Large String Array

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Abstract

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Twelve hundred piano strings reach from floor to ceiling in *Large String Array,* turning the whole of Jack Straw New Media Gallery into an automatic instrument. An ensemble of synthesized voices playback over the array of strings, for a seventeen minute song cycle. Custom high-gain amplifiers and contact microphones were developed to listen in to faint transmissions of daily life during the pandemic of 2020. *Large String Array* reimagines this cloistered soundscape as a tone poem transfigured through the seventeen by twelve foot array of steel wire.

This document outlines the technical and conceptual development of *Large String Array*. First, addressing research and artistic inquiry, the results of which culminate in an installation at the Jack Straw Cultural Center in Seattle Washington in September of 2020. This is followed by a historical argument of the work, detailing the confluence of diverse sound practitioners to whom *Large String Array* is indebted. Next, the core of the paper details the creation of the Large String Array, from its conception to installation. Finally, conclusions and future iterations will be addressed.

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1 CHAPTER 1. INTRODUCTION

1.1 OVERVIEW OF LARGE STRING ARRAY

Large String Array is an automatic instrument installed at the Jack Straw Cultural Centers New Media Gallery. The entire south facing wall is covered, from floor to ceiling, with twelve hundred lengths of piano wire. Through the spring steel, a seventeen minute composition plays back recordings detailing the faint transmissions of daily life during the 2020 global pandemic. Normally imperceptible to the ear, these recordings have been highly amplified and digitally transformed into three choral passages, forming a song cycle reflecting the cloistered soundscape of life under quarantine.

The audience is greeted at the door by the rush of a passing train. A sensor detecting their presence starts the piece on cue. Only one person is allowed in the gallery at a time making for a private, socially distanced, listening experience. The sounds themselves are a tapestry of tape, recorded using extremely high gain amplifiers, along with contact microphones attached to a street adjacent windowpane, while sheltering in place in Oakland California. These intensely amplified sounds sing out over the array of strings installed along the gallery wall.

Twelve transducers transmit vibrational energy to the strings along the array. These electromagnetic devices produce sound by resonating objects which they are coupled to. They shake with force enough to make oscillation of the strings visible. *Large String Array* appeals to many different senses: hearing, touch and sight. What can be heard is the actual structure of the wall amplifying the signal, turning the Jack Straw Gallery into a giant resonant instrument. The hollow gallery wall swells with sound as the exciters transmit their voice through the steel strings to the drywall.

1.2 ORGANIZATION OF DISSERTATION

This thesis is documentation of research culminating in the installation of *Large String Array*. First there is an overview of compositions, engineering experiments, sonic sculptures and musical instrument design leading the conceptual development of this piece. This inquiry then traces the historical context of *Large String Array*. Here we discuss specific readings, artists and artifacts to which this work is indebted. Next, this paper will address the realization of *Large String Array* in the Jack Straw Gallery. This section will be a compendium of design considerations, compositional strategies, real world challenges, notes on tooling and impressions from the installation itself. This chapter closes with a look forward at potentials and iterations of the string array. Last, an appendix of schematics, flow charts and block diagrams used in the creation of this work.

2 CHAPTER 2. OVERVIEW OF PRACTICE

2.1 INSTRUMENT DESIGN

> "The impulse to the growth and evolution of music is generated by the human ear, not by the piano keyboard … the missing element which the human ear wants and needs most is a musical instrument capable of expressing an infinite range of ideas and of infinite mutability" [1]

There have been innumerable attempts at reimagining acoustic instruments. These attempts are responsible for known forms: the piano, the flute, the mbira and the đàn bầu. Instruments can be broken down into five classifications: Idiophones, Membranophones, Chordophones, Aerophones, & Electrophones.[2] To know these classifications is to understand the physical limitations of the

[1] Partch, Harry. *Genesis Of A Music: An Account Of A Creative Work, Its Roots, And Its Fulfillments, Second Edition*. 2nd ed., Da Capo Press, 1979. 95.
[2] Paganelli, Sergio. *Musical Instruments from the Renaissance to the 19th Century. Translated by Anthony Rhodes from the Italian Original.* London: Hamlyn, 1970. 38-41.

sounding universe according to human hearing. Idiophones must be struck and have the body of the instrument ring out like a cymbal. Membranophones have a thin stretched membrane or a skin which produces sound like a drum. Chordophones use strings stretched between fixed points to produce tone such as a harp. Aerophones excite a body of air, such as a trumpet or a tuba. Electrophones are electroacoustic in nature and require an amplified playback system such as a Moog synthesizer.

These classifications can get messy. Some instruments exhibit two or more characteristics such as the banjo, which blends both Chordophone and Membranophone types. These hybrid possibilities are fertile areas of research. But, what can clearly be pointed out is that, there are few basic forms which make musical sound possible. What is considered pitched or tonal sound is even harder to recreate for many of these instrument types. Francios Baschet wrote this tidy list of criteria for musical instrument design:

> “A MUSICAL INSTRUMENT IS THE JOINING OF AT LEAST THREE OF THE FOLLOWING ELEMENTS.
>
> An element that gives periodic vibration (reeds, string, vibrating rod, etc.)
>
> A form of energy that activates the vibrator (wind, bow, percussion, etc.)
>
> A device to implement the scale (keyboard, keys, frets, etc.)

A sound amplifier (sounding board, funnel, resonating box, etc.)

There can be a fifth: one may use additional sympathetic vibrators adding supplemental frequencies, which complicate the sound and spice up the timbre. Added frequencies which are stable are called “formants”.“ [3]

You cannot reinvent the string, but you can give it a new context. This sifting and searching for a new compelling tonality is at the heart of the following.

2.1.1 SUB BOX.

The Sub Box is an instrument designed to produce very low sub bass tones when amplified. It has a flexible tuning system consisting of four thin steel bars an inch wide and a foot long, separated and suspended by a clamping fulcrum. This clamping point is adjustable allowing for one side of the metal bar to be tuned to a specific pitch. The other side’s pitch will be the remainder of that foot long bar. It is best to think of this instrument as having two hemispheres, a stereo arrangement. Both sides are tunable but the frequencies will always relate the length of the bar from the fulcrum and to the thickness of the bar. The box has four separate bars for a total of 8 pitches.

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[3] Baschet, François. *Sound Sculptures of Bernard and François Baschet*. New York-United States, United States, Macmillan Publishers, 1999. 22.

Figure 1 - "Sub Box", 2017

Now this box is not an acoustic instrument. Like an electric guitar being strummed without any amplification, it has little physical structure to reinforce the vibration, as would an Idiophone. It being electric, makes huge percussive bell-like tones possible even though it produces little acoustic volume. This is the result of having one end of the bar clamped tight and the other end free to oscillate with an exaggerated amplitude crest.

The Sub Box was in fact a first foray into hand wound inductors as pickups. These copper coils are placed under both sides of each bar and then fed to independent tone and volume controls. These pickups transmit the electromagnetic fluctuations of the bars. The signal then amplified to create giant bass and sub bass tones.

Sub Box's complex tonality is a result of competing overtones, as the actual fundamental is well below hearing level and simply modulates these obertones. While it is capable of making something closer to a pure tone, where you can make out a finite fundamental when clamped at quite short lengths, this is not its strength. It is the complicated collision of overtones that make this instrument unique. This gives it a rich timbre like that of a bell in short percussive bursts.

> "Experiment has shown that if the fundamental tone be removed altogether, leaving only overtones sounding, we are so accustomed to associating the sound of these overtones with a single sound that the series of overtones alone still sounds like a single tone to us, and we think we are hearing the fundamental tone, with rather a thin quality." [4]

The Sub Box is similar to a marimba or xylophone in nature. In fact it is most reminiscent of Harry Parches Marimba Eroica, a gigantic sub bass marimba.

[4] Cowell, Henry, and Joscelyn Godwin. *New Musical Resources. With a Preface and Notes by Joscelyn Godwin.* Edition Unstated, Something Else Press, 1969. 4.

Notes this low are often not employed in traditional arrangements, blurring the line between tonality and acoustic pressure. Partch wrote of the instrument:

> “Except for the hollowed logs used in Africa at one time (perhaps even at present), which produced a somewhat similar effect of feel-hearing, these very low sounds were and still are, acoustically, a kind of *terra incognita.*” [5]

These sub bass notes are also difficult for playback systems to replicate. The Electric Sub Box, because of its flexible tuning system and reliance on rich overtones, can hold up to audition through small laptop speakers with its generous spectral activity. Allowing for more flexibility than Parch’s fixed pitched Marimba Eroica, while offering a similar timbre.

2.1.2 AUTOSLIDE INSTRUMENT

Picking up from the inductor experiments of the Sub Box, this next instrument begins to explore the energy transfer potential of the inductor. Instead of reading the electromagnetic interference through a copper coil and fixed magnet, the AutoSlide Instrument uses a signal to beam complex electromagnetic waveform

[5] Partch, Harry. *Genesis Of A Music: An Account Of A Creative Work, Its Roots, And Its Fulfillments, Second Edition*. 2nd ed., Da Capo Press, 1979. 276.

energy to four different strings, allowing those frequencies to build up within the wire and ring out.

Figure 2 - "AutoSlide Instrument", view of top with leadscrew and motor housing, 2018

The instrument is quite large, measuring five feet long, three feet wide and three feet tall. It utilizes the Membranophone form, as its base is a handmade oval stave drum. Like a banjo, a large mahogany and ebony bridge sits coupled to the goat skin drum head and held with the tension of the four strings. This vibrates the head of the drum creating acoustic amplification.

A long five foot plank is elevated six inches above the drum base. This is the string actuation and slide adjustment area. Three feet of this length can change pitch as an inch and a half thick brass round bar slides up and down four leadscrews, riding along each string independently. Four separate carriages holding the heavy 1.5” brass slides are controlled by stepper motors for locational accuracy. The motor is computer controlled and pitch locations are determined by assignment. This instrument can easily be tuned to any pitch configuration without preference to fixed tuning systems.

Figure 3 - "AutoSlide Instrument", view of brass slides and carriages along leadscrew, 2018

The use of strings point to the Chordophone as an archetype and the use of a goat skin drumhead to that of the Membranophone. Furthermore, it’s reliance on electromagnetism alludes to Electrophones - a hybrid of three of the five sounding models.

A feature of this instrument is its relaxed attitude to actuation. There is no hurry with this system. It is not meant to bang out a series of rapid fire notes. Rather, it has a very slow onset attack allowing the vibrations from the inductors to build up in the strings. This is a feature of the physics of the system. This instrument is also characterized by its complex unstable overtones and deep bass.

Some aspects of this instrument are modular as well. It can be arranged as a feedback system, where the current state of the string is reinforced by a second listening inductor or pickup. Take the current input of the pickup and drive it back electromagnetically into the same string, this reinforces and amplifies the pitch of the string.

The instrument can also be driven by frequencies independent of the string's physical pitch, as when an unrelated frequency is driven through the coils. For them to sound out, slide locations must agree with the length and tension of the strings. If these variables do not agree, little sound will output. This creates fixed nodes along the actuation path that will sing out when the length is in agreement. There are about three of these harmonic node areas per octave for any fixed frequency.

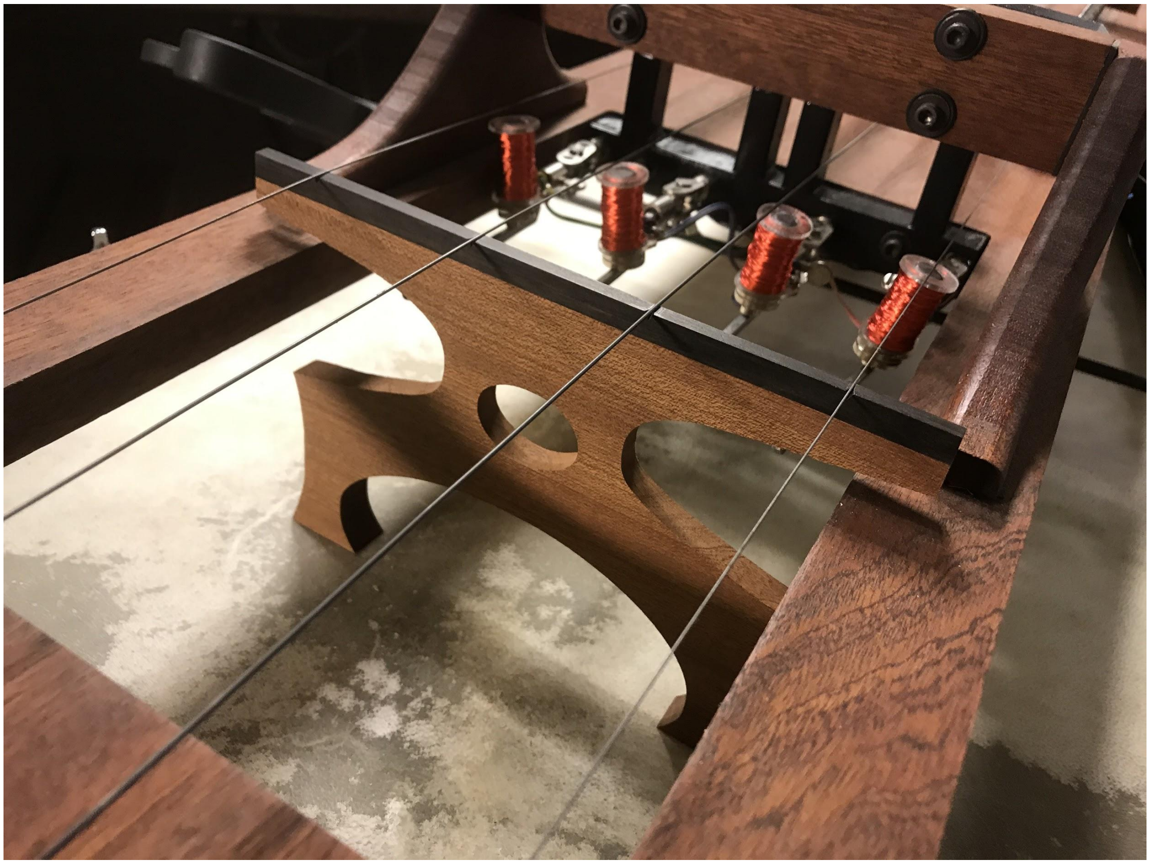

Figure 4 - "AutoSlide Instrument", view of inductor actuators and bridge, 2018

The attributes characterizing this instrument are its ambivalence towards tuning, its four independent voices and its preference for slow repertoire. It also has the strange ability to shift between octaves and accentuate overtones not originally intended. There is a sense of entropy built into this system. Notes change tonal focus without total control. It is important to note, several of these features point to systems at work the construction of *Large String Array*.

2.2 UNCLOUDY DAY (ELECTROACOUSTIC GRAIN SILO)

The first attempt at building self-actuated string arrays, on a large scale, began in an abandoned grain silo just west of Hudson New York in 2015. With the help of Wave Farm WGXC radio, Uncloudy Day was installed on an old farm deep in the rural countryside. It consisted of eight strings, fifty foot tall, stretching from the floor to ceiling of the wood silo.

Figure 5 - "Uncloudy Day", view looking up from center of silo, 2015

Each string was paired with an electromagnet for the purpose of vibrating the strings without contact. This is the same technology employed by the AutoSlide Instrument. Bridges were placed along the walls of the silo, held in tension by the strings, using the walls of the silo as a resonating structure.

You could hear the silo ring out over the lush countryside. Overtones created by the length of the strings paired with the circular shape of the silo. Just turning your head created strange new phase relationships and the sound took on a deep sculptural dimension. The core elements in this piece still resonate throughout this body of work.

Figure 6 - "Uncloudy Day", view of inductors and resonant bridges, 2015

2.3 SUBWOOFER ETUDES (TUNING OF THE FABLAB)

A seemingly inconsequential piece or maybe better described as a series of experiments was conceived in the DXARTS FabLab in 2017. Three etudes were composed with long time collaborator Allen Watke for an array of four subwoofers. The goal of these three pieces was to chart specific frequencies which resonated objects around the room. These objects were sympathetic to the bass frequencies played through the subwoofers, with a frequency range of no higher than 120Hz. The objects along the wall and around the shop were in a sense the score. We cataloged these frequencies and composed several short etudes with the index.

While playing these bass tones at some volume one could catch audience members whispering to each other and hear them quite clearly. The contrast between the defining low end and the absence of frequencies over a hundred and twenty hertz illustrates the vacuum left in frequencies in the higher frequency range. One might be inclined to think these frequencies would somehow be drowned out by the intensity of the low end signal. In truth, there was little masking of quiet sounds. A whisper was audible five feet away while sheet metal and wrenches rattled in various stations around the room. It made clear just how little competition a 55 hertz signal presented to a 440 hertz signal. To know this technically is one thing, to hear it with your own ears is revealing.

2.4 ELECTROACOUSTIC FILE CABINET

The Electroacoustic File Cabinet: a vacant lot, emptied of memory. These old file cabinets, husks of production and accountancy are loitering in our streets and haunting our second hand stores. This next piece takes on these unsightly monoliths.

For a concert put on by DXARTS at the Good Shepherd Center in Seattle WA 2018, a steel file cabinet was retrofitted with a bass transducer to exploit its lesser known, but quite stirring, sonic prowess. The cabinet was placed center stage, with bright white lights illuminating barren drawers. A field of electricity, swarming around it, projected from the mezzanine by collaborator Rihards Vitols, giving it its fantasmic glow.

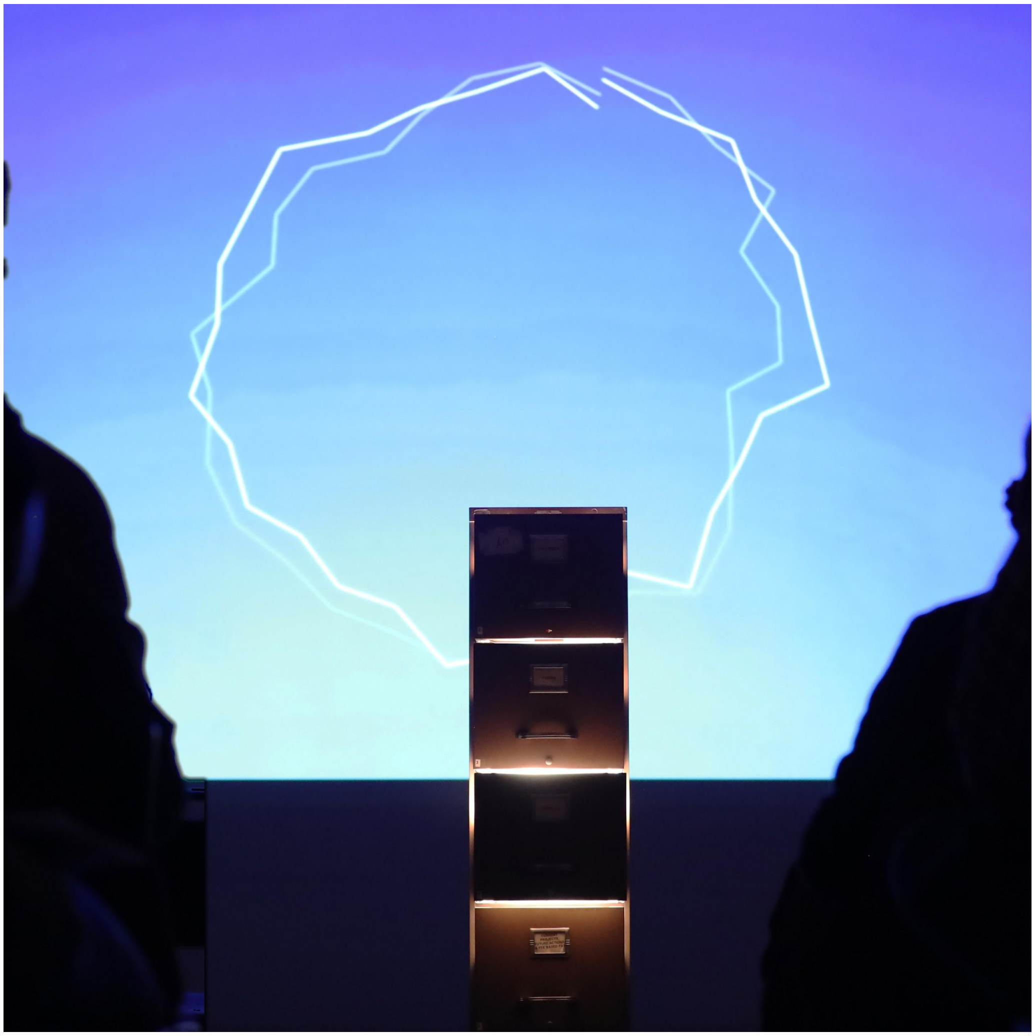

Figure 7 - "Electroacoustic File Cabinet", view of stage, 2018

Swarms of notes made from a sample set of handmade electroacoustic instruments danced around the quadraphonic speaker setup. These sweeping gestures and textures were made algorithmically using Super Collider and arranged in a DAW. Accompanying the tape music, a handmade Circular Koto and harmonium played both orchestrated and improvised passages. The composition, admittedly farcical, explores the manic temperament of the file Electroacoustic File Cabinet. Being a large hollow structure, it is an excellent resonator, like a gong or any idiophone like object. In the climax of the piece, the metal cabinet becomes so overwhelmed with energy, it reaches its natural resonance. It rings out, with a slight upwards glissandi, a frequency it can no longer sustain. This file cabinet, a first experiment in bass driven induction, was capable of exciting the whole structure, ringing out its corporal tone.

2.5 LARGE STRING ARRAY (BOOKS ROOM)

The Books Room in McMahon Hall at the University of Washington hosted the first iteration of *Large String Array* in 2019. A nine by nine foot mahogany frame was installed sharing wallspace with a preexisting photo display. The books room had been vacated for several years, a liminal space, having built in cabinets and chair rails made of mahogany lining the room.

Figure 8 - "Large String Array - Books Room", First Large String Array, 2019

Four hundred strings ran from the top of the frame to bottom, divided horizontally by nine metal bars clamped to the strings. Transducers were fixed to each length of metal to actuate the strings. The fixture illuminated from within. The frame, an instrument, woven into the decor of the room.

The sound was subtle but persistent, trilling with frequencies beyond the simple materiality of the wire. There were other ghostly sounds ringing softly through the strings of the array. A score was written for the array with frequencies which most excited the strings, giving the wire a choreographed movement. The contoured shaking and clawing of the wire by the transducers would not let the ears rest.

The relaxed strings came to life groaning and zapping, the whole array pulsing. The strings rang out like a Sonambient sculpture, the materials themselves on full display. The sound, curious and demanding, like a rattlesnake coiled, it snaps your attention. It was in this altered architecture, a sonic retuning of the space, that Large String Array came to be.

3 CHAPTER 3. HISTORICAL CONTEXT

3.1 MUSICAL AUTOMATA

The term automatic instrument casts a wide net. It can take on an abundance of forms. The earliest examples of musical automata are indeterminate systems, relying on nature for their input. The Aeolian harp is a great example, relying on the wind to pluck a string.

> "Automatic or self playing musical instruments date back to antiquity. Pipe organs which played simple tunes by means of a program arranged by placing pins in a pattern on a revolving barrel were used in ancient times. Records, usually incomplete so far as the details of the mechanisms are concerned, tell of automatic flute-players, mechanical birds, and similar lifelike automata used in Europe during the 1500-1800 era. Such devices, however, were the playthings of royalty." [6]

[6] (Bowers, David. *Encyclopedia of Automatic Musical Instruments*. Amsterdam-Netherlands, Netherlands, Amsterdam University Press, 1972. 10.

Figure 9- Wurlitzer Style 157 Band Organ, 1924

Automatic instruments became mechanized over time, controlling their movements with precision. 17th century France proved a shift in the complexity of these automatic musical systems. They were increasingly elaborate, controlling a great number of instruments at the same time with watch like precision. These musical machines, which started quite small and delicate, would eventually take up entire rooms, often employing actual instruments in their makeup. These contraptions, by the 1880’s, take the name “band organs”, as they contain an entire band, with the centerpiece generally an organ. They are visually striking, displaying bright colors and elaborate filigree, often featuring the choreography of dancers and animals performing small mechanical movements with the music. These objects were meant to entertain.

Large String Array is indebted to these mechanical marvels. The space around these robotic instruments becomes a stage for the listener to navigate. These band organs have a larger than life theatrical presence. *Large String Array* is meant to envelop the listener and engage the viewer with the entirety of the space, just like these marvels of antiquity.

3.2 KINETIC SOUND SCULPTURE

Sculpture meant to move, most likely produces noise as an artifact. Early practitioners of kinetic sculpture took notice of the sounds made. When motors were introduced to sculpture of the nineteen twenties and thirties, these electromechanical assemblages began to hum with the flow of electricity. Take *Light Prop for an Electric Stage* by László Moholy-Nagy. The piece, set in motion with a roller chain, clangs and clanks as it spins its gears. The sound is a pronounced part of the sculpture. A large metal ball slams back and forth along a short track. An aluminum honeycomb circle and varius angular shapes, spin in choreographed movement. The sculpture creaks and groans as the relationship between parts of the sculpture remain in motion, constantly rearranging their visual orientations while creating a soundtrack.

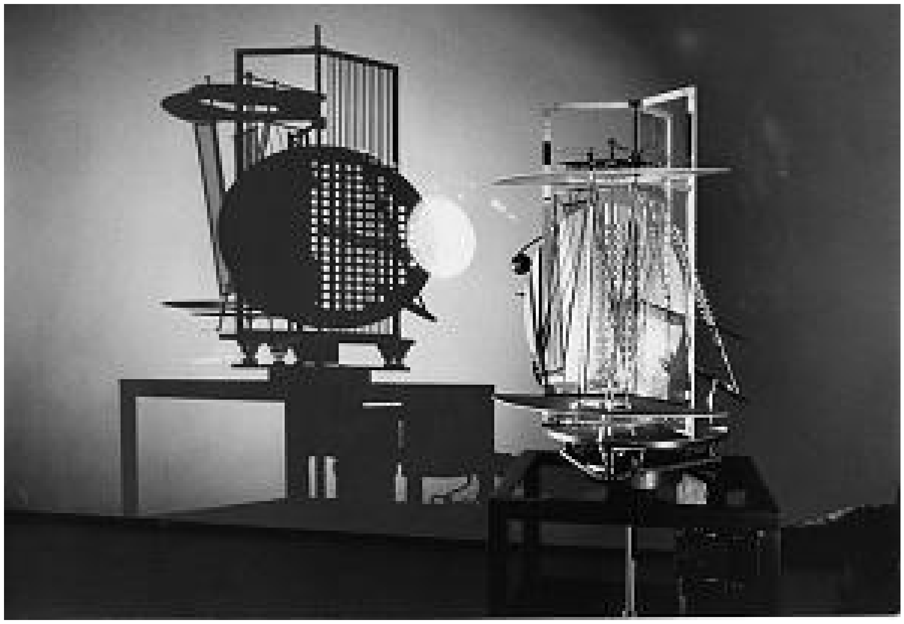

Figure 10 - "Light Prop for an Electric Stage", László Moholy-Nagy, 1930

Jean Tinguely had to have considered sound when creating *Homage to New York* (1960), a towering assemblage made of bike wheels with cams and linkages spinning round, flags flailing, an empty Radio Flyer wagon scraping along the floor. The structure, meant to self destruct, in a din of droll fire and fury. He must have considered the sound - no question.

Tinguely went on to produce audio recordings of his sculptures twenty years later, calling the audio cassette *Sound Sculptures*. The tape consisted of excerpts from a large steel framed assemblage titled *Meta-Harmonie II* (1979). The recordings reveal their clunky jangling repetition, cogs and metal teeth scraping steel and rubber, timing belts imposing rhythmic structure. The recordings somehow create a more faithful image than a photograph. Listening in on different discrete elements of the structure, like a doctor with their stethoscope, the recordings reveal the materials themselves and the intention to create a cohesive sonic topography.

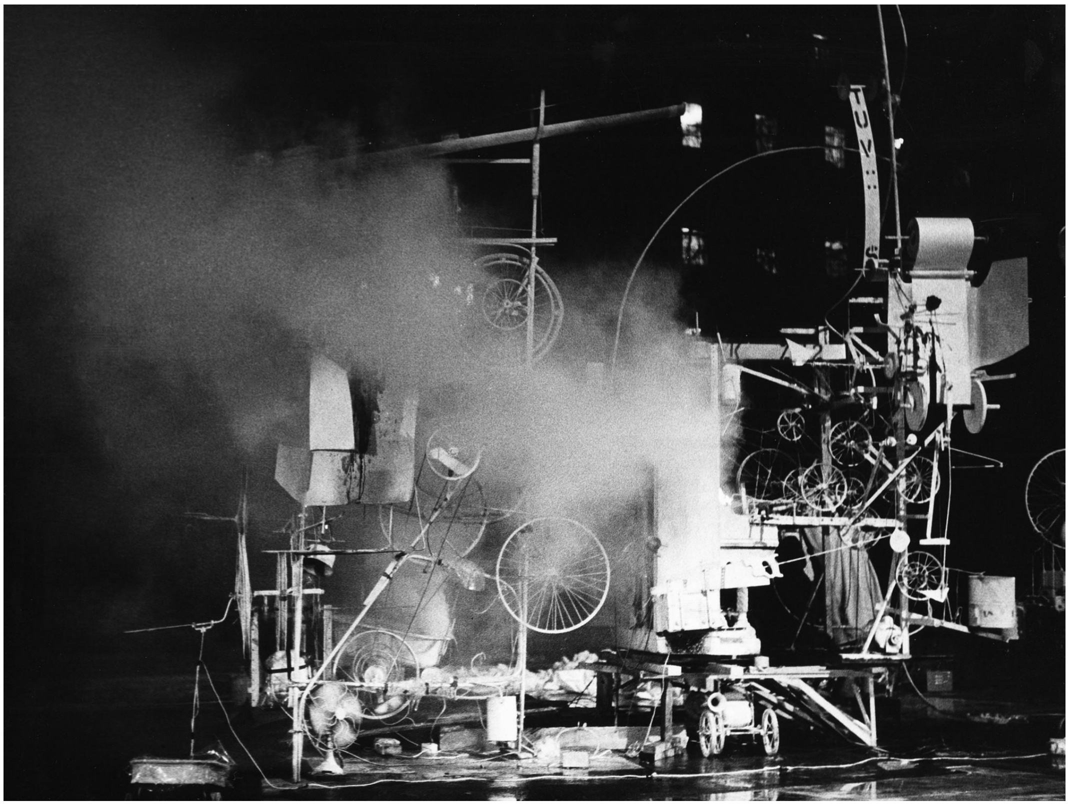

Figure 11 - "Homage to New York", Jean Tinguely, 1960

By the mid 1960's, with the financial freedom found as a successful Knoll chair designer, Harry Bertoia was able to turn his attention to sculpture. He began to develop a body of work devoted to sound and material inquiry. Bratioa called the catalogue of kinetic sculptures *Sonambient* and created eleven volumes of recordings of these works. The sculptures consist of tall clusters of metal rods. Made of a variety of metals, these rods are arranged with a rigid symmetry and are iterated with subtle variations in form and scale. Some sculptures are naturally activated by the breeze and others by hand. These systems, like a Newton's cradle, once activated ring out for some time.

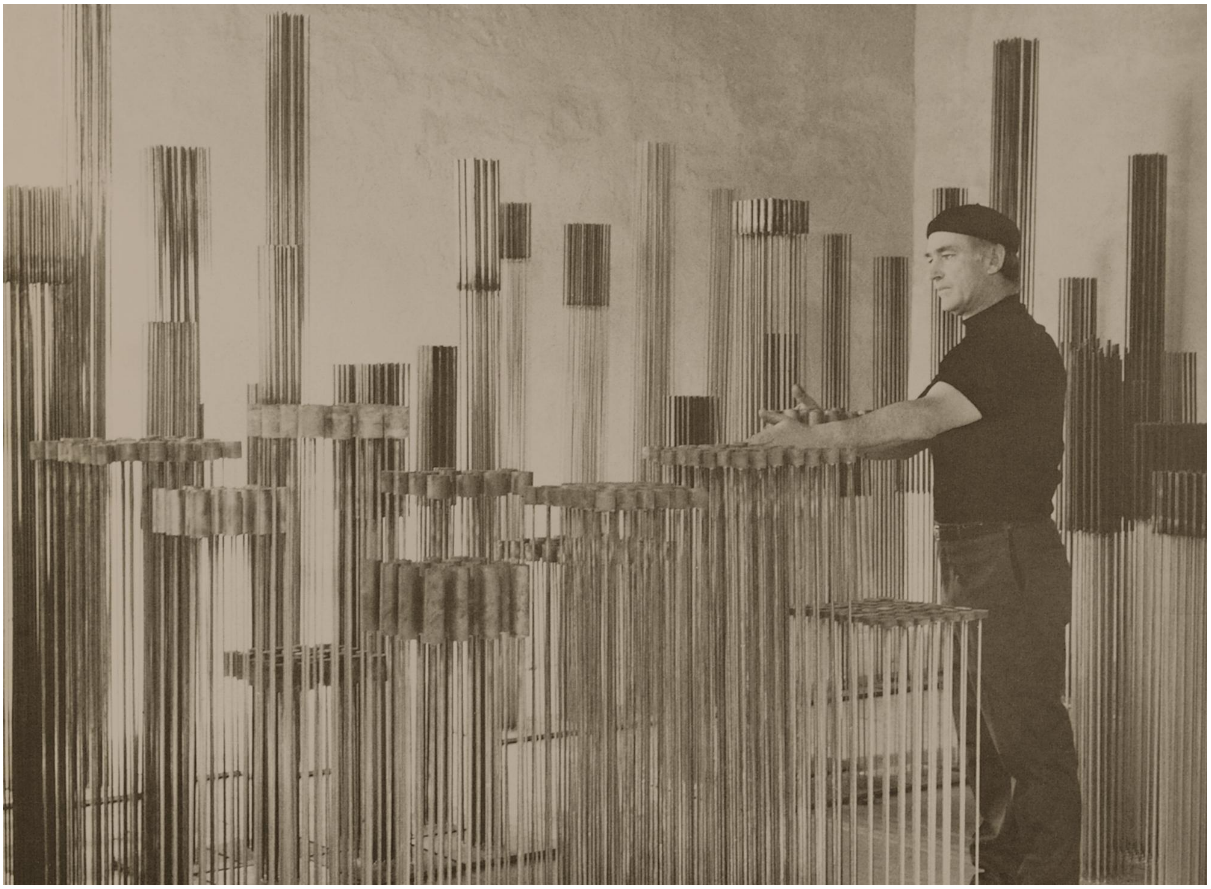

Figure 12 - Harry Bertoia with Sonambient Sculptures, 1970

In two examples, a group of nested large brass bulbs sits on top of four foot long brass stems and strikes its neighbour with a slap. All of the stems are affixed to a base made of a large brass plate. They clang together for several minutes, the sound still reverberating and rebounding for some time. Next, a tightly spaced grid of thin three foot steel rods are twisted and sprung with a twist of the hand.

They chime in oscillation, rotating back and forth again and again, conserving their energy.

In the early 1970's, Max Estley started to build sound sculptures that augment the natural environment, reacting to wind, water and other natural inputs. His work is stripped of conventional musical structure; the sculptures are like streams of data, pitch and timbre dictate real time events. For Eastleay, form follows function. It is most important for an instrument to describe its own workings and enforce its sound signature.

Figure 13 - "Clocks of the Midnight Hour", Max Eastley, 1986

Imagine the frantic zip of flags whipping in a gale. The cloth tied to a pvc pipe half buried in the sandy beach. A steady gust of wind whistles over the lip of the pipe like a flute. The sound of the rushing wind, the whistle of the pipes and the lash of the flags join in the chorus. In another example, picture twenty thin metal triangles ringing steady tones, activated by the rush of a stream cascading through the moss covered rocks where they are mounted. A thin wire stretched taught, protruding from each steel triangle, actuates the whole structure, ringing softly it's fixed pitch. The constellation of triangles hum in unison as the river whisks by. The material choices and fabrication are informed by environmental conditions and sharpened by intended sonic outcomes. There is a symmetry between the location, materials and acoustic expectations. Where Eastly augments the natural environment to create a novel soundscape, the artist Zimoun creates dynamic listening environments, using readymade materials and animates them with motors.

Zimoun works with a focused palette. The materials themselves seem to have an agenda, with large assemblages of common cardboard boxes and unfinished two-by-four planks flipping state, excited mechanically. Much of his work focuses on these two materials. Boxes and two-by-fours conjure ordered space and temporal architecture. One a collapsible paper enclosure, and the other the raw material of a frame. But, material concerns are just a backdrop for these immersive and subtly textured soundscapes. Zimoun uses the repetition and movement of these basic materials to achieve maximal effect.


Figure 14 - Zimoun, Le Centquatre, Paris, France, 2017

Figure 15 - Zimoun, Bitforms Gallery, New York, USA, 2012

> “Using simple and functional components, Zimoun builds architecturally-minded platforms of sound. Exploring mechanical rhythm and flow in prepared systems, his installations incorporate commonplace industrial objects. In an obsessive display of simple and functional materials, these works articulate a tension between the orderly patterns of Modernism and the chaotic forces of life. Carrying an emotional depth, the acoustic hum of natural phenomena in Zimoun's minimalist constructions effortlessly reverberates.”[7]

[7] Laura Blereau. “CV.” *Zimoun*, 2021.

As Laura Blereau points out here, it is the symmetry of these physical systems butting up against entropic forces that give this work its tension. *Large String Array* intentionally sits at this intersection of order and its gradual undoing as well. Zimoun's large kinetic sculptures are often the project of treating space as a volume to structure sound within. The simple material choices have recognizable sound signatures. Hundreds of boxes shuffling, a soft sound magnified by the scale, fills a large gallery space, moving as one organism. Take for instance his installation at a Parisian gallery in 2017, the center of the room filled with roughly a hundred thin wood planks loosely suspended from the ceiling in a grid formation. It is the sound of their twisting and tapping the floor that never lets the ears rest. Each slap of a plank activates the gallery space. Visually this array of two-by-fours is engaging but sonically it is truly compelling. While Zimoun brings the naked sound of the materials used to the fore, this next composer highlights an antiquated mechanical instrument already at hand.

Composer Conlon Nancarrow wrote volumes of works for the player piano. He diligently punched small holes into a scroll of paper to dictate his score, each hole corresponding to a note on the keyboard. His method is in keeping with the way sores were produced back in the nineteenth century. But, Nancarrows stylistic approach in *Studies for Player Piano* comes with a unique gust of energy.

It was important for his compositions to have no human intervention, for instance no dampening or sustain would be used during these piano performances. Another characteristic of the work is that each notes attack was exactly the same, this was totally determined by the limitations of the instrument. There is no note intensity variation, just on-off times written into the score. These limitations become elemental to the composition. Given each notes attack was the same, he emphasized what the system did allow for, superhuman speed and accuracy.

Figure 16 - Nancarrow Percussion Orchestra, brought to life by Trimpin, 2012

These *Studies* tend to have an ebb and a flow to them, shifting in and out of temperamental densities. Swarms, whole constellations of notes suddenly appear out of very spare passages. It often feels as if four hands are playing at once. There is a manic quality to the music. Conlon asks the listener to juggle more than one melodic input at the same time, sometimes three or four voices emerge at once. Notes, thumping away in smears and percussive sweeps, happening in such quick succession it begins to blur the perception of individual notes into one smooth glissando. These runs are so blazingly fast Art Tatum would blush.

Nancarrow in the early nineteen-fifties began development of an automatic drum orchestra. He collected a large number of drums of different material, size and shape, housing them in a large wooden frame. It was Nancarrow's desire to approach their actuation with the same rapid fire fervor in which he composed for the player piano. But there was a problem, he was using pneumatics to move the mallets, a system which frustrated him because of its slow response time. He eventually gave up on the project altogether, but in twenty-twelve the sound artist Trimpin took up the task of revitalizing the *Nancarrow Percussion Orchestra*.

Trimpin, an artist and innovator in his own right, who is responsible for towering vortex-like assemblages of automatic guitars and six story xylophones, started reworking the *Nancarrow Percussion Orchestra* by reconsidering the method of pneumatic actuation. Trimpin updated the drum array with electromagnetic actuators instead, giving it a much quicker response time capable of playing back the compositions Nancarrow had written for the instrument. First, the punched paper score was transcribed into MIDI, updating and archiving the composition while mitigating mechanical error. Trimpin then rebuilt the orchestra's frame, rehousing the original instruments and affixing solenoids to each drum hoop, striking the drumhead when energized.

> "What I'm trying to do," Trimpin remarked, "is go beyond human physical limitations to play instruments in such a way that no matter how complex the composition of the timing, it can be pushed over the limits." [8]

This uncanny percussion instrument displayed the same superhuman abilities of precision and speed that the player piano did. Regardless of human or machine origin, sound embeds the limits of its very nature into its transmission. Nancarrow explores the edges of these thresholds by first considering the constraints placed on the composer, the score, and the acoustic product. The *Large String Array* project is hyper aware of these boundaries as well. Limits are a compositional tool, a frame holding the stretched canvas. Nancarrow pushed the limits of speed while simplifying note intensity and tonal expression. This relationship defines the

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[8] Trimpin, Gerhard. “Trimpin Lectures At Form/Space Atelier.” *Wayback Machine*, June 2010, web.archive.org/web/20100617034212/http://artisttrust.org/node/3214.

sound. Really any variable when probed will reveal its scope. The limits themselves often provide the context and the content of the work.

3.3 SITE OF RESONANCE

> "It is unfortunate that music is still presented as it was in the 19th century, frontally, instead of finding new ways of presenting events. There should be fantastical buildings for musical and sound productions. Not just a lot of speakers, but a really extraordinary architecture that you find your way in, that evolves. This will happen because there is a need for it"[9]

Resonance defines space. It gives aural cues as to the shape and materiality of an object or architecture. Resonance exposes the topography of sound. Growing up next to Langley Airforce Base, the thunder of a sonic boom was not at all uncommon and still excites the memory. The screech of an F-15 in the distance would finally snap and explode overhead, rumbling into the distance through wisps of tupelo and maple. There was little to mirror the sound in the Great

[9] Amacher, Maryanne, et al. *Maryanne Amacher: Selected Writings and Interviews*. Blank Forms Editions, 2021. 285.

Dismal Swamp. The diffuse reflections offered little memory of the blast. That deafening spark with it's dull reflection.

Several years later, that same burst could be heard during the annual Blue Angels flyover in downtown San Francisco. The sound, swollen between the buildings, built up into an ear piercing cacophony. The glass and steel juggling the blast back and forth with the drill-like focus of a toothache.

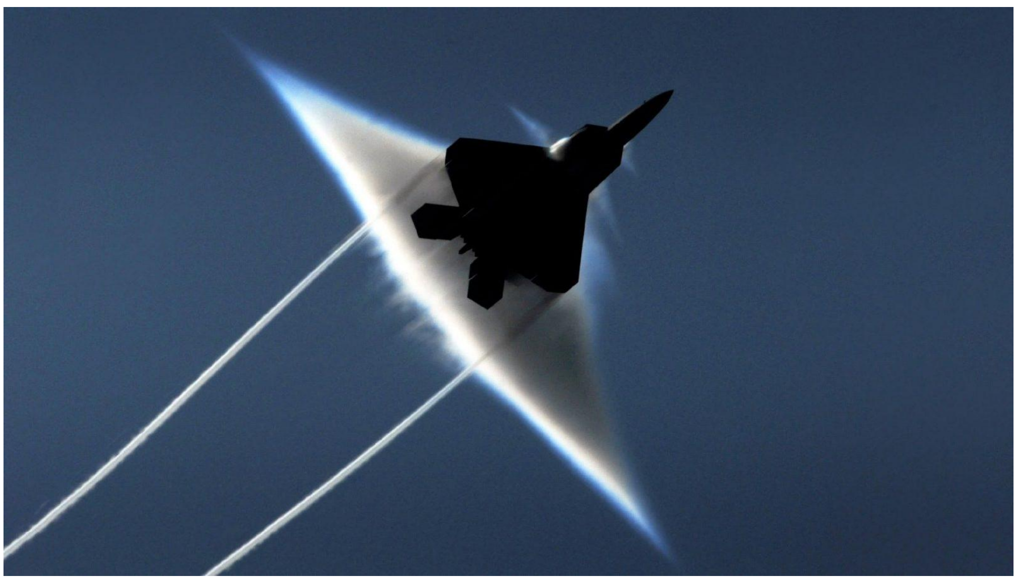

Figure 17 - Shockwave from a Sonic Boom

These are properties of sound people can relate to: The scale of sound, directional cues, the proximity of objects, dampening, diffuse reflections, large reflective surfaces, an empty field, a closet. In these signals space is defined, power is encoded and communication made possible. A noise so loud time stopped, it is your sole focus, lingering in your ears a while. It has the power to control and coerce. It can instantly trigger. All of the nuances of a sound are transcribed as pressure differences in the air. This strength of each individual signal meets the ear, painting a three dimensional map - a sonic topography. Surroundings are permeable to the ear, one can hear through walls if the signal is strong enough and travels huge distances with a quantifiable delay. You “put your ear to the door” if you need to be discrete. And you “keep your ear to the ground” if you want the latest gossip. Hold your ear to a conch shell to magically hear the ocean.

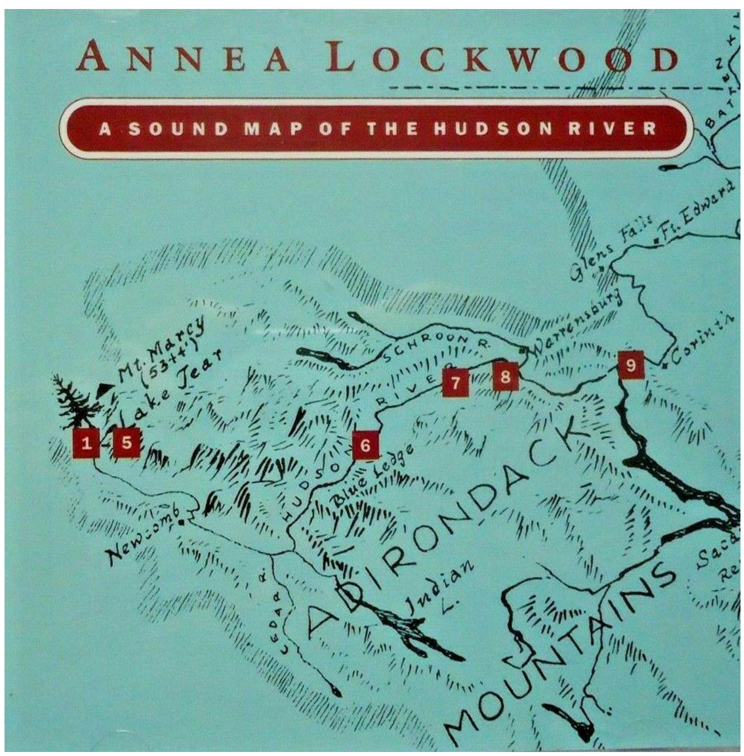

Figure 18 - “A Sound Map of the Hudson River”, Annea Lockwood, 1989

Anea Lockwood explores these sonic topographies in an indexical fashion. A Sound Map of the Hudson River is an exploration of the environmental shifts in the sound signature of the river as it meanders downstream, from the river's source high in Aderandicks to its confluence with the Atlantic Ocean. These snapshots of sound are punctuated by unique input variables and reflective bodies in the environment. From cascading rocks to interactions with the man made world, Lockwood's practice of marrying sound to a specific site, and having that site's unique sound signature reinforce narrative, is a strategy present in the crafting of *Large String Array*.

Scott Arford and Randy Yau developed a series of Infrasound happenings in the early 2000's. The *Infrasound Manifesto* served the framework from which a body of subaudible work grew and is an excellent window onto *Large String Arrays* motivation.

> "Hear with your body. This is not about music. This is not about performance or the performer. The goal is sound and the explicit translation of sound into physical force. The goal is internal and external realization. It is about provoking new modes of perceiving and experiencing one's own body - triggering variable and autonomous psycho-psychological response. It is about the total

> acoustic sense of space - observing sound to measure the capacity of architecture. It is about the phenomenon of resonance or sympathetic vibration - all things working in one continuum.” [10]

Forty Part Motet by Janet Catdiff consists of forty speakers arranged in a circular formation. It is partially a reworking of an early choral piece, "Spem in Alium Nunquam habui" (1575), by Thomas Tallis and sung by the Salisbury Cathedral Choir. The recorded audio is played back to a gallery audience with each speaker acting as a discrete voice of the choir. This piece bears resemblance to *Large String Array* in many respects.

> “The speakers do more than stand in for the individuals of the choir; they represent them, and do so as specifically absent -- one of the recurring themes of sound art being the uncanniness of the playing of sounds both present and signaling that presence is now gone.” [11]

Maryanne Amacher’s *Sound-joined Rooms* uses loudspeakers aimed directly at the wall, with live audio from several mic'd stations scattered around an old Victorian house. The first in the series *Living Sound: Patent Pending* (1980), presented as part of the Walker Art Center’s New Music America programming. Amacher described it as follows:

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[10] LaBelle, Brandon, and Claudia Martinho. *Site of Sound: Of Architecture and the Ear: Vol 2*. Pap/Com, Errant Bodies Press, 2011. 196.
[11] Hegarty, Paul. *Noise Music: A History*. Continuum, 2007. 176.

The house, on a hill in St. Paul with its panoramic view of Minneapolis, was lit by tall quartz spots, as if a movie set. The time: midnight. [In the] music room, where two grand pianos had been, was now an “emergent music laboratory,” there were 21 petri dishes with something growing in them — the musicians and instruments of the future. DNA photos and biochemical diagrams were placed on music stands. Meanwhile, the entire house was full of a spectacular sound — incredibly loud and unbelievably dense — sound, circulating throughout the rooms, out the doors and windows, down the hill, past sedate Victorian mansions. It seems to contain the energy of all frequency ranges at once, yet never approached white noise. [Listeners] felt themselves pushed, as if by acoustic pressure, out into the garden, where the entire house was heard, sounding, as a gigantic instrument. [12]

[12] “Her Work – Blank Forms.” *Maryanne Amacher*, 2021, blankforms.org/the-maryanne-amacher-foundation/her-work.

Figure 19 - "Music for Sound-Joined Rooms", Maryanne Amacher, 1980

Here Amacher foldes the signal of the house back into its own construction. In *Music for Sound-Joined Rooms* the structure reinforces frequencies that are in agreement with the physical properties of the house. This is known as Structure Borne sound, a term often used in architectural acoustics. It is typically used in a negative context. In most cases walls are meant to baffle airborne sound, not amplify the jarring slap of a shutter or the moan of old pipes. The wall is a protective layer, swaddling the listener. In Large String Array this arrangement is subverted. The wall itself is transformed into a resonant body. The structure, meant to mute and incubate, becomes a sounding board. Amacher forms a feedback loop within the site, working here strictly within the audible range. But, what are we to make of the persistence of signals all around us? How might we tune into the swarm of transmissions, in a way that gives shape to the unseen?

Listening to faint signals reaching through the wall, the radio frequency of a distant satellite, Afroditi Psarra studies the clutter of the RF spectrum for her ongoing work *Embodied RF Ecoliges*. She designs garments with embedded fractal geometries tuned to specific frequency bands.

Figure 20 - "Embodied RF Ecoliges", Afroditi Psarra, 2021

The garment pictured in Figure 20 is tuned to the NOAA Weather Services satellite transmission, in the 162,400-162,550 MHz frequency range. Afroditi intercepts the raw signal with an embroidered antenna sewn into the back of a handmade sleeveless kimono. The signal is transposed into the audio range so the wearer can hear its modulation with a headset, revealing bursts of digital chatter and rogue FM signals. The constellation of sounds morph, changing shape as the wearer shifts the antenna's orientation. In this way the listener performs this piece, navigating the seen world while interpolating the hidden sonic topography that the RF signal reveals. Large String Array borrows from this interpolation of ecologies, with one space mapping to another space sonically. The whisper of a signal is plucked out of thin air and amplified. Psarra sees this act of ultrasonic listening as a “quest to embody the invisible transmissions that surround us”. [13]

Figure 21 - Christina Kubisch listening to the ATM electromagnetic field

[13] Psarra, Afroditi. “Embodied RF Ecologies.” *Afroditi Psarra*, 2021, afroditipsarra.com/index.php?/on-going/embodied-rf-ecologies.

Like Afroditi Psarra, Christina Kubisch works in the domain of the hidden signal. In her series of *Electrical Walks,* Kubisch maps out the unseen electromagnetic cityscape with a pair of custom built “magnetic headphones” which have been fitted with an inductor and amplifier to intercept the electromagnetic emissions. These signals are in abundance around any metropolitan area. So far she has mapped out sixty six locations world wide.

> “Creative listening is the starting point for my sound installations and sound-zones in which the structure of the composition is combined with sequences of tone and movement. The audience is able to move freely between various acoustic fields distributed throughout the sound zone, enabling the listener to discover ever new and individual sound combinations.” [14]

Digital and analog signals abound. ATM machines, wireless internet, neon advertising, cell phones, the shape of their electrical aura can be explored, unmasking their electromagnetic song. There is a pulsing heartbeat to some signals and deluge of high frequency chatter in others. Drones emanate from streetcar cables. A topography of electrical systems emerges. This act of

[14]Christina Kubisch, ‘About My Installations’ In a Different Climate: Women Artists Use New Media (Dusseldorf, Staatliche Kunsthalle, 1986); reprinted in *Sound* edited by Caleb Kelly *(Whitechapel: Documents of Contemporary Art)*. 1st ed., The MIT Press, 2011. 199.

intercepting the invisible signal, the mystery of its shape and origin are the musings of *Large String Array* as well.

> "The 'composition' for any given installation is related to the 'sound-structure'" [15]

3.4 KLANG: MATERIAL EXPLORATION

> "A musical instrument is like a spanish fan or a piston - it's all the same. It's a surface, which comes and goes, striking the air with a frequency somewhere between 16 and 18,000 oscillations per second, or, in our current scientific language, 16 to 18,000 hertz." [16]

The idiosyncrasies of material limits are constantly pushing back and informing the artistic process. With sounding materials, the forms have been refined over a great period of time and curiosity rarely seems to wander outside of platonic instrumental forms. That said, there are still a great number of troubadours who continue to play and shape new sonorous structures.

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[15] Christina Kubisch, 'About My Installations' In a Different Climate: Women Artists Use New Media (Dusseldorf, Staatliche Kunsthalle, 1986); reprinted in *Sound* edited by Caleb Kelly *(Whitechapel: Documents of Contemporary Art)*. 1st ed., The MIT Press, 2011. 199.

[16] Baschet, François. *Sound Sculptures of Bernard and François Baschet*. New York-United States, United States, Macmillan Publishers, 1999. 30.

Figure 22 - Ensemble of Baschet Instrument

French artists, brothers Francios and Bernard Baschet explored sounding materials with a great number of innovative twelve-tone equal temperament sound sculptures. Their designs prominently feature large lilly shaped metal resonators called foils, blossoming over scaffolds of metal and glass rods. They belong to that lost Space Age aesthetic of the 1950's.

The brothers refined a few forms over time, the most famous of which is the Cristal Baschet - glass rods played with wet fingers and amplified by the conical metal resonators. The sound is akin to the Glass Armonica, Benjamin Franklin's favorite invention, where glass bowls of staggered radii, ringing out the notes of the scale. Most are familiar with a similar instrument, an array of glass goblets, tuned by varying the amount of liquid - a Glass Harp. The sound of the Cristal Baschet is particularly haunting. The six octaves of Glass rods sing with an exaggerated reverbrence from the steel resonators. A note that lingers. The structure itself is the signal's memory.

For Harry Partch, his innovative instruments and compositional strategies are always in dialogue with one another. Reflecting the constraints of materiality and impulses of his imagination. Patch did not shy from augmenting traditional instruments, as he did with his two Adapted Guitars. He simply adjusted the conventional frettings of both instruments. In Fact many of his instruments had their genesis in the husk of an old cello or hodgepodge of wooden organ pipes. Partch also explored whimsical new forms, such as the *Gourd Tree* and *Cone Congs.* In Partch's words "Twelve temple bells, attached like exotic fruit to a bough of eucalyptus." [17]

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[17] Partch, Harry. *The World of Harry Partch*. Columbia Masterworks, catal. MS 7207, 1969.

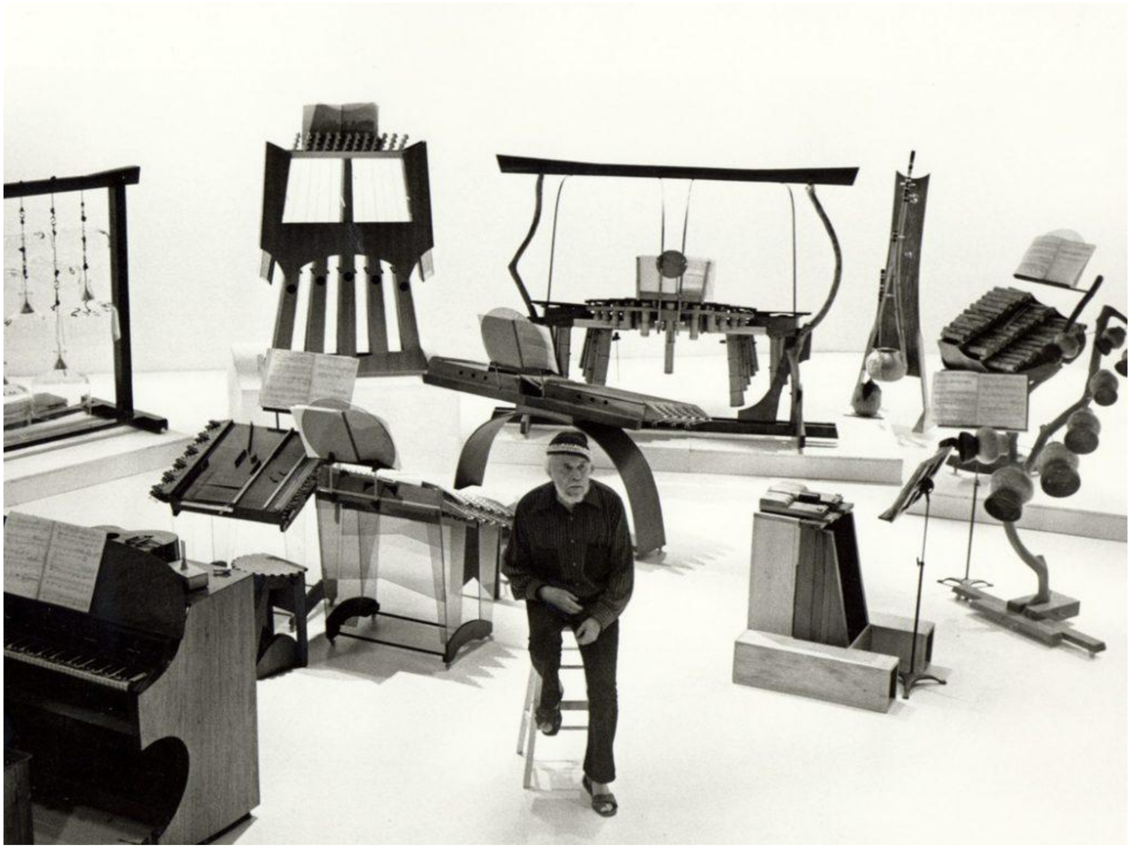

Figure 23 - Harry Parch with his Instruments, 1949

These creations blur the line between sculpture and instrument. They are a nod to the theatrical impulses in his work. To perform these instruments is to partake in musical theater, following the natural lines of the branches while reaching for each new bell tone. In *Large String Array* there is a touch of this theatricality, a nod to Partch's sensibilities.

Figure 24 - "Millennium Footbridge", Bill Fontana, 2006

These next two pieces focus on the material properties of wire. Alvin Lucier's *Music for a Long Thin Wire* and Bill Fontana's *Harmonic Bridge* simply magnify the sound of long wires resonating, steel cable the length of a bridge in the case of one, and a piano wire the length of a room in the other. The pieces are in essence about transmission. The wire is telling us something, can we hear?

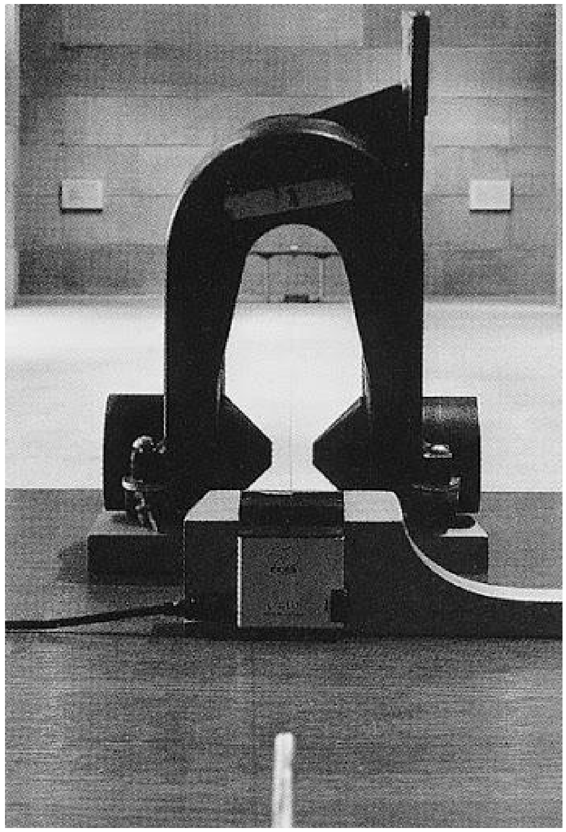

Figure 25 - "Music for a Long Thin Wire", Alvin Lucier, 1977

These pieces simply amplify the signal that the wire transmits. In the wire the signal persists, amplifying and canceling new input as signals interpolate. In the case of Lucier, the piece is an exercise in reduced listening, focused simply on the string's sinusoidal properties and the subtle fluctuations that occur in the slack wire over time. In the case of Harmonic Bridge, the cable has an encrypted message. The audience is listening for causal cues in the signal coursing through of braided steel wire spanning London's Millennium Footbridge. Whereas, Lucier’s wire is about its very materiality set in motion. For Fontana the footbridge is the input - the source of transfiguration.

Figure 26 - "Long String Instrument", Elane Fullman, 1981

Elane Fullman is an artist that works specifically with piano wire. Her project, the seventy foot *Long String Instrument,* creates two rows of dozens of strings, one on either side of the performer. She uses rossen on the tips of her fingers to actuate the strings like a violin bow. The strings are tuned with pure intonation, using whole number ratios to determine pitch. The instrument sounds similar to a glass harp, with deep sinusoidal overtones. Fullman has made a career out of reinstalling this string array for performances around the world. The work, like *Large String Array*, highlights the reverberant characteristic of the wire.

Figure 27 - EMT 140 plate reverb unit, 1957

In the wild, "the reverberant quality of any space, whether enclosed or not, helps define the way in which it was received." [18]. Reverb is an important cue, helping to navigate the nuanced language of materials interacting with each other. Acoustic reverbence is the property of energy persistence in a medium. High carbon steel wire, also known as piano wire or spring steel, is ideal for holding at high tensions and for its property of energy persistence. This material is very common with chordophone design and can be easily illustrated by the sound of an undamped grand piano. Because of steel's sonic properties, commercially

[18] World Soundscape Project. *The World Soundscape Project's Handbook for Acoustic Ecology (The Music of the Environment Series)*. 1st ed., A.R.C. Publications, 1978. 104.

available electroacoustic reverb solutions were introduced in 1939 by Hammond Organ with the spring reverb. By the mid fifties plate reverbs added a lush alternative to the spring sound. *Large String Array* is, in part, a giant reverb unit.

3.5 A LEXICON OF SOUND

One of the earliest tape recorders on the market was known as a “Soundmirror", a fitting descriptor. The magnetic tape transcribing every detail of what it hears before recounting its hazy dictation. Tony Schwartz, the pioneering sound archivist and media theorist, set out listening to the New York streets of the late forties with a custom battery powered tape recorder. Recordings rarely breached studio walls before Schwartz’s modifications

Figure 28 - “Soundmirror “Magic Ribbon” Recorder” SEE IT! HEAR IT!, 1948

Like audio snapshots, Schwarts documented different aspects of everyday American life; as if Rober Frank had pawned his Leica for a Soundmirror. Schwartz made compilations of taxicab conversations, and was first to record street musicians such as Moondog. He once made an album recording life in New York City from the perspective of his dog. Schwartz put these recordings out through the Smithsonian Folkways catalog.

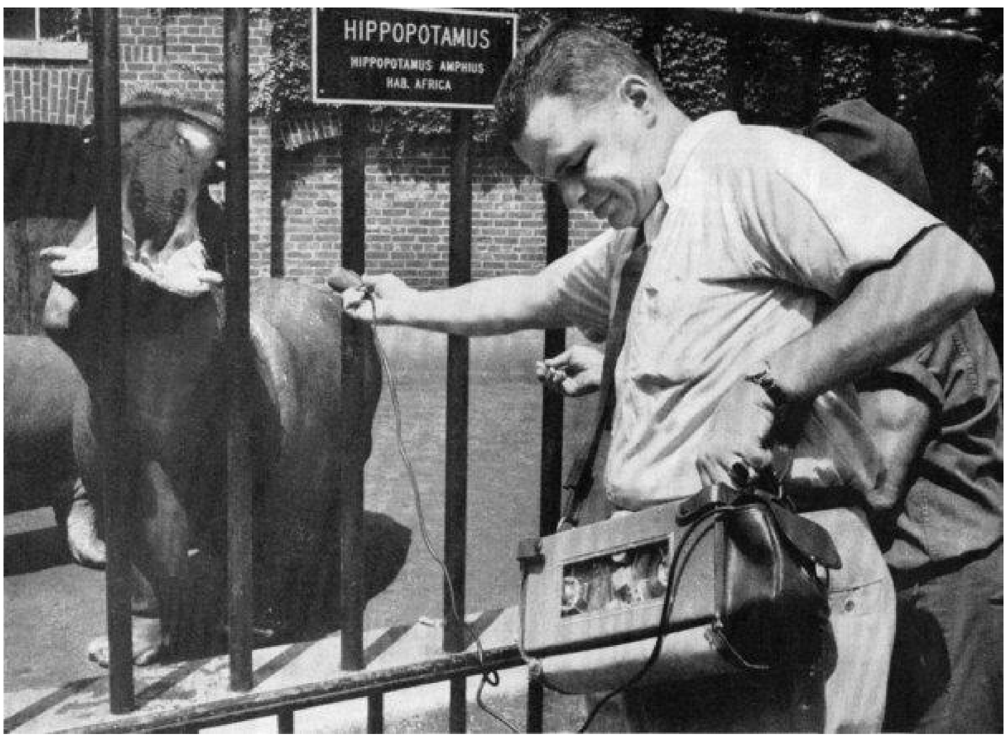

Figure 29 - Tony Schwartz interviewing a hippopotamus

The eclectic label, connected to the institution, often found itself releasing niche recordings of sound experiments and educational records. These categories are actually too neat for the breadth of experimentation that happened under the Folkways umbrella. For example, Albro T. Gaul in 1960 released the Sounds of Insects on the label. This recording, an early example of highly amplified recording techniques, playing back the microcosmic sounds of the Grape-Leaf Beetle Walking and of Wasps Chewing. The indexing of sound and the impulse to amplify very small signals has its roots in these early experiments.

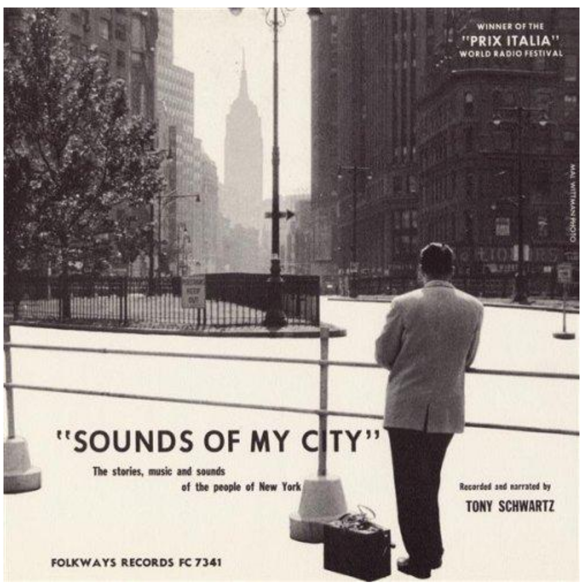

Figure 30- "Sounds of My City", Tony Schwartz, 1959

Figure 31 - ”Sounds of Insects”, Albro T. Gaul, 1960

In the third issue of the early new music journal Source: Music of the Avant-Garde, Pauline Oliveros opened *Some Sound Observations* with this lighthearted screed.

> "As I sit here trying to compose an article for Source, my mind adheres to the sounds of myself and my environment. In the distance a bulldozer is eating away a hillside while its motor is a cascade of harmonics defining the space between it and the Rock and Roll radio playing in the next room. Sounds of birds, insects, children's voices and the rustling of trees fleck this space." [19]

Environmental sounds can be irritating, they can shock and their absence soothe. But, they never cease to remind of their existence. There is always tension in an unexpected sound, even more so when the world suddenly stands still. The first few months of the pandemic, April and May, were definingly quiet. The usual narrative rhythms of everyday life came to a pause. But it was this quiet that proved the spark of inspiration for the orchestration of Large String Array.

Luigi Russolo, around the turn of the twentieth century, began reimagining the sonic palette composers would soon draw inspiration from. He argued that the speed and force of urbanization had to make its mark on music. Russolo barked that no matter how novel a new composition might sound, the mode of delivery was always mundane. He asserted that the audience was "waiting for an

[19] Austin, Larry, et al. *Source*. Amsterdam-Netherlands, Netherlands, Amsterdam University Press, 2011.134.

extraordinary sensation that never comes" [20] and urged instrumentalists to use the city as their palette.

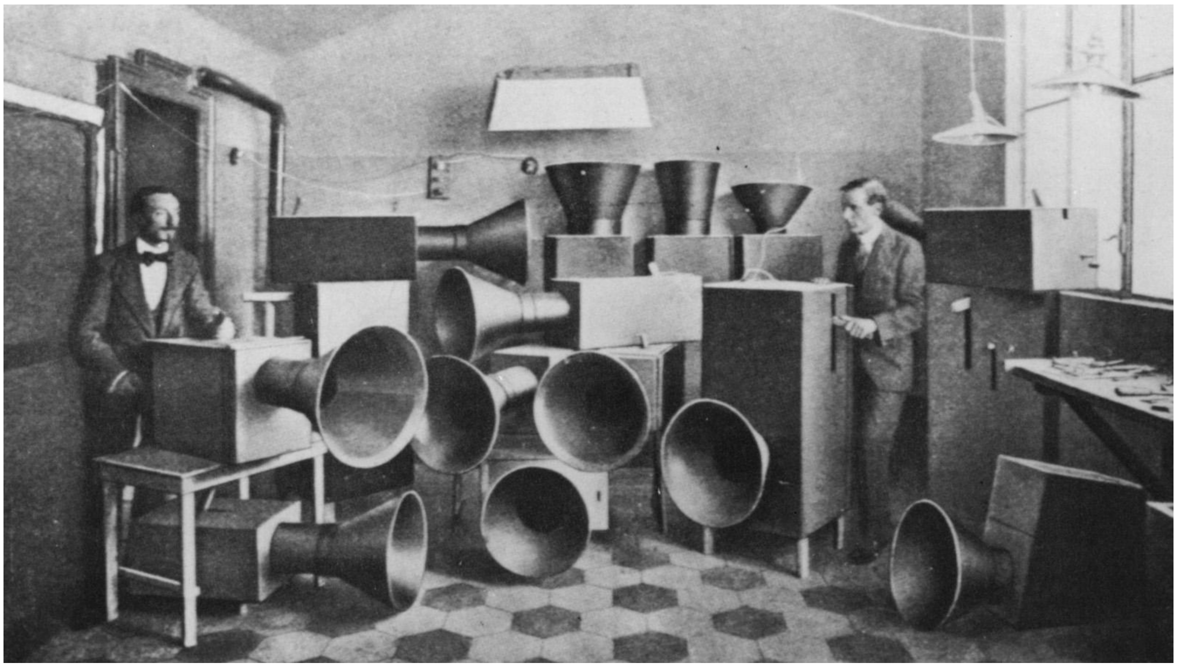

Figure 32 - "Intonarumori", Luigi Russolo, 1913

Russolo devised a series of instruments he felt captured the sounds of the metropolis in all its bustle and clangor. He called these strange boxed acoustic contraptions *Intonarumori,* translating in Italian to "noise-maker". Russolo gave the new sounds of the city a taxological framework called the "six families of noises". [21] He broke these city style sounds down into bangs, whistles, gurgling, buzzing, beating and vocal noises. The *Intonarumori* were fashioned after these classifications, making the palette of sounds from the city accessible to the composer for the first time.

[20] Cox, Christoph, and Daniel Warner. *Audio Culture*. Bloomsbury Academic, 2004.12.
[21]Cox, Christoph, and Daniel Warner. *Audio Culture*. Bloomsbury Academic, 2004.13.

Laurie Spiegel, the brilliant algorithmic electronic music pioneer, famously asked John Cage what he was listening to. He replied that he “opens the window and listens to the traffic on 6th Avenue” [22], listening to the rhythms, the cadence, the arrangement of the street. He was right to insinuate that this sound wafting in through the window was music. The sound, after all, has intention and structure. These sounds are choreographed by lights and the ebb and flow of traffic -- the bars on a staff. The metre, punctuated by car horns and the syncopated percussion of feet. In a similar way, *Large String Array* listens intently to sound drifting through the windowpane. A steady stream of information hitting the glass. What can be parsed from the noise of the city that might illuminate the present?

Figure 33 - "A Line", Juan Pampin, 2015

[22] Peleckis, Mindaugas. “LAURIE SPIEGEL: I Asked John Cage Once What Music He Listens to When He Just Feels like Listening to Some Music. He Told Me He Opens the Window and Listens to the Traffic on 6th Avenue | Mindaugas Peleckis | Garsas / Sound.” *Radikaliai.Lt*, 2016.

Several compositions had a profound impact on Large String Array. Juan Pampin's *A Line* (2015) first comes to mind, a piece for ambisonic 3D spatial audio which showcases recordings of a train in Buenos Aires. The wooden subway car had remained in service since 1913, taking the rider on the same trip for a century. The piece takes the listener through the city's underground on a hypnotic journey. Pampin takes binaural recordings of the train and encodes them into B format for further spatial processing.

> "Recordings from places and events happening on the line (under and above the ground) were algorithmically edited and transformed to create a soundscape that attempts to capture the chaotic energy of this lively part of the city of Buenos Aires". [23]

With *A Line,* Pampin recalls his personal history of riding on the car as a child. Hearing it must hold recognizable sonorities for those daily commuters. But, the sound can also be understood by the general audience as the signifier for a train. The symbolic image is held in the mind's eye with attentive listening. These layers of legibility, when working with the complex signals of ambient spaces, are drivers of narrative for the listener. The curator of these sounds is responsible for

[23] Pampin, Juan. "A Line | DXARTS | University of Washington." *DXARTS | University of Washington*, 2015, dxarts.washington.edu/research/creative-work/line.

shaping their meaning. The listener must frame each new nuanced detail by holding it up to their personal and the shared vocabulary of sound.

The locomotive has long been a curiosity of audio enthusiasts. Thousands upon thousands of commercial train recordings exist, some to demonstrate certain engine builds, others taking you on a leg of a particular car's journey. Fast forward to 2020, you can virtually ride The Flåm Railway in Norway over the internet anytime you like. [24]

Trains represent power and embody futurist ideals. They physically link isolated geographies. There are commuter trains and freight rails, lumbering giants and bullet trains. But in one respect most trains are similar, they are quite loud. Each train leaves a large sonic footprint on the area it frequents.

In the case of *Large String Array*, it focuses on a train which carries an added social weight. The BART (Bay Area Rapid Transit) railcar has a pronounced high pitched whine. The train sounds light, much less menacing than a large steam engine. There is no clack of the tracks, like on New York's famous A Train. You could say it zips along. Because the BART's sound signature is so distinct, it triggers specific memories for those familiar with the Bay Area. For many it recalls the tragic death of Oscar Grant. He was killed at the hands of police at the Fruitvale BART Station in 2009. In its wake there sprung a powerful movement

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[24] RailCowGirl. "TRAIN DRIVER'S VIEW: Flåm to Myrdal with Sun and Rain In 4K UltraHD." *YouTube*, 12 July 2018,

for police accountability. In its sound, this train has become a symbol of the struggle for restorative justice.

Figure 34 - BART (Bay Area Rapid Transit) train, 2021

As it so often does, music became a source of solace during the time of Large String Arrays conception. John Luther Adams *Night Peace,* a choral work accompanied by percussion and harp, had been on repeat much of the time those first few months, when time itself felt upended. Long spare passages, splashes of harmony and rolling percussion accented the stillness of its tone. The cathartic tenor of *Night Peace* had sparked the imagination, to morph this complex symbol of the train into the calm austere beauty of a choral work.

Choral music today is generally imagined through the lens of cinema and in the context of the Advent Season. It reads to listeners as symbols of reverence and introspection, both qualities *Large String Array* aims to evoke. Admittedly, choral music such as Gregorian Chant and Plainsong, has its own problematic origins as a tool of Roman conquest. While the content and context of these works over time have been both secular and sacred, its relevance hangs on as a rather curious artifact of an early musical form.

Today, chant is imagined through the lens of cinema, conjuring the metaphysical and symbolizing perseverance through adversity. This is how the signifier of the chorus operates as a cinematic trope. This read is in no small part due to the popularization of Gregorian chant gussied up for the new age market, releases like *Chant* by The Benedictine Monks of Santo Domingo de Silos repackaged the sacred for pop audiences simply with its psychedelic packaging. Similarly, before the pandemic, on any given Sunday evening, Seattleites might find themselves at St. Marks Cathedral on a blanket in repose, meditating to the evenings compline service. Listening to the unadorned chorus, the audience is reminded of how compelling the simple symmetry this modality is.

The signifiers of houses of worship are pervasive. They are not necessarily benign signals, but they are a fixture of the soundscape the world over. For instance, the ring of a church bell left quite an imprint on Stephen Vitiello when he probed the glass windowpane of the World Trade Center for the first time with a contact microphone. Vitiello took part in an artists residency there, making use of the vacant office space in lower Manhattan just a year before the towers collapsed. Having proposed an artwork using a live microphone feed, he soon found out that the triple-thick panes of glass could not open, presenting an obstacle. Artist and technician extraordinaire Bob Bielecki proposed the solution of a piezo contact microphone paired with a high gain amplifier. Vitiello explains:

> “The microphones became a stethoscope through which I could listen to the pulse of the building.”[25]

> “The first [sound] that I ever heard come through was church bells, it was chilling and so liberating. In retrospect, I think the fact that the windows did not open made the project successful. I had the task of bringing in what we were denied. The second filled in the void - allowing an emotional, physical connection to the view that was otherwise impressive but also flat. The airplanes and the helicopters, the storm clouds, the movement of the building suddenly had presence.”[26]

These recordings capture the physical essence of the building, embodying its structural soundscape. The glass is a membrane, absorbing and detailing the

[25] Toop, David. *Haunted Weather: Music, Silence and Memory (Five Star Fiction S.)*. 1st ed., Five Star, 2006. 123.
[26] Toop, David. *Haunted Weather: Music, Silence and Memory (Five Star Fiction S.)*. 1st ed., Five Star, 2006. 122.

airborne sounds bombarding the window. This signal is in tension between what is inside and outside. This archive of recordings was then further complicated by the tragic events of the September eleventh attacks. The context of the recordings were forever altered by those events. Listening to Vitiello's recordings offer a sobering reflection on the mantra "we will never forget".

Figure 35 - September 11th memorial poster

Sound has a curious way of reimagining space and time, listening in many ways is a creative process, there are subtletie cues the listener picks up on and projects onto the circumstance of the recording. There is a dissonance in the signifier being divorced from the sign and the mind races to fill the void. Audio and its context are always in dialogue with one another. It is what drives meaning and narrative for the listener. In Vitiello's *World Trade Center Recordings* the results are humbling, provoking both sadness and catharsis. The *Large String Array* recordings, in many respects, are a companion piece to Vitiello's *World Trade Center Recordings*, both in the tenor and with the tools employed.

4 CHAPTER 4. LARGE STRING ARRAY

4.1 INTRODUCTION

First, consider the entirety of *Large String Array*. Let's take it apart in some detail. It consists of two main elements; a sculptural playback system and a musical composition. The playback system is the physical transformation of the entire south facing wall of the Jack Straw New Media Gallery into a huge zither like instrument. Two seventeen foot aluminum L-beams are fastened to the wall twelve feet apart, one along the floor and the other along the ceiling. From the beams, twelve hundred high carbon steel wires are tensioned vertically across the width of the gallery

There are two rows of bridges parallel to the floor and held in place by the strings, each roughly three feet from where the string meets the aluminum frame. The lower bridge is a sympathetic bridge, like that of a violin, converting the oscillatory motion of the string into the body of the instrument. The bridge transfering acoustic energy, in this case, to the wall.

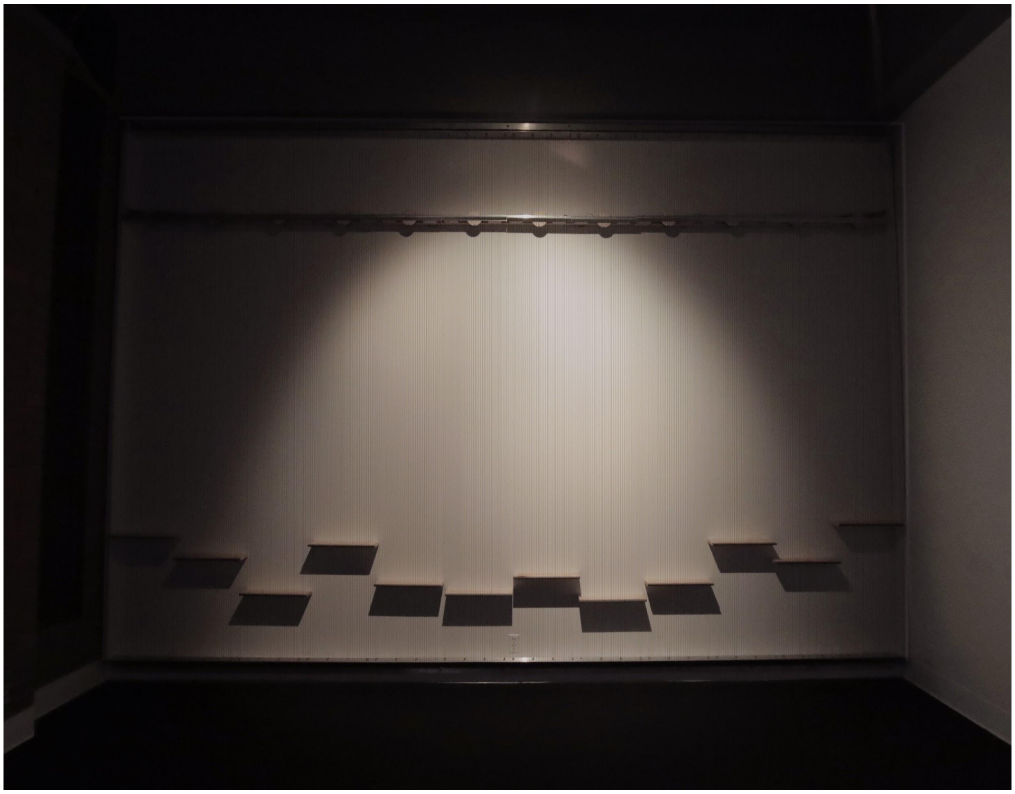

Figure 36 - "Large String Array", installation view, 2020

“A vibrating string or tuning fork radiates only small amounts of sound because the surface area of either object displaces very little air. When the same string or tuning fork contacts a soundboard or table top and transfers its vibrational energy to a larger surface. The radiation of sound increases dramatically. Suddenly, upon contacting a large structure, a faint sound becomes clearly audible from a distance.” [27]

[27] Forster, Cris. *Musical Mathematics: On the Art and Science of Acoustic Instruments*. Illustrated, Chronicle Books, 2010. 119.

The second set of upper bridges are in fact very different in design. They have been fashioned to drive vibrational energy into the array of twelve hundred strings. Bass exciters are used to drive the motion of these upper bridges. The fundamental purpose of these upper bridges is twofold. First, it allows for the audition of an audio signal by driving the sound into the string array, resonating the entire wall with its signal. Second, this orientation allowed for the strings to visibly oscillate when sympathetic to the vibrational input. This driver bridge has the dual function of creating both an audio and visual composition. This also means the two elements must be considered separately.

The audio component of this work originated while sheltering in place in Oakland, California. In response to the pandemic, this composition took on the complexion of life under quarantine. A palpable sense of anxiety and introspection were literally in the air. Recordings of ambiences, from life in retreat, were transformed into three distinct choral movements with digital signal processing. Ultimately these two elements, the audio and visual feedback, were fused together. The sound of the street anthropomorphised and then reamplified through the *Large String Array*.

4.2 HIGH GAIN WALL RECORDING

4.2.1 INTRODUCTION

There is a natural desire to peer into the microcosm of sound, to hear beyond human ability, to shrink the scale of waves to fit within our biology, that 20htz to 20k hearing range. It's a desire to amplify the small mechanical movements of insects and to pitch up the low inaudible ringing of earthquakes, to understand it with our ears. The corti is excited by elastic sounds, noises that shift the scale of time and focus. Sound at these extremes is fragile, peeling through layers of noise to excavate meaning. Sound at the microscopic scale is often heavily filtered. The desired signal competing with a high noise floor, resulting in a messy transmission. This is especially true of sounds in urban environments. Cities constantly have competing signals overlap. The sum of which masks what is to be heard and obscures meaning.

Using high gain and low noise amplification, a contact microphone brought the faint signals of a pane of glass to life. Ensuring the fidelity of the signal, an amp was designed to allow for a signal of less than a millivolt in strength to still exhibit the characteristics of both the glass and the airborne signal hitting the pane with minimum of distortion.

4.2.2 CONTEXT - RECORDINGS

The pandemic relocated many people in the process of locking down the country. Seattle was the first place in the United States to have an outbreak and King County responded to the crisis quickly. The news came swift, almost instantly affecting everyone across the globe. The recordings which constitute *Large String Array* are an artifact of that sudden migration.

The move to Oakland was abrupt, having traveled to spend just the weekend in the Bay. News of a stay at home order came the following day. There was no return flight. One of the very few things to make the sudden move was an audio amplifier designed for high gain listening applications. This had been under development as a separate project, a curiosity really, and came to California to be debugged. This amplifier became a core element in the composition for *Large String Array* - a stroke of luck.

The hush of April was deafening. The restless quiet begged for attentive listening. After some experimentation, the high gain amplifier was paired with a contact microphone and fixed to the front windowpane. This offered a novel way to observe the outside world. Most noises simply remained mysterious, a hushed curiosity, others left small details as to their purpose. Idle minds harbor strange narrative desires. Some sounds were borne of the structure of the house, others happening just out of sight. There was a thick layer of background noise, now much more present than in the past. The wash of pink noise was the soup from which curiosity sprung. Sounds finding that windowpane were not heard as a single point of sound, rather listening to the diffuse vibration of the entire windowpane.

The world outside was so very still. The house walls had almost completely filtered out the sounds of the city. With the signal from the pane of glass amplified, you could hear the uncanny calm in the walls, their hollowness sagging, dimming the high frequencies while tiny choruses air conditioners and finches carried on. It was patient listening all April and May, wanting for the percussion of the past. Without the persistent roil of traffic and the rhythm of footsteps on the pavement, the soundscape droned on without feature. The sounds outside subtly shifted shades, soft textures, over the course of the day.

The ambient sound averaged ~40db outside that April, very low for the city. Seattle and the sounds of Lake Union, that had been a backdrop for years, instantly seemed lightyears away. The world scrambled shut as COVID quickly drew everyone indoors. Listening for the faint transmission's of the outside world was a comforting exercise. Like being stationed at a remote fire lookout in the Sierras, late in the summer, and trying to divine the slow changing weather.

Listening in the Cagean sense is to hear each moment passing, as it is unadorned. On the contrary, much money and fuss is spent isolating and manicuring sounds for the public, with the aim of creating an antiseptic soundscape. These are the sounds of capital's reach, sounds primed for consumption and control. Commodified listening is programmatic, meant to encode and reify power. The hierarchy of volume licensed to a specific entity has a direct relationship to power. In the city, sound is a feral animal meant to be domesticated. How might an artist subvert these systems of coercion and control?

> "Eavesdropping, censorship, recording and surveillance are weapons of power. The technology of listening on, ordering, transmission, and recording noise is at the heart of this apparatus."[28]

In 1970 Luc Ferrari stood a microphone outside of his window while staying in a small Yugoslavian village, close to the Black Sea. This experiment led to the composition *Presque Rien No. 1*. It is a piece of gentle beauty and cinematic scope. A twenty minute sound collage constructed simply from what his window hears over the course of a day. Ferrari finds himself among the audience, free of fussing over the sounds input, letting the microphone do the work. His presence

[28] Attali, Jacques, et al. *Noise: The Political Economy of Music (Theory and History of Literature, Vol. 16) (Volume 16)*. Univ Of Minnesota Press, 1985. 7.

is that of a “contextualized” listener.[29] Here Ferrari is orchestrating chance as well as leaning on an acousmatic interpretation of the transmission, the sound being divorced from its referent, existing simply as an auditory phenomena.

It is the composer's charge to shape the narrative potential of a sound source. Each unique signal is duly referenced against its archetype by the listener, derived straight from their personal sound vocabulary. While not as immediately legible as vision, sound offers a material reading of the surroundings. Artifacts of force, density and distance come into focus.

> “While it is perfectly possible to recreate the decibel level of a hammer hitting an anvil form the nineteenth century, or a piece of music from 1600 (especially if we still have the score and original instruments), it is impossible to experience the sensations in those same way as those who heard these sounds in the past.”[30]

The recordings that comprise Large String Array stem from the tradition of acousmatic listening. But, that does not absolve the sound from referent or

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[29] LaBelle, Brandon. *Background Noise, Second Edition: Perspectives on Sound Art*. 2nd ed., Bloomsbury Academic, 2015. 31.

[30] Novak, David, and Matt Sakakeeny. *Keywords in Sound*. Duke University Press Books, 2015. 59.

context, it simply amplifies the mystery inherent to direct sound - listening to an unfiltered signal with its wavering degrees of legibility and its sense of surprise. Like radio waves sent adrift from Proxima Centauri, the listener is forced to interpret the faint transmissions intercepted by a windowpane in Oakland California.

4.2.3 TECHNICAL OVERVIEW - RECORDINGS

The high-gain amplifier used for these recordings consists of a preamp first, followed by an amp stage with three discrete gain stages. The preamp is a JFET 2N5457, this transistor is used to convert a high input impedance to a low output impedance. This effectively boosts a weak signal and gives ample headroom above the noise floor. Next, the amplifier stage takes the primed signal and boosts it up to a possible one thousand times gain. The LM324N multiples the signal in three separate gain stages to avoid distortion.

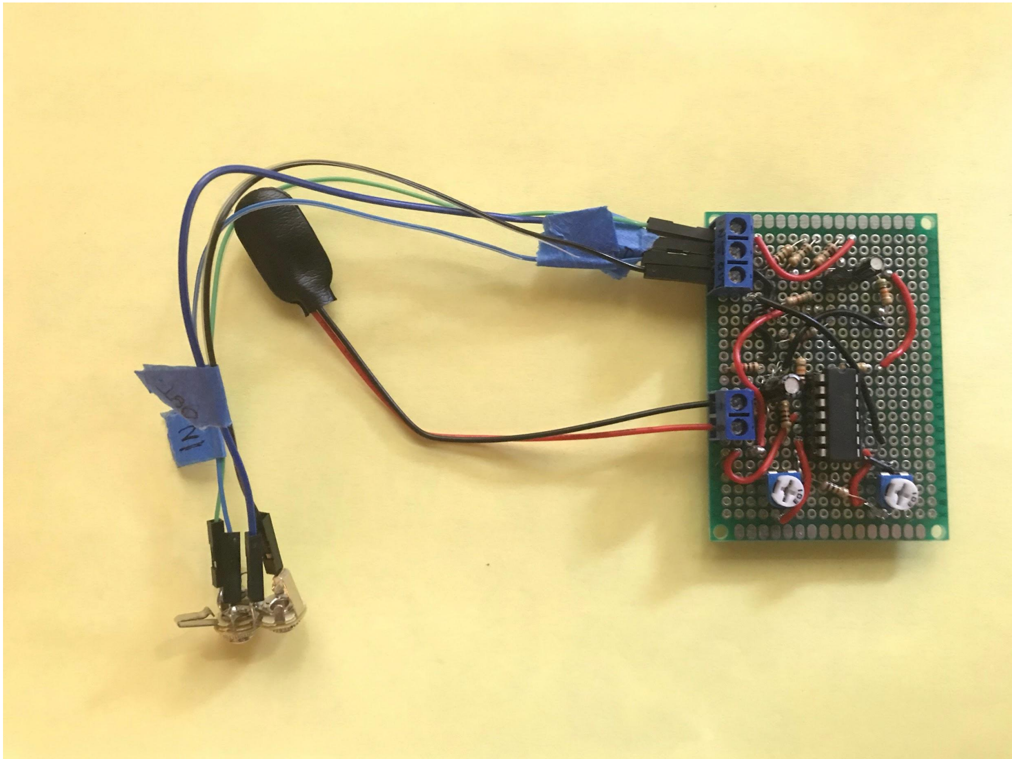

Figure 37 - Amplifier Circuit, taking less than a millivolt input and amplifying the signal up to 5v

The first stage is fixed at ten times gain of the incoming signal while the last two stages are variable; they potentially give ten times amplification at each stage. Resistors R5, R7 and R9 in Appendix B.2 are responsible for this ten to one signal boost. The first stage is a fixed 10k resistor, while 10k potentiometers sweep the final two variable gain stages. Signals under one millivolt are amplified up to five volts with this amplifier while maintaining a minimum of distortion. It is also important to use a thirty-two bit floating point bit depth when recording audio. This avoids transient spikes from overloading an otherwise quiet signal path.

Figure 38 - Hand made contact mic with piezo elements

The contact microphone consists of a piezo element and shielded audio cable with a dollop of hot glue for strain relief where the cable has been soldered to the chalky crystalline piezoelectric center of the disk. A 1/8“ TRS connector soldered to the other end of the cable.

4.2.4 CONTEXT - COMPOSITION

The sound for *Large String Array* is a product of uncertain circumstances. The 2020 pandemic left everyone trapped indoors with future plans indefinitely put on hold. The installation at the Jack Straw Cultural Center was one of such plans deferred. This caused a dramatic change to the composition of *Large String Array.* It was originally proposed as a network of inputs culled directly from the day to day workings of Jack Straw. But, the composition could no longer be animated by a space that was little used.

It was listening to *Opus 17* by French composer Elaine Radigue that sparked the remedy to this problem. Radigue's practice in the late 1960's, had been dedicated to exploring feedback. Her work took aim at that delicate envelope of sound, where a signal is multiplied by its own frequency spectra. This of course quickly amplifies the boldest frequencies in a signal, creating pleasant wandering tones when controlled, but also capable of producing brutal unstable screeching if the engineer is not extremely cautious. She had developed her practice around this chaotic potential and knew well how to tame it.

Radigue's idiosyncratic approach to composition was fully realized in *Opus 17*, a work created at the Fête en blanc Festival in Verderonne in 1970. Epic in scope, yet focused and quite minimal, this ninety minute piece synthesized her early feedback efforts into this, her masterwork. Radigue builds soundscapes which draw listeners focus to simple persistent frequency interactions.

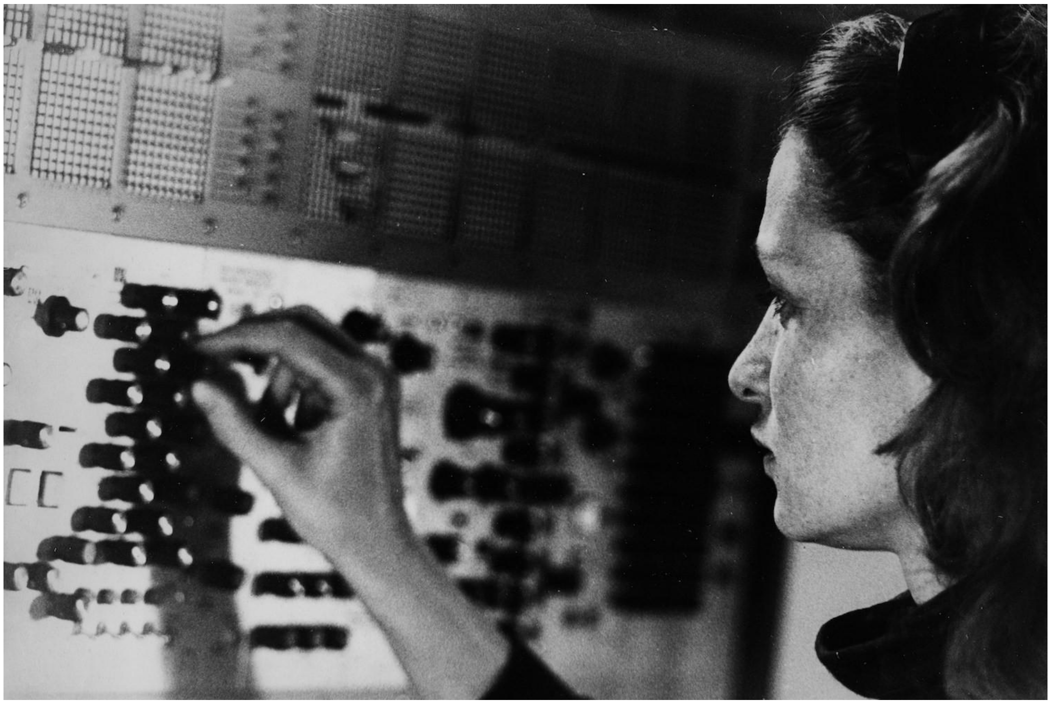

Figure 39 - Elaine Radigue at the Buchla 100 Modular Synthesizer

The piece begins with a looped sample from a Chopin Étude for piano. It slowly morphs for the first nineteen minutes into a gentle stillness, a wash of sound, steady and luminescent. The original source material is totally obscured by the end of that nineteen minutes. A Buchla 100 modular synthesizer was used to manipulate the piano sample from something recognizable into something sublime. This was the transformative musical gesture *Large String Array* could borrow from. Transformation was after all at the heart of *Large String Array,* a sound playback device which takes a mundane source and saturates it with a cathedral like reverberance.

Figure 40 - BLM poster by Noah Smith below contact mic attached to the window pane

Large String Array starts with a hush, a train slipping by as the audience enters the gallery space, the sound flattening out to a gentle chorus, a calm before the downpour. This first movement actually begins to trace the contour of the pandemic itself. Audio from the window recordings of the first two months in quarantine set a pensive tone, absent of people or discernible curiosity, with only the trains passing to keep time. A lull building to a crescendo.

The stillness of the early pandemic was to melt away on the evening of May 28th 2020. Black Lives Matter activists took to the street in response to the murder of George Floyd by Miniapolis police. For the next month protests consumed downtown Oakland. The business district was converted overnight into an outdoor museum devoted to the protest of police brutality. Shop windows were lined with plywood canvases, every surface painted over in bright bold strokes - an incredible sight.

The daylight hours proved peaceful, but in the evenings tensions escalated, with provocative confrontations from city police. The first of many restless nights was punctuated by rounds of tear gas. For days on end, the whine of sirens and the buzz of helicopters filled the air. The soundscape was again totally disrupted. The quiet drone of the first two months was never to return. In this way *Large String Array*'s composition became a reflection of the arc of the pandemic itself. The composition tracing the same outline; from the enigma of sudden stillness, to the clamour of shots ringing out in the night. Of course all of this was documented by a small but powerful contact microphone coupled to a pane of glass.

The second movement starts with a bang. Shots of teargas signal the change in tone. New tensions are summoned by the clanging of wire, the sub bass exciting strings to visible oscillation. Suddenly, a string strikes its neighbor, the sub bass frequencies displacing some strings an inch or more. Further down the array another clang, then another. All the while, a chorus of synthesized voices, steady in their palliative refrain, ring out over the strings.

A third and final movement ruminates on what is to come. It paints with a cautious brush. While similar in tone to the first two movements, it takes on the themes previously established with a new voice, less plaintive and more assured. It can be best described as the desire for resolution, without offer of respite. The chant settles into speculative calm but first, a very long winter. This third movement is less dissonant as the strings no longer strike one another with frequency, offering the listener a meditative space, evoking stillness and a quieting of the mind, allowing the viewer to ponder the deceptively simple symmetry of *Large String Array.*

4.2.5 TECHNICAL OVERVIEW - COMPOSITION

Xenakis, an artist of great influence on *Large String Array*, described his compositional strategies for developing the work *Concert P-H* for the Philips Pavilion at the ‘58 Expo in Brussels as follows:

> "I seek extremely rich sounds (many high overtones), sounds that have long duration, yet with much internal change and variety. Also, I explore the realm of faint sounds highly amplified … start with a sound made up of many particles, then see how you can make it change imperceptibly, growing, changing, and developing, until a entirely new sound results. " [31]

Much of the ethos behind the sound composed for *Large String Array* can be summed up in these statements by Xenakis. From highly amplified sounds to long durations with evolving passages. A recurring theme of transformation emerges sonically from the instrument and wall. The faint recordings of life in lockdown are transfigured. A BART train cuts through the silence and is given a voice.

How are these train sounds morphed into that of a small choir? The answer is convolution, the process of taking two sound files and multiplying their frequency spectra. This reinforces common frequencies and attenuates unshared frequencies.

> "Convolution is becoming a favorite operation for transforming two separate sound files into a file that incorporates some of the

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[31] Brody, James. *Iannis Xenakis Electro-Acoustic Music.* Nonesuch, catal. H-71246, 1970.

characteristics of each.” write Dodge and Jerse, by “treating one file as an impulse response and the other as the input to that impulse.”[32]

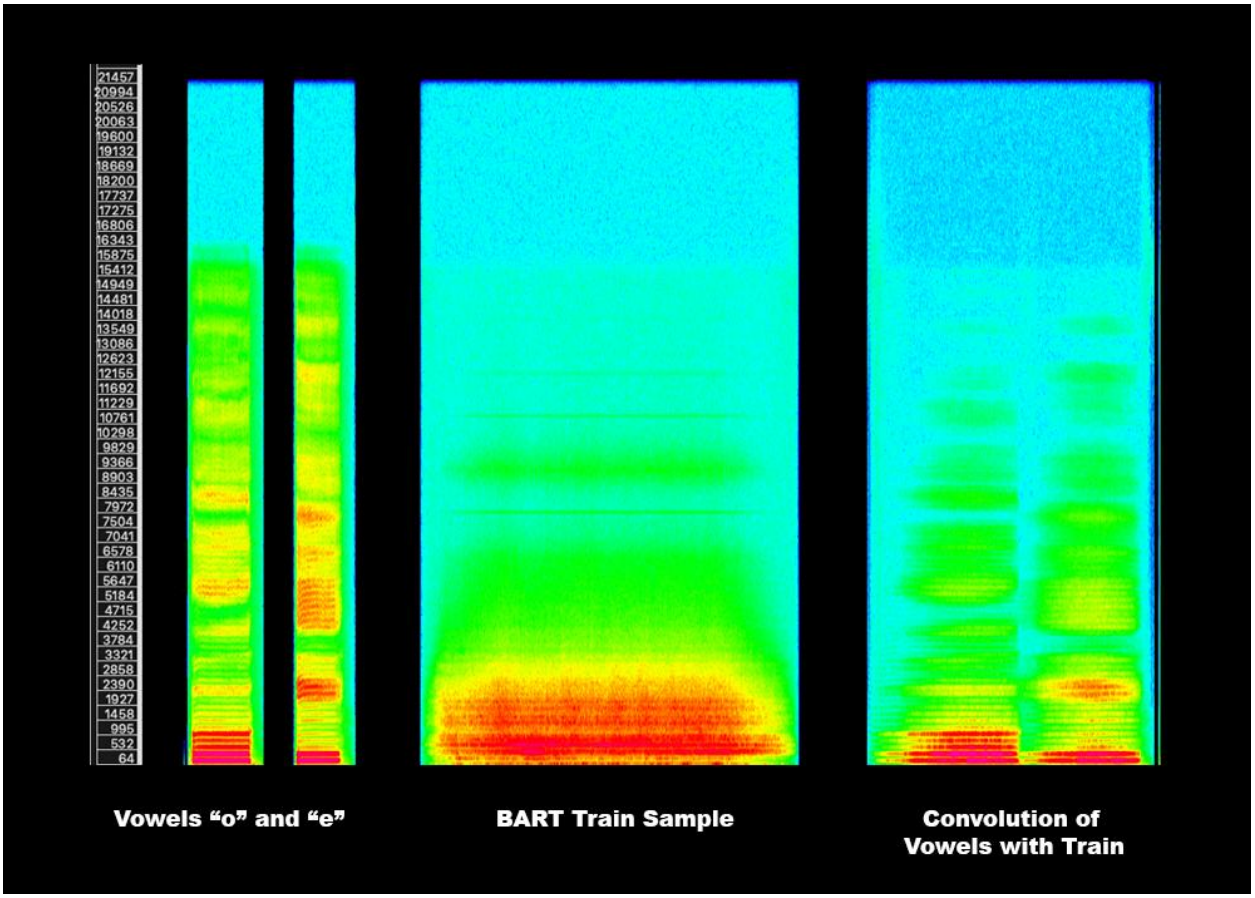

Figure 41 - Spectral analysis of vowel and train sample convolution

A catalog of formants from vowel sounds, specifically the long vowel sounds ‘e’, ‘a’, ‘o’ and ‘u’ was first created. The long ‘i’ was omitted because of its nasil quality. There are several variations of these four long vowels types. The collection of samples were recorded indexing these subtle differences -- ‘ee’, ‘eh’.

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[32]Dodge, Charles, et al. *Computer Music*. Amsterdam-Netherlands, Netherlands, Adfo Books, 1997. 327.

‘oh’, ‘oo’ and so on. This vowel sample set, in the form of an impulse response, was then given its input, a collection of BART train samples collected from the window pane recordings.

Out of this process, a palette of long vocal passages emerged. These new hybrid recordings were further manipulated, pitched digitally and arranged in F minor. This key was noted by pianist Glen Gould as being “rather dour, halfway between complex and stable, between upright and lascivious, between gray and highly tinted... There is a certain obliqueness."[33] These sentiments seemed appropriate.

Because of its contemplative tone, John Luther Adams *Night Peace* was on heavy listening rotation at this time. The stillness of this piece, wisps of percussion and gentle harp accents, over long sustained choral passages, resonated with the moment. This led to research in ambitus and reciting tones -- characteristics of Gregorian Chant. With circular themes emerging and chords forming around foundational recurring pitches, the composition began to coalesce. A tapestry of sound, *Large String Array* weaves voices of the city with the voice of the cathedral for a seventeen minute dialogue.

[33] Meng, Cathering. *Tonight’s the Night*. 1st ed., Apostrophe Books, 2007. 21.

The duration of *Large String Array* reflects time constraints imposed on early media. It takes roughly twenty minutes to develop an episode ready for television. It is a time frame audiences understand to hold their attention and adequate for developing a narrative arc. A twelve inch LP record takes on average between sixteen and twenty two minutes to finish a side. It was decided upon by record distributors and consumers in the late nineteen fifties as an appropriate increment of time, before being forced to get up, walk over to the record player and flip the disk. Muzak's Stimulus Progression, used by corporations and retailers to boost productivity and as a mood enhancer, relied on this interval of time as well. Starting the progression with a mellow easy listening repertoire, Muzak slowly shifted programming to an upbeat and engaging timbre over the course of roughly seventeen minutes. Then, quite suddenly, the program stops and is followed by a long silent pause before more "elevator music" begins to play. These media restrictions no longer exist within the world of streaming. But, as an archetype, this interval persits in our collective consciousness.

4.3 VISUAL ORCHESTRATION: STANDING WAVES

Standing waves occur in a string, of two fixed ends, when the frequency of energy transferred into the strings agrees with the length, tension and diameter of the string. In the case of *Large String Array* the strings are twelve feet tall and 0.022" in diameter. This fixed tension results in nodes along the string that are stationary while the string vibrates sinusoidally - the wave rippling through the string cresting with the amplitude of the incoming signal.

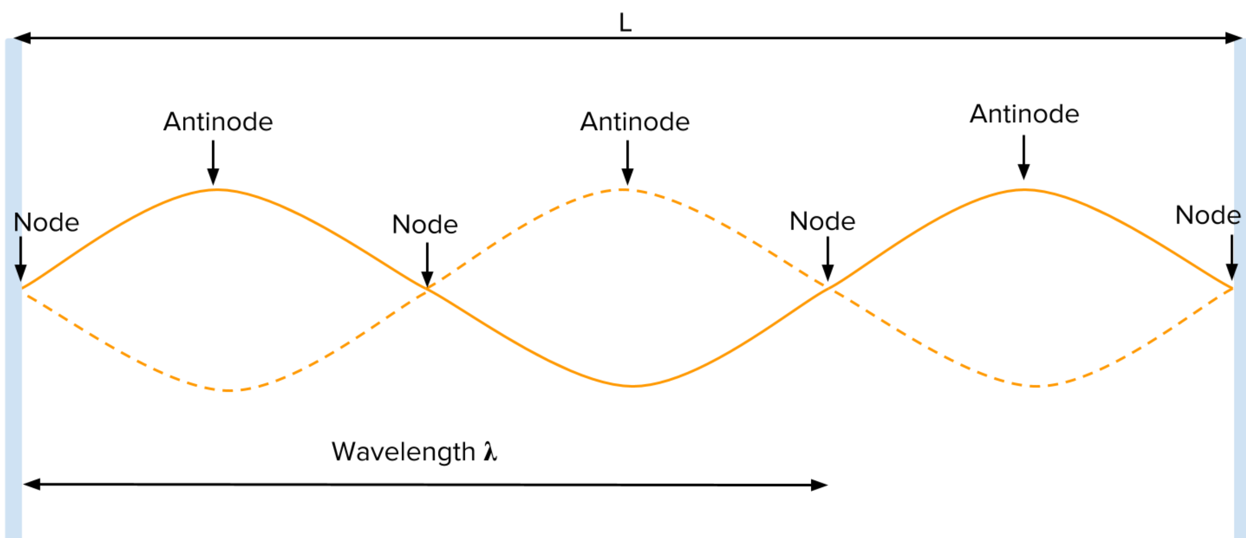


Figure 42 - Standing wave

Large String Array has two scores. One score for audition and another for visual feedback from the strings. Standing waves are the result of the visual score. After much experimentation to achieve the exaggerated movement within the strings, it was found that the sub-bass frequencies of twenty to ninety hertz had the largest crest to crest amplitude swing. These standing waves are activated throughout the array, as strings that are sympathetic to the incoming signal’s frequency start to shake. Any of the strings in the array have the potential to be actuated by the incoming oscillation but only move if they agree with the factors that determine the string's pitch.

The visual score has its roots in the audio composition. It was written to be a compliment to the audio and shadows its movement. But, the visual score is also totally independent in its aim. It is designed to bring out moments of intense string movement. This results in both visual and new auditory artifacts. It is further shaped by the three distinct movements within the piece. *Large String Array* reaches its visual climax in the second movement, the longest and with the most internal tension. The vibrations cause the string to strike together, taking on a second sonic presence, the crisp sharp metallic pings of the overly excited strings. This sound palette is in sharp contrast to the audio composition. The visual composition joins its audio counterpart with a clang.

Figure 43 - Standing waves propagating through the steel wire

It is important to note, since the visual score accompanies the audio, when strings strike each other, the pitch of that interaction is also in agreement with the audio's input - further amplifying those same sounds. The standing waves of the visual and audio scores are aligned yet independent. Most of the energy in the piece is used to activate this sub-bass region. It takes a lot of energy to move the strings visually.

4.4 TECHNICAL CONSIDERATIONS: PRE-INSTALLATION

The goal, turn an entire wall of the Jack Straw Gallery into a string instrument, like a cello or piano, and have the structure play back an audio and visual composition tailored to the structure. A lot of care went into amplifying the idiosyncrasies of the Large String Array, the hulking presence of a seventeen by twelve foot wall covered with twelve hundred strings.

This system was first studied in miniature to determine what qualities might be best exaggerated and how. Bridges of different materials and dimensions were experimented with to find the best mode of vibrational transmission. Methods of transduction, where the strings are excited, were tested and catalogued for their sound and visual properties. The qualities of reverberence, sympathetic motion and material distortion stood out when the array was energized. These properties became core elements of composition.

Figure 44 - Seventeen inch wide model of Large String Array

One seventeen inch sample section of the gallery wall, consisting of one hundred strings standing six feet tall, was constructed for testing purposes. The final installation of *Large String Array* at Jack Straw was made up of twelve such panels standing twelve feet tall. The prototyped bridges consisted of a variety materials such as steel flat bar, brass t-bar, aluminum t-bar, thin spring steel, acrylic sheets, thin plywood, felt, mahogany, rubber and douglas fir. The hodge podge of materials were often coupled to the wall and held in tension by the strings. Other experiments involved exciters actually attached to the strings, free of the wall.

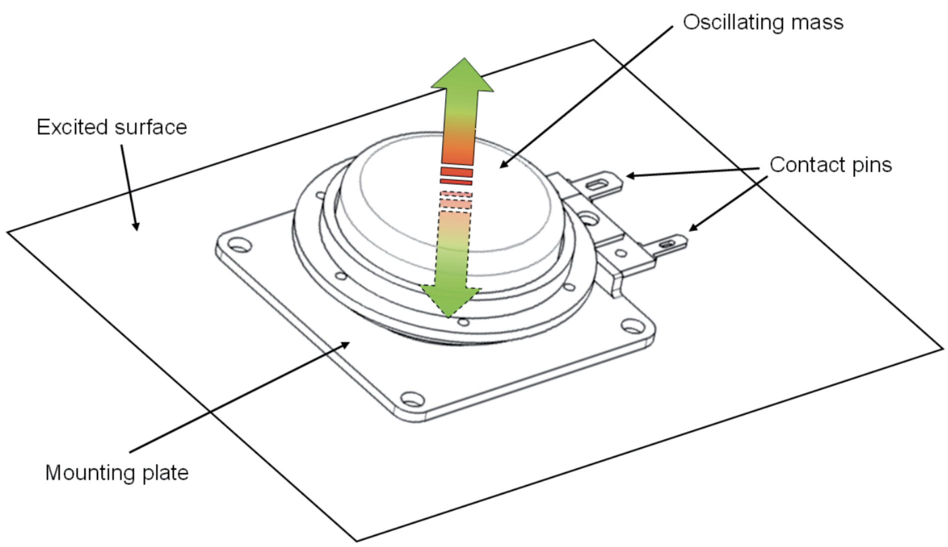


Figure 45 - Physical action of an acoustic exciter.

These exciters, known more generally as audio transducers, vary in shape, power and frequency range. They are essentially copper wound coils creating a varying electromagnetic field and converting that difference into physical energy. When tested, small thirteen millimeter three watt transducers had interesting resonant peaks in the high mids but did nothing to physically move the strings. The strings began to jump and get excited visually when a Dayton Audio TT25-8 PUCK Tactile Transducer Mini Bass Shaker was installed behind a length of one inch aluminum t-bar and wedged between the wall and strings with a pine two-by-four base. This visual feedback came to life only with very low frequencies, in the twenty to ninety hertz range.

Figure 46 - 17’ driver bridge segments before construction

This sub bass energy animated the strings, exciting them until they produced large standing waves, large enough to ring and jangle adjacent strings. The bass frequencies work to visually excite strings that are sympathetic to the interval playing back through the array. Only strings that agree in pitch with the incoming signal moved the steel wire. They reinforced and amplified the sound directed into the strings. The experiments settled into a large zither like system, with a set of bridges held in tension against the gallery wall. The two rows of bridges are for two very different purposes. First there is a bridge to drive energy into the strings transmitting the sound and creating movement. Second, a sounding bridge that intercepts the signal traversing the length of wire and drives the wall behind it to resonance, amplifying the sound acoustically.

Figure 47 - Large String Array south facing wall with frame installed

Tensioning twelve hundred piano wire strings takes a lot of labor and demands a lot of tension. To build a frame, the width of seventeen feet, and to make that span dense with strings requires careful material considerations. The type of wall construction is important. The wall has to be resonant, like a standard sixteen inch studded frame covered with drywall. This arrangement creates pockets of air behind the drywall, like the air excited inside the bracing and body of a guitar.

This structure produces a resonator for the strings in *Large String Array* to be amplified by.

Brick walls on the other hand have limited resonant potential because of their density. In the Jack Straw Gallery, only three walls are of drywall construction. The fourth wall is made of brick. Two of the other walls in the gallery are interrupted by natural features, so the south facing wall, without obstruction, became the focus of the piece.

This wall measures seventeen feet wide by twelve feet tall. So these initial dimensions were predetermined by the space. Knowing these measurements marked the extent of the piece but how many strings can fit into a seventeen foot span?

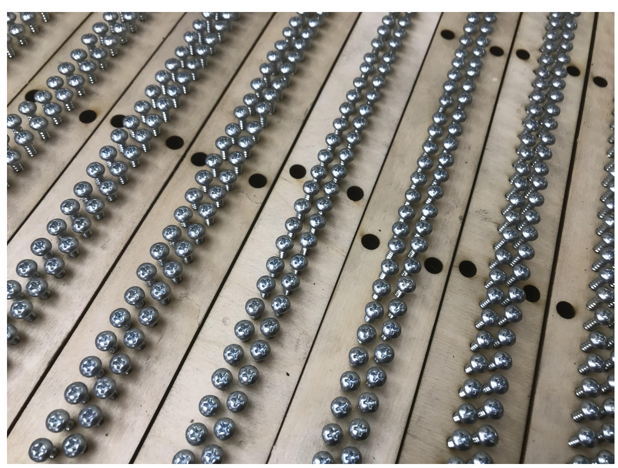


Figure 48 - Tuning pin blocks for the bottom L- bar.

Figure 49 - Ties for the top aluminum L-bar.

For the tuning of the strings, zither tuning pins were used. This style of tuning pin, slightly smaller than a piano tuning pin, makes a good choice for array applications. They are thin, but when installed properly, are very effective at holding tension. These are the same pins used in large zither and hammer dulcimer tuning systems.

Figure 50 - Tuning pin and wire ties

The standard zither tuning pin is 0.198" in diameter, but they are meant to be fitted into smaller predrilled holes of 0.17” in dimension. This is convenient. If the decimal moves a few places over, it arrives at the number seventeen - also the measured width of the room. This means the dimension of the tuning pin is divisible by the width of the wall. This symmetry of the numbers seventeen and twelve are recurring throughout the piece. The width of the array was further divided into twelve vertical panels of one hundred strings, each set of strings corresponding to twelve pairs of bridges. Each of the seventeen string segments are twelve feet high.

4.5 TECHNICAL NOTES: INSTALLATION

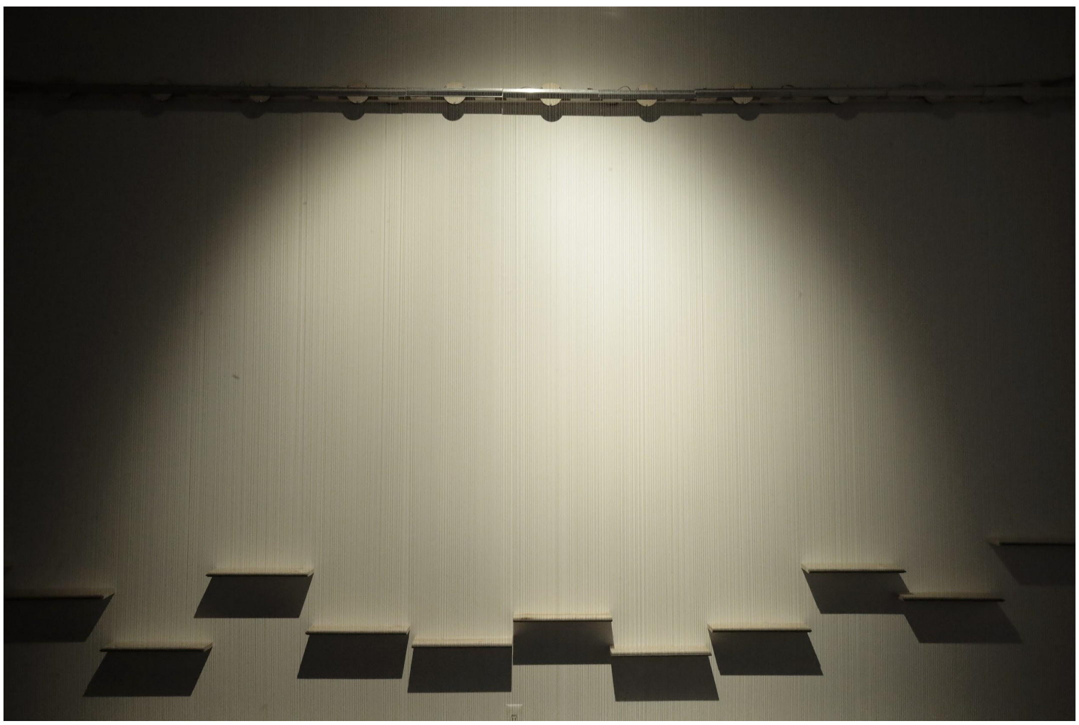


Figure 51 - "Large String Array" front and center

With *Large String Array*, the metal plate or harp of a piano is comparable to the aluminum L-beams conjoined with the wall. Piano frames developed into its conventional form of cast iron frame in the mid eighteen hundreds. By the nineteen fifties commercial piano manufacturers began to incorporate aluminum into frames instead for its comparable tensile strength and much lighter weight. Individually, the strings do not exhibit a large force on these structures but, collectively the strain of a frame supporting this array of wire is huge. For instance, the average piano of eighty eight keys has two hundred and thirty strings, with a total holding tension of eighteen tons. *Large String Array* must brace a force of this magnitude over a seventeen foot span.

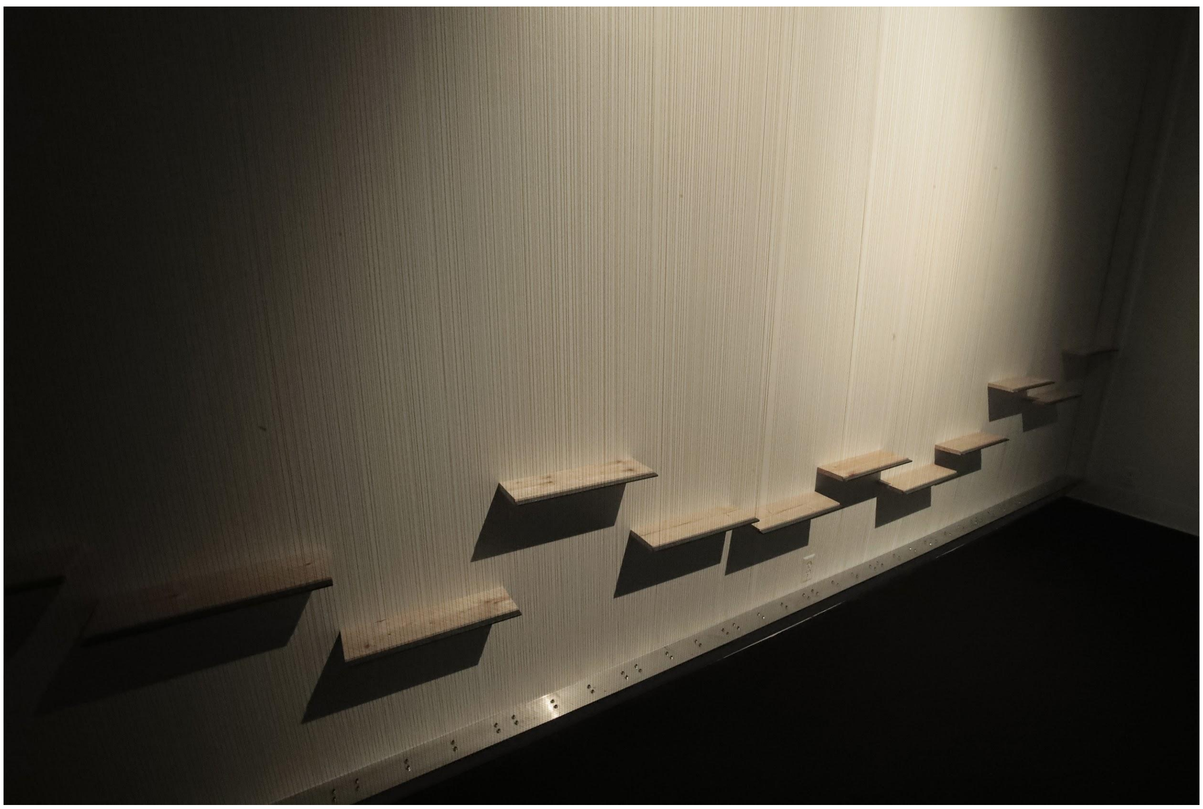


Figure 52 - Lower bridges held against the wall with the tension of the strings.

The strings themselves are all the same diameter of 0.022” and made of high carbon steel. This proved a malleable diameter, as the strength of the string grows exponentially if the wire gauge decreases. The only difference between strings is that the tension is not standardized across the entire array, instead the tensity is determined by chance. Because this tuning is entropic in nature, it does not need to adhere to any specific tuning convention. With twelve hundred potential pitches, the array at any one time would have a great number of frequencies to play back and actuate the strings sympathetically. This frequency range is also influenced by bridges inserted at varied heights along the array.

The twelve hundred strings, to get sympathetic movement and resonance, need only agree with the pitch interval between any octave in the spectrum. These sympathetic frequencies double, triple and halve with higher or lower intervals, and are actuated when they align. The strings do not represent an ideal system where only one pitch is played back at a time. Instead the array describes a complex interaction of waves, where sympathetic vibrations begin to occur within a margin of deviation.

Figure 53 - Looking up at upper bridge with transducers

While the pitch of individual strings does not require specificity, there are still two important considerations for the tension of the strings. First, that the strings collectively must hold the upper and lower bridges in place, under tension firmly against the wall. The two sets of bridges span the seventeen foot wall and are integral to sound distribution throughout the array. The second consideration is that the tension of the strings must not exceed the collective tension required to warp or destabilize the frame. The possibility of having the piece collapse on itself is very real.

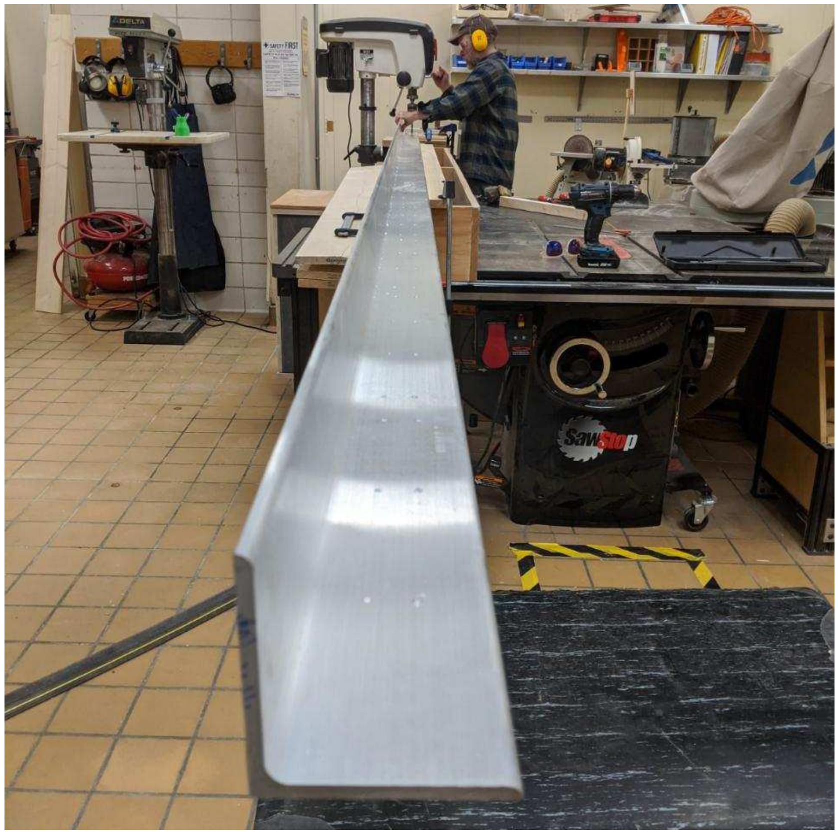


Figure 54 - prepping 17' length of aluminum L-beam

Because the force of twelve hundred strings is great, aluminum was chosen for the horizontal expanses. Structural aluminum L-beams were cut down from their twenty five foot lengths to fit the seventeen foot room. They were further supported by twelve foot two-by-fours at the far ends of the flanged beams. The beams themselves are four inches tall, four inches deep, a quarter of an inch thick and measuring 0.375” at the flange. Many calculations were made to assess the overall strength of these beams in relation to the entire system, but because of a large number of variables, specific tensions were difficult to establish, instead relying on safe ranges of values to ensure stability by leaving a comfortable margin of error.

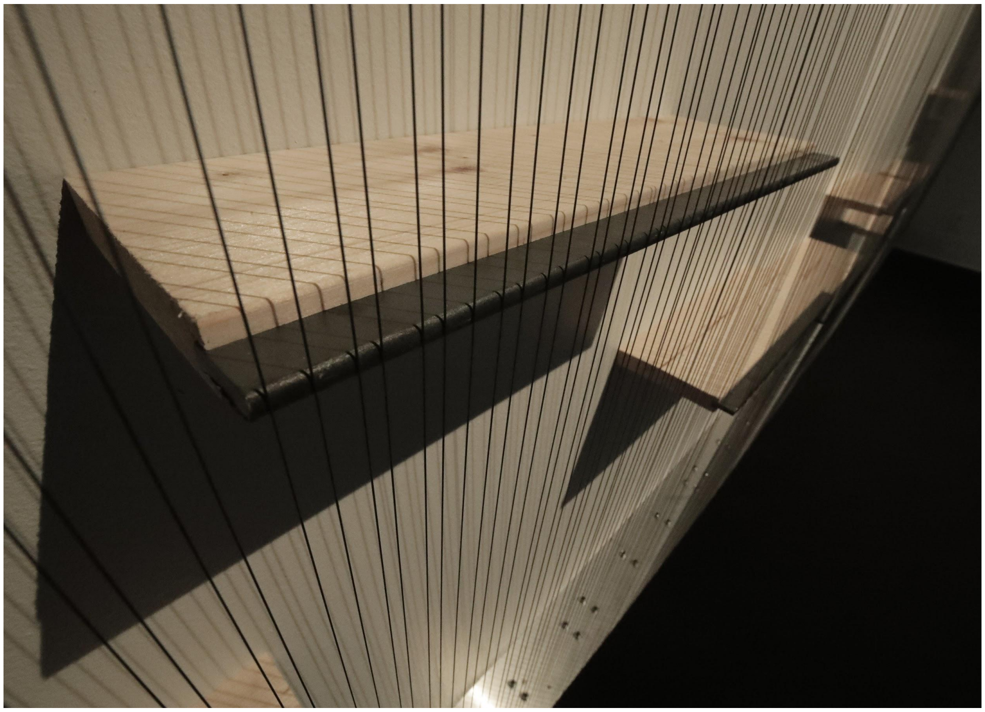


Figure 55 - detail of lower bridges with steel edge

Pairs of bridges, twenty four in all, are responsible for exciting the sound and driving the vibrational energy to the drywall. One row of bridges is held to the wall ten feet in the air. This line of bridges is responsible for vibrational input. The lower shelf of bridges are staggered between two and four feet from the aluminum base and are responsible for resonating the wall. The wall amplifies the sum of the array's vibration, traversing first the length of strings, then through the steel trimmed wood bridges and finally, reaching the wall and ringing out.

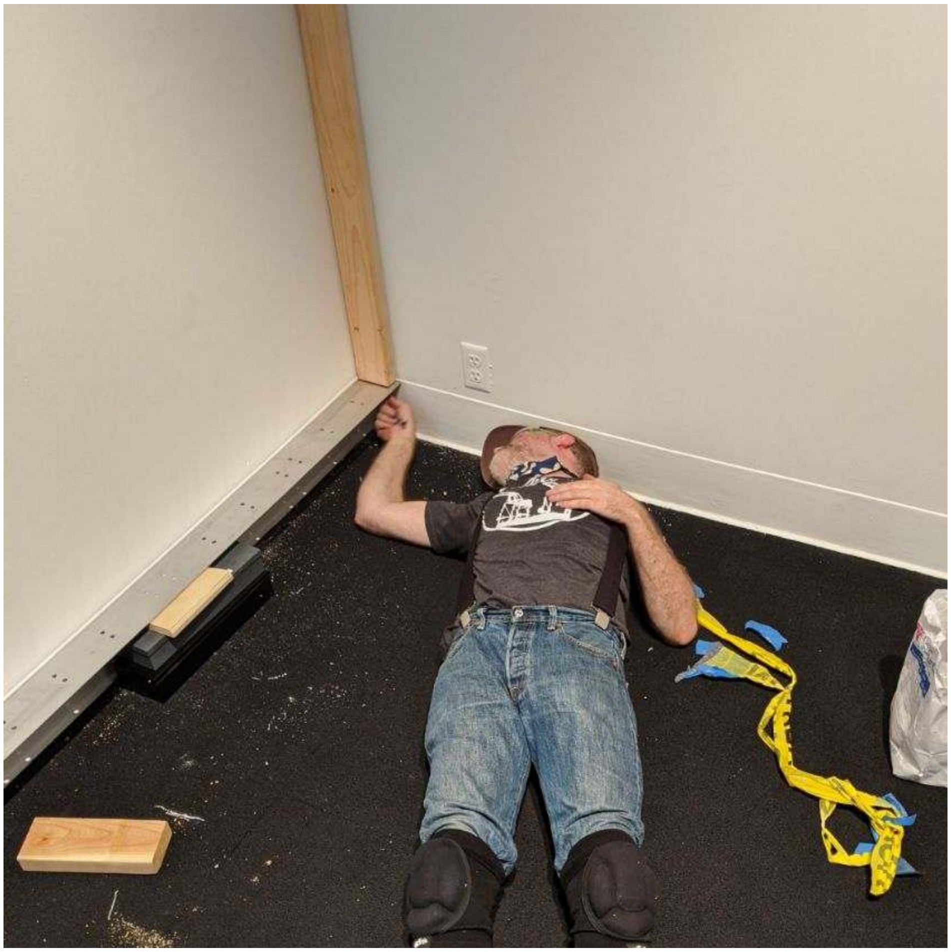


Figure 56 - Installation of the frame

The installation of Large String Array began with the frame. First the lower L-beam was installed one inch above the floor, with the flange facing towards the ceiling. It was important to measure and predrill the L-beams to accommodate the sixteen inch width of each wall stud. The beams at the top and bottom must be anchored to studs to hold the tension of the strings. Next, twelve foot two-by-fours were secured at the two far ends of the aluminum beam, made flush and secured to the wall itself. The second seventeen foot expanse of L-beam was hoisted up to sit on top of the two vertical two-by-fours and secured to studs with four inch long heavy duty fasteners. Finally, to complete the frame screws were inserted coupling each end of the L-beam to the two-by-fours.

Figure 57 - Tuning pins along the lower L-beam

The lower length of aluminum houses the zither tuning pin arrays. This made tuning easily accessible. Each array segment is seventeen inches in length and has exactly one hundred pins. There are twelve of these segments in total. They run the complete length of the lower L-beam and are fastened by nuts and bolts to the beam. Mirroring this lower length of aluminum, along the top beam, seventeen inch segments of one hundred posts were installed to anchor the strings to the top of the frame. The frame was now ready for installing the strings.

Figure 58 - the Large String Array crew

Each string was first measured out to fourteen feet and clipped, adding a little extra length for workability. Next, the length of wire was fashioned into a small half inch loop and twisted back around itself several times. This loop was then draped over the upper post and threaded through the eyehole of the tuning pins below, one at a time. The strings, at first, were tensioned just enough to stay in place as all twelve hundred were installed across the array.

Figure 59 - Top bridges held in tension by strings

After all twelve hundred strings were threaded and tensioned, the frame was ready for the bridges to be inserted behind the strings, using the tension of the wire to carefully hold it in place. Remember the strings had not yet been fully tensioned, and there was still slack from the missing bridges. The top bridge was broken into three segments equal segments. Once inserted behind the strings a few wires were further tensioned to hold the segments in place until finally the lower bridges were put into place.

The lower bridges were made of twelve separate seventeen inch segments of one by six inch pine. Each segment was cut to accommodate a quarter inch wide strip of steel, press fit into the string adjacent side. Each bridge was inserted behind the strings and flipped into tension, with the steel bar meeting the strings. It is key to have a hard edge along each bridge as it increases the energy transmitted from the strings into the bridge.

Figure 60 - Running speaker wire through the rafters to the small projection room over the entryway

All twelve bass exciters along the top bridge are connected, via speaker wire, to a pair of amplifiers in a hidden room. The wire first connects to the Dayton Audio Exciters, then is passed over the gallery lighting and tied to scaffolding above. Finally, the wire was dropped through a small porthole window in an AV crawl space above the entrance to the gallery. The twelve channels are then coupled to two one hundred watt multi-zone Dennon amplifiers in this small overhead room.

Figure 61 - amplifier's and arduino setup inside the small projector room

This room was an important hub for the electrical workings of *Large String Array*. It is here where an arduino and computer communicate with a MOTU UltraLite-mk3 to start the piece when a PIR movement detector is triggered. As soon as the viewer walks in the room the piece begins. In Pure Data, the arduino communicates serially via Firmata protocol with the PIR sensor. As soon as five volts is detected by the Arduino from the sensor, it relays that message to Pure Data and the twelve channels of the piece begin playback, out through the Motu and to the amplifiers for the signal to be transmitted to the array. It plays back continuously for the seventeen minute duration of the piece, without being interrupted by the PIR signal again. Once the piece concludes it is followed by four minutes of silence before the motion detector is reset.

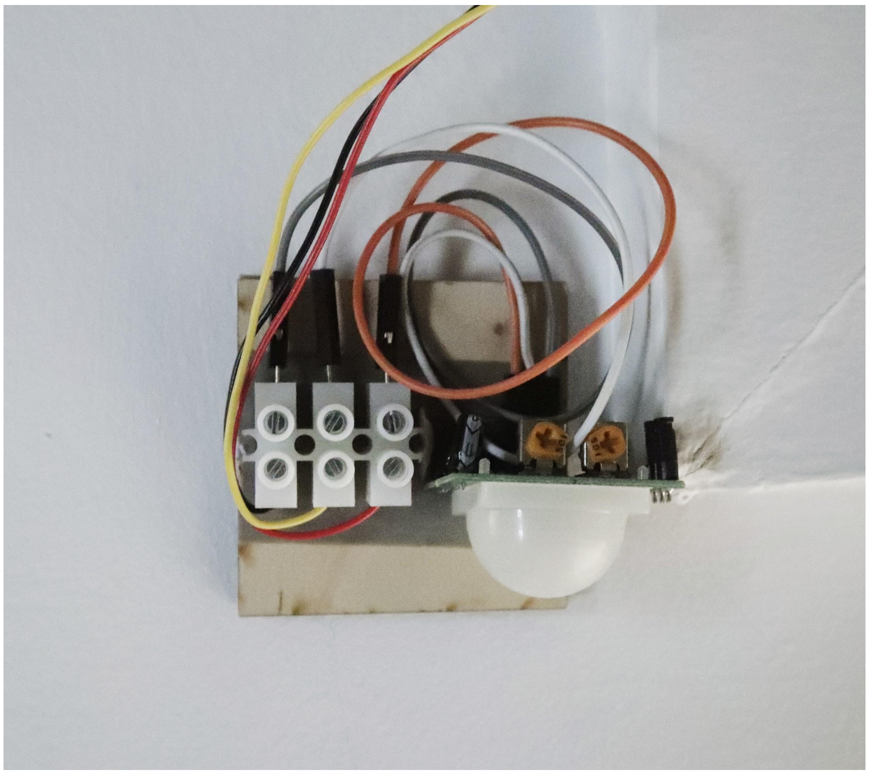


Figure 62 - PIR motion sensor installed over gallery entrance

The PIR sensor was located just outside the door to the crawl space and a few inches above the entrance to the gallery. The start was seamless with the push of the door. This allowed the viewer to be immediately immersed in the piece, cluing the listener into the fact that *Large String Array* has a fixed duration.

4.6 FINAL IMPRESSIONS AND FUTURE ITERATIONS

Large String Array is a marriage of unlikely places and sounds. It is a transposition in time and space. Take a whisper of sound from a windowpane in Oakland, CA and magnify it in a grand way, using a wall in Seattle, WA as its soundboard. Under normal circumstances this piece would have been localized, only existing in Seattle. After quarantine, it now seems natural for Seattle and Oakland to fit together in some mangled virtual geography. The disruption of the pandemic led to a retooled interconnectedness, dystopian as it may be. The true effects of these changes will take time to interpret but *Large String Array* is certainly the product of this moment of disruption and resilience.

The goal of the Large String Array project is to transform architectural space into sonorous space. In the spirit of Gordon Matta-Clartk's "Anarchitecture", Large String Array challenges our predetermined roles and relationships to space and sound. "Anarchitecture" refers to both anarchy and architecture, a mode of questioning these predefined spaces through radical intervention - in this case centering sound. This concept could easily be amplified in future iterations.

There were many discoveries along the way. One came quite by surprise. At Jack Straw they do a lot of programming for people with disabilities. It just so happened that a vision impaired group was there to experience the array. They were overjoyed when I asked them to touch the strings. Large String Array might have been most successful as an experiment in tactility. In the future, engineering work for people with special needs would be a rewarding artistic enterprise. Working with sound offers unique insights for all of the senses.

Another discovery, in the course of this installation, came from filming the array at 24 frames per second. The frame rate caused the movement of the strings standing waves to be exaggerated. For a visually driven audience, there was a strong response to this artifact. In the future, stroboscopic lighting could be used to amplify the perceived movement.

The *Large String Array* project will continue to grow, engaging charged sonic spaces. While Jack Straw offered a blank canvas for this iteration of the piece, the white cube of the conventional gallery leaves something to be desired in the way of compelling sound interactions with the site itself. Future engagement will likely include portabile array systems capable of quick setup, exploring distinctive acoustic environments. New iterations will continue to explore novel resonating shapes and materials using Large String Arrays organizational strategies. Surveying material interactions while highlighting the physical nature of sound will remain strong currents through this work. All the while, working to divorce sound from the loudspeaker.

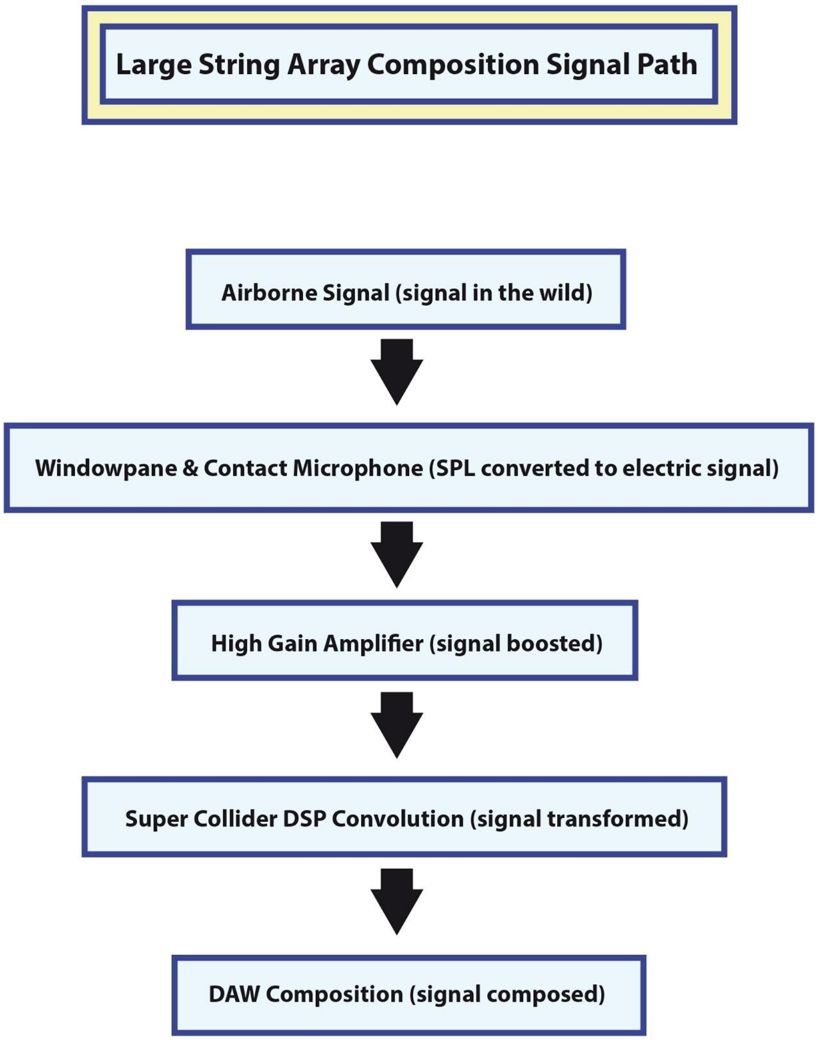
Methods of actuation is another important consideration going forward. Using inductors to actuate the strings electromagnetically on a large scale is a definite curiosity. Just as each sound source has its own sonic signature, transduction leaves its unique imprint on the sound. The method of actuation is key to a sound's timbre. A study of plectra and telematic potentials are other avenues of future array consideration.

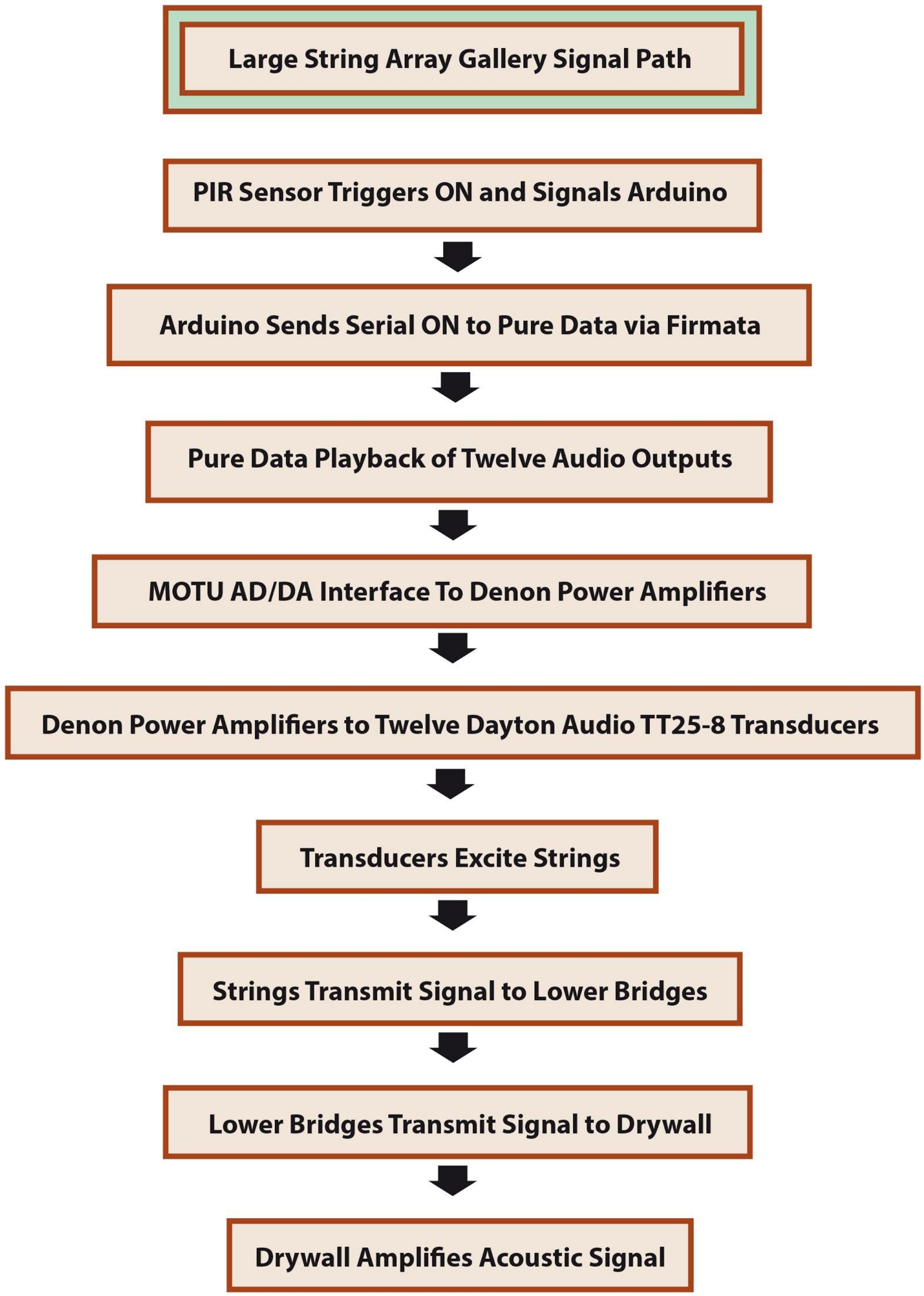
Instead of one large array, it is possible to break up the monolithic array into smaller tiles. This would allow for discrete pitches and an increased sense of locationalized stimulus when activating a space. The tiles themselves could be portable or possibly networked. This is the beauty of a modular system. Its origination is malleable. It adapts to the space and reacts to the place it inhabits. After all, if the site is compelling, it gives shape and frames the context of the work.

As an artist and educator, Large String Array has provided insight that lands in the classroom. Creative circuit and software design are now tools that have been incorporated into the DXARTS 470 curriculum at the University of Washington. Even with the difficulties of distance learning, these tools were still able to translate. Given the complexity of these tasks this seemed rather remarkable. Having access to this knowledge has forever changed my practice and teaching methodologies.

Like lines on paper, *Large String Array* dissects space and directs the eye. It provokes materiality. So deceptively simple, yet a testament to endurance, feeling both effortless and improbable. Because of its elegant refinement, *Large String Array* embodies these points of dissonance - two signals interrupting each other's orbit. This piece expresses dueling impulses. It reflects on a deep sorrow in this season of resilience, but there should also be joy to be found in this work - catharsis in a cathedral of sound.

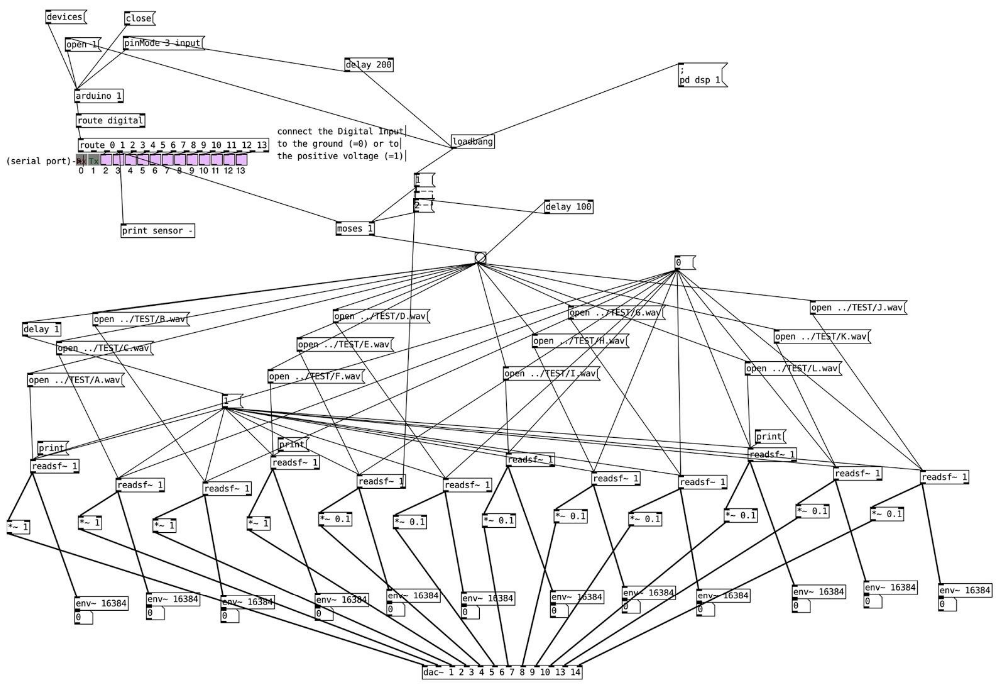
APPENDIX A - WORKFLOW: BLOCK DIAGRAMS


Large String Array Composition Signal Path
Airborne Signal (signal in the wild)
Windowpane & Contact Microphone (SPL converted to electric signal)
High Gain Amplifier (signal boosted)
Super Collider DSP Convolution (signal transformed)
DAW Composition (signal composed)


Large String Array Gallery Signal Path
PIR Sensor Triggers ON and Signals Arduino
Arduino Sends Serial ON to Pure Data via Firmata
Pure Data Playback of Twelve Audio Outputs
MOTU AD/DA Interface To Denon Power Amplifiers
Denon Power Amplifiers to Twelve Dayton Audio TT25-8 Transducers
Transducers Excite Strings
Strings Transmit Signal to Lower Bridges
Lower Bridges Transmit Signal to Drywall
Drywall Amplifies Acoustic Signal

APPENDIX B - SCHEMATICS

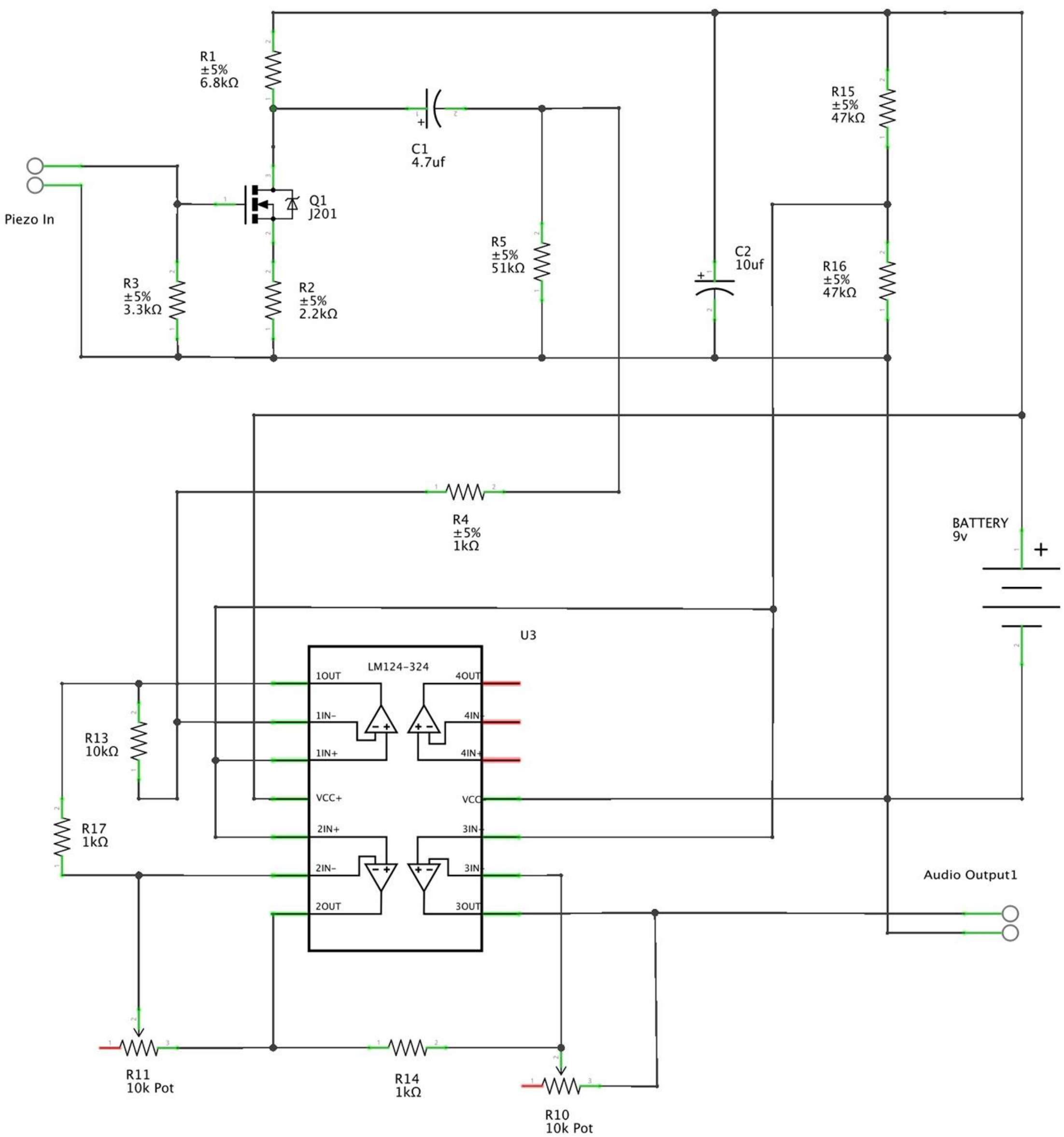
Pure Data Twelve Channel Audio Player



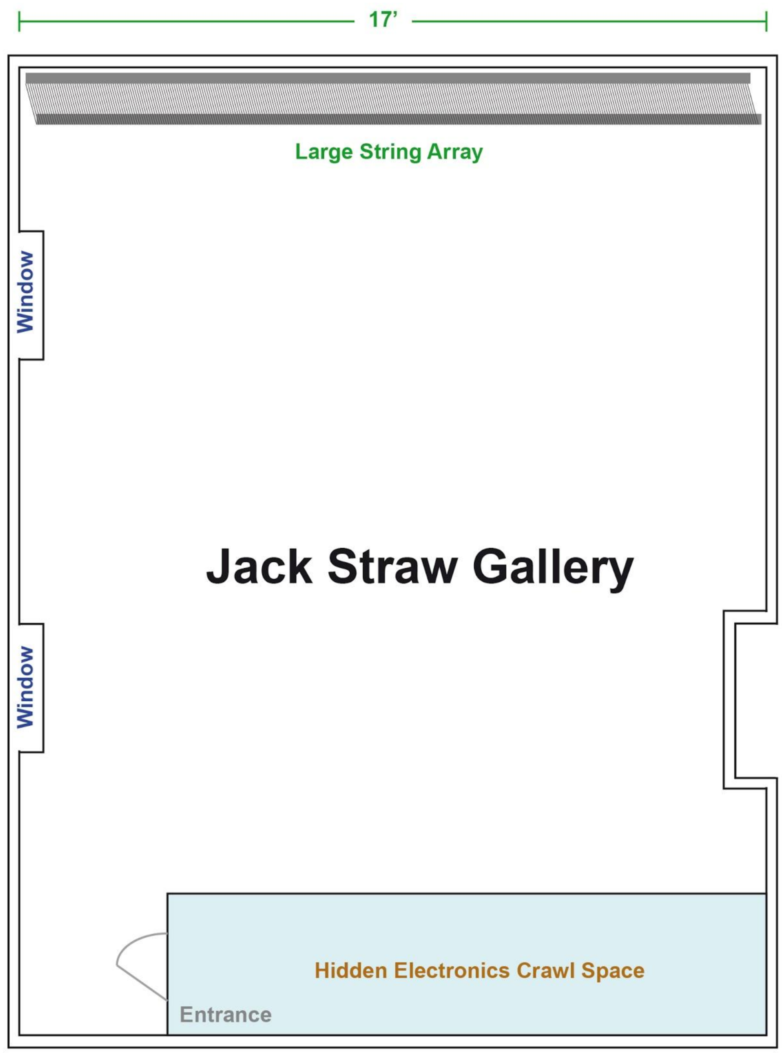
Piezo Amplifier

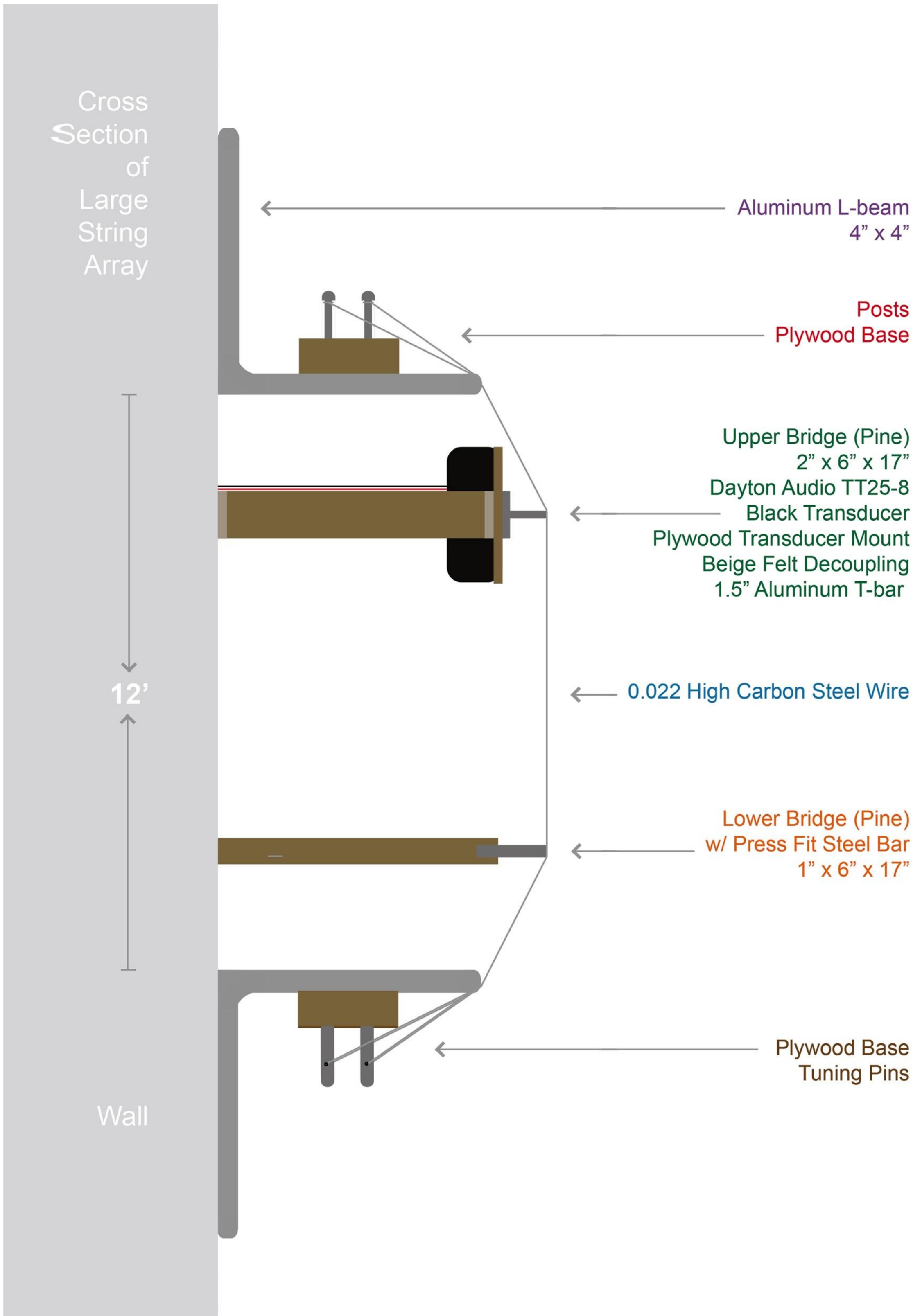
LM324 Quad-Operational Amplifier

2N5457 JFET Preamplifier



APPENDIX C - ASSEMBLY DIAGRAMS


17’
Large String Array
Window
Window
Jack Straw Gallery
Hidden Electronics Crawl Space
Entrance


Cross
Section
of
Large
String
Array
12’
Wall
Aluminum L-beam
4” x 4”
Posts
Plywood Base
Upper Bridge (Pine)
2” x 6” x 17”
Dayton Audio TT25-8
Black Transducer
Plywood Transducer Mount
Beige Felt Decoupling
1.5” Aluminum T-bar
0.022 High Carbon Steel Wire
Lower Bridge (Pine)
w/ Press Fit Steel Bar
1” x 6” x 17”
Plywood Base
Tuning Pins

BIBLIOGRAPHY

Adorno, Theodor. *Quasi Una Fantasia: Essays on Modern Music (Radical Thinkers)*. Reprint, Verso, 2012.

Attali, Jacques, et al. *Noise: The Political Economy of Music (Theory and History of Literature, Vol. 16) (Volume 16)*. Univ Of Minnesota Press, 1985.

Amacher, Maryanne, et al. *Maryanne Amacher: Selected Writings and Interviews*. Blank Forms Editions, 2021.

Austin, Larry, et al. *Source*. Amsterdam-Netherlands, Netherlands, Amsterdam University Press, 2011.

Baschet, François. *Sound Sculptures of Bernard and François Baschet*. New York-United States, United States, Macmillan Publishers, 1999.

“Basic Principles of Exciter-Technology.” *Nanomedicine & Nanotechnology Open Access*, 2020. *201004 / SB*, www.visaton.de/downloads/pdf/visaton_exciter_principles.pdf.

Blereau, Laura. “CV.” *Zimoun*, 2021, www.zimoun.net/cv

Bowers, David. *Encyclopedia of Automatic Musical Instruments*. Amsterdam-Netherlands, Netherlands, Amsterdam University Press, 1972.

Brody, James. *Iannis Xenakis Electro-Acoustic Music.* Nonesuch, catal. H-71246, 1970.

Cowell, Henry, and Joscelyn Godwin. *New Musical Resources. With a Preface and Notes by Joscelyn Godwin.* Edition Unstated, Something Else Press, 1969

Cox, Christoph, and Daniel Warner. *Audio Culture*. Bloomsbury Academic, 2004.

Dodge, Charles, et al. *Computer Music*. Amsterdam-Netherlands, Netherlands, Adfo Books, 1997.

Forster, Cris. *Musical Mathematics: On the Art and Science of Acoustic Instruments*. Illustrated, Chronicle Books, 2010.

Hegarty, Paul. *Noise Music: A History*. Continuum, 2007.

“Her Work – Blank Forms.” *Maryanne Amacher*, 2021, blankforms.org/the-maryanne-amacher-foundation/her-work.

Kelly, Caleb. *Sound (Whitechapel: Documents of Contemporary Art)*. 1st ed., The MIT Press, 2011.

LaBelle, Brandon. *Background Noise, Second Edition: Perspectives on Sound Art*. 2nd ed., Bloomsbury Academic, 2015.

LaBelle, Brandon, and Claudia Martinho. *Site of Sound: Of Architecture and the Ear: Vol 2*. Pap/Com, Errant Bodies Press, 2011.

Meng, Catherine. *Tonight's the Night*. 1st ed., Apostrophe Books, 2007.

Novak, David, and Matt Sakakeeny. *Keywords in Sound*. Duke University Press Books, 2015.

Paganelli, Sergio. *Musical Instruments from the Renaissance to the 19th Century. Translated by Anthony Rhodes from the Italian Original.* London: Hamlyn, 1970.

Pampin, Juan. "A Line | DXARTS | University of Washington." *DXARTS | University of Washington*, 2015, dxarts.washington.edu/research/creative-work/line.

Partch, Harry. *Genesis Of A Music: An Account Of A Creative Work, Its Roots, And Its Fulfillments, Second Edition*. 2nd ed., Da Capo Press, 1979.

Partch, Harry. *The World of Harry Partch*. Columbia Masterworks, vol MS 7207, 1969.

Peleckis, Mindaugas. "LAURIE SPIEGEL: I Asked John Cage Once What Music He Listens to When He Just Feels like Listening to Some Music. He Told Me He Opens the Window and Listens to the Traffic on 6th Avenue | Mindaugas Peleckis | Garsas / Sound." *Radikaliai.Lt*, 2016, www.radikaliai.lt/garsas-sound/3712-laurie-spiegel-i-asked-john-cag e-once-what-music-he-listens-to-when-he-just-feels-like-listening-to-/watch?v=yHuGHrzwlqE.

Psarra, Afroditi. “Embodied RF Ecologies.” ~*Afroditi Psarra*, 2021, afroditipsarra.com/index.php?/on-going/embodied-rf-ecologies.

Toop, David. *Haunted Weather: Music, Silence and Memory (Five Star Fiction S.)*. 1st ed., Five Star, 2006.

Trimpin, Gerhard. “Trimpin Lectures At Form/Space Atelier.” *Wayback Machine*, July 2007, web.archive.org/web/20100617034212/http://artisttrust.org/node/3214.

World Soundscape Project. *The World Soundscape Project’s Handbook for Acoustic Ecology (The Music of the Environment Series)*. 1st ed., A.R.C. Publications, 1978.

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