounds are obscured in an overdense population of sounds. The pellucid sound - a footstep in the snow, a church bell across the valley or an animal scurrying in the brush - is masked by broad-band noise.”[130] Schafer describes what he calls the “flat lining” of sound in the post-industrial age: while the pre-industrial sounds of work powered by muscle have, by necessity, an on and off cycle, like the chopping of wood or the hammering of a blacksmith, the sounds of motors and engines powering fans or car wheels, for example, have a more uninterrupted sonic envelope and are thus more effective at masking other sounds. While the blacksmith's hammer may have caused irritation among those people who lived in proximity, its inherent on-off cycle, a duty cycle, allowed other sounds a chance at a co-existing and simultaneous presence. Traffic noise, as a relatively constant sound source, offered no such chances, no windows within which other sounds could be heard.

While hi-fi/lo-fi was never translated into an index, score-able in terms of percentage, the concept nevertheless acts as a kind of expansion and implicit critique of the articulation index. For Schafer, many sounds were signals, not just speech. Footsteps, bells, the movements of animals, these all contributed to a listener's sense of surroundings. That sense itself - the environment as musical composition - was the ultimate goal. In other words, one didn't need to be hunting for dinner in order to value the sounds of an animal's movements. Additionally, as sound propagated from environmental sources to the listener it gained important spatial information based on how it reflected against any surfaces. The path of sound was just as important as the source itself. The hi-fi soundscape is really a "signalscape," composed of signals only, opposed to the lo-fi "noisescape" of the modern city. The desire for a signalscape, sanitized of all noise, runs through much of the WSP's work.

Hi-fi/lo-fi implicitly critiques the articulation index by expanding the range of sounds that matter. While the World Health Organization attacked the articulation index's conception of human speech, Schafer asserts that more sounds than just speech are important in constructing a listener's sense of place. These expanded signals could easily represent a future point of intersection between modern day noise control and acoustic ecology. One imagines the results of a built environment shaped around an articulation index for birdsong, for ocean waves, for footsteps on grass, on concrete, on snow. In this way, the concepts of hi-fi/lo-fi, the desire for a signalscape, could become a useful way to reconcile an expanded sense of environmental sound with the constrained communications frameworks that inform noise control guidelines.

Hi-fi/lo-fi is problematic in a variety of ways, though. One problem is its arbitrary division between signal and noise. Noise gets defined in three different ways: as purely sonic content ("broad-band noise"), as perceived information content ("meaningless sound"), or simply as the number and spatial configuration of sounds (an "overdense population of sounds"). [131] Perhaps a more useful definition, given Schafer's emphasis on listening, involves conditions of receivership, as when in the hi-fi soundscape the "human ear is alert, like an animal's,"[132] while in the lo-fi soundscape the ear, dirtied by noise, is less focused. Hi-fi/lo-fi also operates categorically in the examples given in the work of the WSP. An environment is either hi or lo, with little space in between: it is a dualism. Perhaps this is simply exaggeration to prove a point, but this lack of gray area allows a host of other ideological dualities to be dragged along into the hi-fi/lo-fi distinction: country vs. city, pre-industrial vs. industrial, acoustic vs. electronic. The division between signalscape and noisescape is made not only by conflating the aesthetic qualities of a sound and its social meaningfulness, but through an idea of history.

Schafer's historical interests run through many of the WSP's activities. WSP members painstakingly searched through texts of all sorts in search of mentions of sounds and sonic experiences, creating a library of quotations indexed by location and sound type. In addition, they interviewed older residents at each location studied about what that place had sounded like in years gone by. *The Vancouver Soundscape*, for example, opens with two chapters of nothing but these "ear-witness" accounts. Before this research began, though, Schafer had already published narrative accounts of a history of human sound experience, as in a 1970 pamphlet *The Book of Noise* and the article *The Music of the Environment*. *The Book of Noise* outlines a narrative of degradation from a pure, noiseless, pre-technological state to its modern noisy condition. Schafer imagines the sonic world of a man living in a pre-technological society, a world revolving around the human voice. Sounds other than the voice, like those made by simple tools and zithers and flutes, would also be present. More than just the sounds present, Schafer imagines this man's listening habits: "often he will sit quietly making no special sounds at all."[133] The pages following this speculation describe in text and illustration how this original, pure state of hearing is soiled by urbanization and increased population density, by electric guitars and transistor radios, by almost every facet of modernity itself. This history of paradise lost, of dirty ears exiled from the garden of sonic purity (the "soniforous garden") is a key component of Schafer's ideology.

Schafer's imagined history of sound is more fully developed in *The Tuning of the World* published in 1977. Using the WSP's library of ear-witness quotations, Schafer attempts a history of sound on planet earth, moving from non-human sounds - the ocean (the "first soundscape"), weather and vegetation, animals - to the sounds of rural human settlement, to the sounds of urban settlement and the industrial revolution, to the invention of sound reproduction and recording technology (the "electrified soundscape"). The categories of hi-fi/lo-fi operate along the pre and post-industrial rift line. Nowhere is there a sense of the political and economic struggles that took place in the 18th century and before, of the creation of the countryside. The pastoral quality of many rural landscapes that Schafer was so attracted to was not the result of "nature," but of political and economic struggles. A landscape free of human traces, of human noise, had to be created. Karl Marx's famous quote about the enclosure movements in England and Germany, in which land was consolidated into the hands of a few powerful owners, is relevant here: "first the laborers are driven from the land, and then the sheep arrive."[134] Schafer's "acousmatic" history erases the contested nature of human existence before the 18th century and in so doing risks taking its patriarchy, racism, and inequities as givens; risks an acoustic design that is aesthetically rich but politically and socially impoverished.

Telephonic ecology

Hi-fi/lo-fi is a useful foil for a general discussion of the concept of "articulation" in noise control, its deficiencies, and its future potentials. As we have seen, noise control operated within a relatively limited register in post-war North America. In general it worked for clients whose goals were the betterment of their offices and products and not the "public" sound environment as a whole. Schafer and the World Soundscape Project attempted to invert that balance, focusing on public environments and attempting to promote a positive approach to sounds by deciding which sounds were most important and clearing sonic space around those sounds. In many ways this was a worthy goal. While Schafer's general idea of soundscape is immensely useful, in detail his concepts do not offer a way out of or through traditional noise control. In fact, they re-inscribe the telephonic approach to sound, an approach that easily divides sounds into signals and noises, into larger and larger domains.

A further problem is that many of Schafer's ideas about sound, such as hi-fi/lo-fi, were fully formed before the WSP's research began. These are not hypotheses to be tested by research, but concepts for which the WSP was gathering evidence. For example, when performing the fieldwork for *Five Village Soundscapes*, the WSP researchers spent most of their time not interviewing residents or recording, but searching for villages that fit their model of a pre-industrial town. In other words, they needed the right kind of evidence for their case against the soundscape of modern life. Alas, Schafer's concepts and terminology play an ideological role, one that still predominates Acoustic Ecology.

The source-path-receiver model and its extended relative, Acoustic Ecology's listener environment system, have received an implicit critique of their own through recent studies of animal behavior. While these previous models are clearly influenced by telephone systems, and retain the point-to-point "dyadic" quality of those systems, recent models of behavior are more influenced by computer networks. Rather than using sender-path-receiver, many scientists are now using the model of senders-eavesdroppers-receivers arranged in various spatial configurations. "Noise," or as Schafer defines it, "any sound that interferes," is an inherent part of these environments and in many cases essential to survival. Many species have been shown to exploit the masking potentials of other sounds in their environments to avoid eavesdropping predators. Studies have also shown that the message structures of many species evolved to be resistant to the effects of interfering noise that are in reality present in any environment. These findings cast the work of acoustic ecology, its desire to "clean" the environment of all noise, in a new light, as bordering on a practice more ideological than ecological.

Chapter 5 – Re-articulating Soundscape

This work is largely about how noise has been defined in North American history, and how those definitions have informed architectural designs, approaches to landscape and the meanings of “soundscape.” As with many facets of acoustic life in the 20th century, sound reproduction and transmission technologies vitally influenced these definitions. In particular, the development of the telephone system in the 1910s and 20s played a central role in defining an approach to signal and noise that shaped how environmental sounds were perceived. Noise is a discourse, one that articulates a soundscape, drawing lines through gradations of auditory experience. This discourse has a history, one that informs our present-day ideas about sound. My attempts at recovering aspects of that history have been to more fully understand the present moment, the pressure points of noise in contemporary life. There are many parallel and related historical inquiries that I could have written about: how music has been defined, how silence has been defined. Sound, silence, music, noise - at any given time these terms implicate each other, though most often as negations of the other. Of these terms, though, noise is the one that makes it into laws and becomes a standard part of zoning regulations. Tracking noise means tracking legal, political, and architectural expressions of ideas about sound. Noise is directly connected to acoustic sensibilities in a culture of building that shapes the built environment.

Articulated Time

Neck-deep in the past as the preceding chapters have been, I have tried to keep at least my head in the present and in my own artistic practice. The piece which has occupied most of my life as an artist over the past five years is *Call Notes*, which inserts into public spaces electronic bird songs synthesized to fit the contours of popular melodies. In the summer of 2009, this work was installed along two blocks of Melbourne's Hardware Lane, using solar-powered speaker devices with simple 8-bit microcontrollers to generate the sound of the birds. The laneway, which is filled with restaurants and shops, but also residences and office spaces, is used by thousands of people each day. The installation ran from August 2009 to February 2010. The challenge was not only the creation of the bird songs and melodies themselves, but of a durational structure that would accommodate the various users of the site. Due to the limited computational capabilities of the microcontroller, a simple structure was used. Each hour was divided into 10-minute sections of varying intensities, with five minutes of rest between each section. Some sections featured only one tune, and others a random assortment of tunes. The overall intensity and volume of this hour-long cycle changed throughout the day to match the variations in the amount of activity. The piece began sounding at 10 a.m., gained intensity around the lunchtime rush, tapered off in the afternoon, and peaked again between 4 p.m. and 6 p.m. as people again flooded the site after work. Ten songs were chosen, sung by five different models of bird species. These songs rotated around the day, so that at 12 p.m. a different song would be featured on each day of this 10-day cycle. A graph of that structure can be seen in the appendix.

Call Notes, and other publicly sited installations that I have made, have been a catalyst for my interest in the history of noise control. I originally approached public sites with a desire to bring ambient sounds to the fore, to focus attention and find layers of meaning in sounds that are usually ignored, to re-define the categories of background and foreground. I quickly found out that when working in public, other people's ideas about sound are just as important as one's own artistic re-definitions. My first public installation, *Etchings* from 2003, began with a self-designed stylus to inscribe sound in acetate disks spinning on a turntable. Recordings of these sonic results, picked up by a turntable needle, were broadcast via speakers around the second and third floors of Wesleyan's Davenport Campus Center. Within a week, the speaker lines had been cut, the acetates removed or defaced, even though at each step in the installation process I had sought permission from those who managed the building. The first few truly public installations of *Call Notes* also ran into trouble. In Vienna and Seoul, speaker devices that were installed close to apartment buildings were torn down by residents, and, in both cases, residents called the police with noise complaints. In other words, my work had become a noise to those people living with it. The complaints that came in were relatively specific, criticizing the repetition and hours of operation of the piece rather than the sound material itself. These critiques were immensely useful. They pointed to the importance of careful attention to timing and rhythm.

The Melbourne version of *Call Notes* was an attempt to address this issue. Thankfully, only one complaint was called in and was easily addressed by changing the location of a single sound device. Ideas about rhythmic behavior and durational structure have become central concerns in my present work. *L&*, a string quartet written in the fall of 2009, uses a genetic algorithm to evolve rhythmic patterns that overlap as little as possible while still expressing a fixed number of notes in a melody. What results are rhythmic textures that gradually evolve into a form of hocketing. Articulation and dynamics all flow from the amount of rhythmic overlap that each note has. *For an Intersection*, composed in the winter of 2009-10, uses an algorithm originally developed for computer networking and adapted to simulations of frog choruses. The algorithm, pioneered by Brush and Navins attempts to bring competing signals into a phase relationship where each signal has maximum clarity while also allowing competing signals their own space. In *For an Intersection* this chorusing behavior is applied to control synthesized crickets that react to high frequency sounds. However, these concepts have potential application to a broad range of sonic signals. I have begun preliminary work on a sound system to be used in hybrid cars, which uses the Brush and Navins algorithm to increase the audibility of an approaching car while keeping the overall amount of sound produced to a minimum. My future work will no doubt explore these issues in more depth. In a way, through having my own work classified as noise, subject to control and abatement of varying severity, I have become more engaged with the issue of noise in general, its past and future.

While the articulation has its glaring limitations, it also is clearly useful in the day-to-day work of noise control engineers. One of these is its lack of durational measurement, its lack of temporal sense. In the coming years, I would like to re-define the articulation index to incorporate time and frequency parameters for an expanded range of sounds. This could be applied to the sounds of an installation, measuring how "porous" its sound textures are in relation to its site. Through my discussions with curators and project managers who have been involved in a number of public sound art projects, I have learned that it is not uncommon for pieces with a sonic component to run into substantial conflicts with the inhabitants of a site. These conflicts, how to avoid them or productively use them, are an under-explored area in the discipline of public sound installation. It is interesting for me to imagine new sets of artistic tools and approaches, such as a revised articulation index, which explore methods for designing sound with these issues in mind.

Masked pianos

Before I focused on sound installation and computer programming, I was a dedicated improvising piano player. Lacking the extremely powerful fingers of some of my piano-playing peers, I found that audibility was always an issue when playing in ensembles. The resonating piano has an amazing ability to sustain sonic details at thresholds of audibility - a single held chord can have at least nine lives, if not more. Add the wash of a drummer's cymbals, or a pair of saxophones, and those sounds are masked. When using extended techniques, creating sounds by preparing the strings or playing directly on the harp, one is always “testing” the sound for how it compares, cuts through, and coexists with the sounds of the other players. In large ensembles, I tended to venture to the high or low registers of the keyboard, where I had little masking competition and a chance to cut through. Perhaps my interest in articulation began here - how to articulate a sound palette largely created through solo practice in a group setting.

However, there is a second tactical dimension to articulation that emerges in many improvisational contexts where musical form emerges in terms of flows and ebbs of group energy. In free jazz especially, crescendos build: one instrument after another. Tactics arise around these flows of energies. One could surf the tail end of a crescendo into quieter sections, where more delicate sounds might be heard. One could instigate a play on the traditional device of “trading fours” in an ad-hock way. One could cut through the usual hesitancies at the beginning of a session with a clear sound idea. Of course, one could discuss one’s sensitivities with other players, and I usually sought out those players who shared my interests, but the unwritten ethos of “just play” meant that often my sonic desires needed to be activated through strategies in the moment of the music, rather than a kind of composition beforehand. Perhaps this is where the self-organizing aspects of my current work originate. It may also explain my instinctual negative reaction to Schafer’s idea that we listen to the environment as a total composition rather than an improvisation in which we ourselves play an important role. Jane Jacobs described urban life as a collective “dance” where each person played a particular role in space and time.

Following my interest in free jazz, the first composer that I studied in any depth was Ornette Coleman. When I was 19, I had consecutive surgeries on both of my wrists, and many activities, including practicing the piano, were put on hold for six months. My musicality developed more during these six months than it has before or since. I began transcribing by ear Ornette Coleman compositions and solos from his early 1958-1962 records. I spent a few months on *Ramblin’* alone, transcribing the head, Coleman’s solo, and the accompanying bass and drums as well. I would sing the head and solo while riding the volume wheel of my CD player - silencing the recording for a few measures to see how well I could stay in sync on my own. While I had done very ordinary transcriptions of canonical solos of Miles Davis, Wynton Kelly, and Bill Evans in high school, *Ramblin’* and others required a new palette: microtones, bars of 2/4 mixed with 4/4, and multi-phonics.

Coleman’s concept of harmolodics forms an interesting counterpoint to the discussion of masking mentioned above. Harmolodics erases a variety of distinctions in the roles of group improvised music, most dramatically between soloist and accompanist; instead using counterpoint as a guiding principle. While in the 1950s and 1960s, harmolodics seemed to exclude chordal instruments, by the 1970s Coleman had included single and multiple electric guitarists in his band Prime Time. The dense layering of the recordings that Prime Time made in the

1970s, such as *Dancing in Your Head*, still excite and reward my repeated listenings. Rhythmically, drummers such as Ronald Shannon Jackson and Denardo Coleman have interpreted harmolodics as making available multiple tempos and time feels at any given time. Rather than "keeping" time, they articulate its multiple possibilities. The harmolodic concept, emerging in the 1950s and finding new expression in the 1970s, provides an interesting counter-example to the ideas of signal and noise and their articulation in noise control and contemporary music, which I have begun to outline in the previous chapters.

Research into harmolodics might be a starting point for my future research into noise control, which needs to dramatically expand its scope. Schafer's writings and influence have been one area where the influence of the dominant trends of noise control is clear. It is time to look elsewhere for alternatives.

Sound categories

One interesting facet of the 1878 elevated railway episode is that the categories of signal and noise, while being developed in medical practice and telegraph operation, had not yet hardened into a conceptual framework which could be applied to all sound. Instead, sounds were necessary or unnecessary, depending on their social function and the ability of engineers to control them. Through the 1920s the distinction between necessary and unnecessary shifts to signal and noise, and sounds are evaluated in terms of how they function within circuits and communication systems. Schafer and the World Soundscape Project adopt this model, expanding the categories of signal and noise to include natural and man-made, pre-industrial and industrial, rural and urban, all flowing predictably through an expanded system of idealized communications. These categories, perhaps an inevitable side-effect of 20th century sound transmission technologies, are nevertheless seriously lacking. In my own work, I have tried to create hybrid sounds and situations that elude categorization and suggest other directions in which sound can flow.

Hybrid sounds have been one of my preoccupations since I began to experiment with piano preparations and extended techniques as a teenager. Bowing was one of the first techniques that I learned, simply because it allowed me to create a slow attack and long sustain that were impossible for notes played on the keyboard, yet retained a timbral similarity to those notes. My work with car horns, explored in the piece *Aioli n Carp* has followed a similar course. Typical car horn circuits have only a binary state - either on or off. At Wesleyan, I created a circuit to activate the car horn that allows for gradations of sound in between those states. Audio waveforms can be sent directly to this circuit, turning the car horn into a kind of speaker, albeit a bad one. *Call Notes* works explicitly to create a sonic hybrid, a sound in between birdsong and a whiff of a popular tune.

Car horns are inherently a hybrid of signal and noise, at least in the moments just after they speak. Conditioned by years of commuting on the road by car and bike, I react to car horns in a way that is more spinal than cerebral. In the moments after a horn sounds, I often unconsciously try to resolve the location of its addressee (you talking to *me*?), its status as signal or noise from my vantage point. These moments, where the meanings of sounds are still up in the air, so to speak, continue to fascinate me. My work attempts to juggle potential meanings and interpretations, to sustain these moments where sound confounds category. The articulated soundscapes that I have described in the preceding chapters have all drawn clear divisions between signal and noise, between nature and culture. Actual sonic experience, in all its fine-grained temporal nuances, is much richer, much more confusing and complex.

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Appendix

Documentation of Artworks:

Aioli n Carp (2010)

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Call Notes: Melbourne (2009)

For an Intersection I (2009)

L& (for string quartet, 2009)

For sound recordings and additional images, please visit http://hearingthings.net