MODERN SOUND WORKS: BUILDING NEW MUSIC

by

George Numrich III

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Signature of the author _____
George Numrich III
Department of Architecture
May 15, 1987

Certified by _____
Otto Piene
Director of the Center for Advanced Visual Studies
Thesis Supervisor

Accepted by _____
Nicholas Negroponte
Chairman
Departmental Committee on Graduate Students

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ABSTRACT

The use of sound as a medium has increasingly become a viable source for artistic expression. This is especially evident in our current culture where sound has formed a new environment of man-made noise, and where many people can not tolerate a sound-free space.

Modern Sound Works: Building New Music investigates the different approaches artists have had in using sound as a medium, including an analysis of the materials and construction involved. It is important for the sound artist of today to know and understand the history of the medium. It is the artist's role to research the roots of this relatively new and rarely documented art form, to futher understand and develop the medium.

It is important to me and my work in this medium to see the references and correlations of past sound pieces. Everything I have done with sound has its roots in the past. We all need to be aware of historical and current developments so we can learn from those works. "The 37 Strings", an instrument I completed as a result of several years' research, will be reviewed. Its construction will be discussed as well as my relationship to the current work of other contemporary sound artists.

Thesis Supervisor: Otto Piene
Title: Director, Center for Advanced Visual Studies

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Introduction

Sound has become a medium of its own. Its roots are traced through a variety of sources, from the work of visual artists searching for new forms in sculpture, to the composer searching for new forms of composition. Sound has reached a point where it is a medium as real as paint or steel. Sculpting with sound can offer new approaches to space and dimension.

Many sound works are the result of a fusion between musicians and visual artists, and in some cases, physicists concerned with the science of sound. Combining several schools of thought has resulted in a strengthening of the developing medium. It is important for the sound artist of today to know precisely what has been done in this medium to continue its growth. Recreating things done twenty years ago is a result of inadequate research, and as inventors of sound sources we must continue to research our own medium.

I have concentrated on the sound work involving acoustic principles rather than electronic works. I refer to electronic work only in cases which overlap or require further insight into a specific area.

As a sound artist, I find that I have been drawn to the medium because of its infinite potential. Sound instruments can act as a tool for creativity; they are art works that continue to grow with the artist. Many works in other mediums are finite, meaning once it is done, its creativity has been completed for the artist. I am not opposed to this kind of end, but I feel much more compelled by media that continue to grow, forming new identities as time changes.

Most of the sound work discussed in this thesis finds similarities in my own work. With different approaches to similar materials, I can further understand my medium. Working in sound represents to me a collaboration of the

arts and sciences, and an opportunity to expand sonic perception.

The medium of sound is a field which often draws upon the musical and visual arts. Collaborations between artists associated with those fields have confused curators trying to label it, for documentation has its disadvantages. Sound in the early part of the century, as well as today, was rarely recorded or distributed, leaving written descriptions as the documentation. Historically many visual artists created sound (as well as using musical instruments as subject matter in artworks). Marcel Duchamp composed several musical pieces ("The Bride Stripped Bare by Her Bachelors Even", "Errratum musicale", and "Musical Sculpture") and Kurt Schwitters wrote several piano pieces. Schwitters also used the voice as an instrument (as did many Dada artists). The "Ursonate", written out in stanzas, marks pitch, tempo, and dynamics next to the text of words and syllables.

Many composers sought a color-pitch equivalence to form a relationship between the senses, and eventually a new artistic medium. Wassily Kandinsky found a pitch-color relationship that led to his stage play "The Yellow Sound". Alexander Scriabin was one of many who worked on a color organ which produced different hues when different keys were depressed. Scriabin's "Tastiera per luce", or light keyboard, was used for his composition "Poem of Fire (Prometheus)" in 1911.

Collaborations between visual artists and musicians continued through the early part of the century. Mondrian and the Dutch de Stijl movement included composer George Antheil and Jacob van Domselaer. Eric Satie composed music for films by Rene Clair and Francis Picabia, and in the film "Entr'acte" Picabia designed a glass player piano. Satie also collaborated with Picasso in "Parade" and was drawn closer to the visual artists.

Sound environments were also the basis of experimentation. Scriabin's "The Universe", which was never

completed, called for the use of a dirigible to float three miles above the Himalayas and ring temple bells. Although Scriabin never realized "The Universe" (he died in 1915), this kind of massive approach to a sound environment was achieved by the Russian government. "The Concert for Factory Whistles" (1918-21), utilized the entire soundscape of urban factory noise. To emphasize the Bolshevist belief that a state music was indeed the sound of industry, the poets Gastev and Maiakovski organized the participation of the entire population in the performances. Noise became such an issue in the new industrial world that Luigi Russolo began to use noise as the basis of his theories and instruments.

"We shall amuse ourselves by orchestrating in our minds the noise of metal shutters of shop windows, the slamming of doors, the bustle and shuffle of crowds, the multitudinous uproar of railway stations, forges, mills, printing presses, power stations, and underground railways."1

Russolo, an Italian Futurist, found noise so overwhelming in our society that he felt we should compose with it. He began to realize his convictions by creating an ensemble of noise instruments. F. Balilla Pratilla, considered the leading futurist composer, called for a violent break from the traditional mediocrity of Italian music, but Russolo, in his "L'arte dei rumori", manifesto of 1913, advocated a music based on the sounds of daily life.

Russolo began building a series of instruments called the "Intonarumori", or noise intoners. The "Intonarumori" had onomatopoeic names such as the "Rombatore", "Ronzatore", and the "Scoppiatore". The construction of these instruments is vague because none have survived the years (only one photograph exists of the inside mechanism), but through old patents, builders have attempted to reconstruct the "Intonarumori". Their principle was based on the hurdy-gurdy

system. A large box housed a steel or gut string in which one end was seated into a drum head and amplified through a projecting horn. The string was vibrated by a resin covered wheel or a steel wheel with teeth. A moveable bridge controlled the tension and pitch of the string. The performer would control the wheel speed with the right hand (some had an electric motor) and the moveable bridge was operated with the left hand. Russolo created eight different types of the "Intonarumori" which varied in timbre, sonority, and pitch range. He achieved this by preparing the drum head with different chemical processes and using a variety of different vibrating wheels. By 1921, twenty-nine "Intonarumori" had been made.

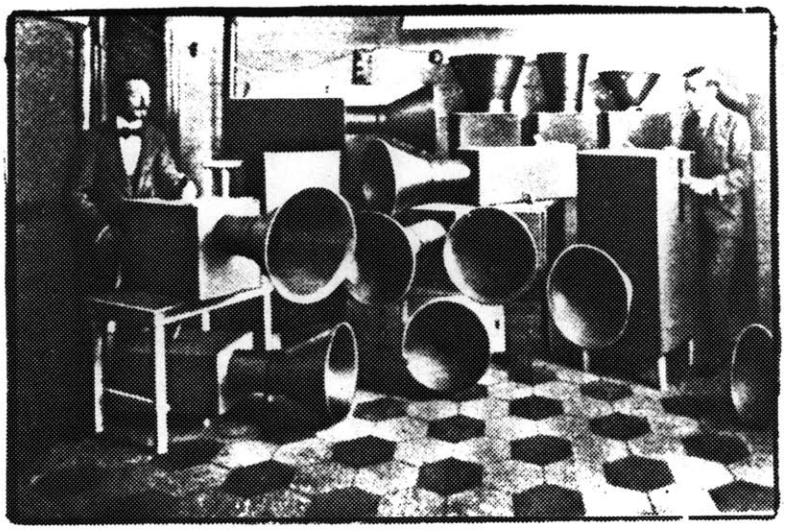
From 1920 to 1929 Russolo worked on an instrument called the "Rumorarmonio" (sometimes called the "Russolfono"). It was a keyboard instrument which played several "Intonarumori". Many of the original "Intonarumori" had been re-assembled in the "Rumorarmonio" which was stored in Paris and destroyed during the war.

Russolo invented two other sound instruments. The "Piano Enarmonico", which was similar to the "Rumorarumori" in that it was a keyboard instrument with similar mechanisms, but vibrated springs instead of strings, and the "Arco Enarmonico", an adapted bow used in playing traditional string instruments. It was constructed of a rod tightly wrapped with wire and when played achieved inharmonic sonorities.

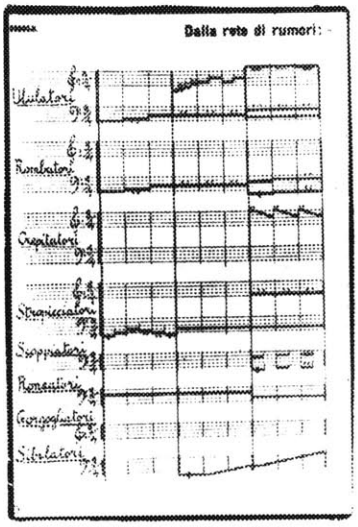
During the early years Russolo performed noise concerts with his ensembles in Milan and Paris causing the familiar public disdain. Russolo wrote several scores for his "Intonarumori" such as "The Awakening City". Pratella and Casavola, both Futurist and colleagues of Russolo used the "Intonarumori" for musical and theatrical settings. The attempt to create a new music reached composers who became fascinated with the music of the machine. Edgar Varese began

using mechanical devices in compositions ("Ionisation", 1931) as did Eric Satie ("Parade", 1917) and George Antheil's use of an airplane propeller ("Ballet Mecanique", 1926) caused as much havoc as Russolo's noise concerts. From sirens to typewriters and propellers, the new approach to sound can be traced to Russolo's original manifesto.

The sound of the "Intonarumori" and Russolo's attempts and achievements were not fully realized until electronic music and "musique concrete" of the late 1940's. Pierre Schaeffer, the primary impetus behind "musique concrete" used natural sound composed "concretely" on tape rather than abstractly through performance. He foresaw, as Russolo had, the impact that sound as a medium would have on the composer. Russolo was one of the first to open the door to the experience of everyday sound and the creation of noise. His dedication to create an entire ensemble of instruments to realize his earlier conviction, is something which places Russolo as one of the founding fathers of modern sound works.



Russolo and the "Intonarumori"



The score to the
"Awakening City"

Inside the "Ronzatore" >

The collaboration of different media found a true bond in the work and efforts of John Cage. Some of his early influences came from Henry Cowell who pioneered the use of the piano in unorthodox playing techniques. Cowell coined the word "tone cluster" in which groups of strings could be played with fingers, fists, or forearms ("Advertisement", 1914). Strings were strummed with the keys slightly depressed lifting the dampers ("Aeolian Harp", 1923), or stopped as they vibrated to sound individual harmonics ("The Banshee", 1925 and "Sinister Resonance", 1930). Cowell was a true creative force in the developing Cage, as was Arnold Schoenberg.

"Schoenberg said I would never be able to compose, because I had no ear for music; and it's true that I don't hear the relationships of tonality and harmony. He said 'You always come to a wall and you won't be able to go through.' I said, well then, I'll beat my head against the wall; and I quite literally began hitting things, and developed a music of percussion that involved noises"2

Reminiscent of Russolo's earlier convictions Cage began developing an instrument of dynamic proportions. The "Bacchanale", composed in 1940, marked Cage's first compositional use of the prepared piano. Created to accommodate an entire percussion ensemble in a room where only a piano could fit, Cage used the opportunity to create a new insight into the traditional instrument. By placing things between, on, and around the strings of the piano, new sonorities were created to form what sounded like an entire percussion ensemble from one instrument. Cage's prepared piano has influenced many musicians through the years including many who still write compositions for it. Lou Harrison, Christian Wolff, and Cornelius Cardew are among the hundreds of artists who have employed some form of the

prepared piano in compositions.

Historically, the creation of the prepared piano was a result of a space requirement. Cage had been writing for percussion ensembles previously using instruments ranging from kitchen utensils to found objects. The prepared piano was an inevitable realization in his growth towards new percussion ideas.

The preparation of a Cage piano requires the use and placement of specific materials. Using metal may create a metallaphone sound like gongs and cymbals. The most common material in this category is the bolt or screw. When considering timbre requirements for a certain key, one may choose a screw with a finer thread creating more contact with the string thereby changing its timbre. Cage specifies small, medium, and large which refers to length rather than mass. Washers and nuts can make a buzzing vibration and are generally secured by a screw or bolt. The relation between size and weight of the washer are obvious and the difference between star lock washers and a 1/4 inch nut are apparent. Cage used many other metals such as coins, U-bolts, and metal strips, all of which reflect the metallaphonic sound in some manner.

Fabric, cloth and, specifically, piano felts are weaved in and out of the strings. The use of the material creates audible harmonics, but the attack becomes a dull thud. The placement of the material along the length of the string is crucial to which harmonic (or partial) will sound. A string with a felt at the midpoint will sound the 2nd partial (or octave) and a felt placed at the 1/3 length will sound the 3rd partial (or the octave and a fifth).

Rubber materials create a very dead thud and Cage specifies only an 1/8 inch measurement. Many rubber materials can be used such as piano tuners mutes, foam rubber, sheet plastic, and erasers.

These materials are only a small sampling of the

endless possibilities that can be used, compounded by the fact that many of these preparations can be used together. The amount of attack can alter the sound significantly, and the placement of the preparations, in regard to the length of the string, affects the outcome of the sound.

Cage's preparations are usually included in the score. He designates the note, the kind of preparation, the strings used in the unison, and the placement on the string's length. The composition, "Two Pastorales", is the only piece for which Cage demands the specific use of materials requiring exact sizes and dimensions.

Most preparations are done before the performance and therefore the written notation is traditional. When a preparation is done during a performance, there is generally a footnote giving an instruction.

Although Cage did not really invent a new instrument, he did alter an existing one, opening a new avenue for thought. The prepared piano was a very untraditional creation, almost a toy, but it was capable of making competent music. As Russolo opened the world's ears to the environment of noise, Cage opened the world's ears to the environment of sound as a musical possibility. In this respect he gave us a new freedom to make sound in any fashion and with anything. He continued to use everyday ojects, such as brake drums and rice bowls, for instrumentation into the 1960's.

Cage experimented with the idea of using the radio as a sound source in 1942, and in 1951 used 12 radios and 24 performers to realize "Imaginary Landscape no.4". Cage, with associate David Tudor, experimented with placing objects into magnetic phono cartridges ("Cartridge Music", 1960). Recently he has become interested in amplifying natural sounds, such as the spines of a cactus ("Branches", 1976), and the sound of water gently rocked back and forth in sets of conch shells ("Inlets", 1976). Cage became a leading philosopher of the arts, bridging the music world and the

art world with his collaborations. His commitment to experimenting with sound and silence has significantly contributed to our present sound position.

Contemporaries of Cage include Earl Brown, who in 1963 composed music centered around an Alexander Calder mobile. Calder made the "Chef d'orchestre" sculpture specifically for Brown's "Calder Piece". The performers strike the metal pieces of the mobile as it revolves, to create a kinetic percussion ensemble.

Cornelius Cardew, Morton Feldman, Christian Wolff, and Karlheinz Stockhausen were all composers extremely devoted to using new principles in composition, and open to using new instruments, especially in the area of percussion. Mauricio Kagel was interested in new percussion sources, and made his own instruments to use in performance. "The Drum Man" (1966) included a performer with several drums attached to his body while being played by percussionists. Kagel also wrote "Zwei-Mann-Orchester" (1971-73) in which two performers attached chains, strings, rods, and wires to 19 different parts of the body. Each connection led to an instrument which was played by movements of the body. The score informs the performer to take different positions to make different sounds. Kagel has also worked on a prehistoric orchestra (Die Erschopfung der Welt, 1974-77), in which animals were created as instruments including a giraffe with springs for the legs and neck, a frog with pan pipes for its lower jaw, and a hippopotamus with castanet toes and two guitar bodies for jaws.

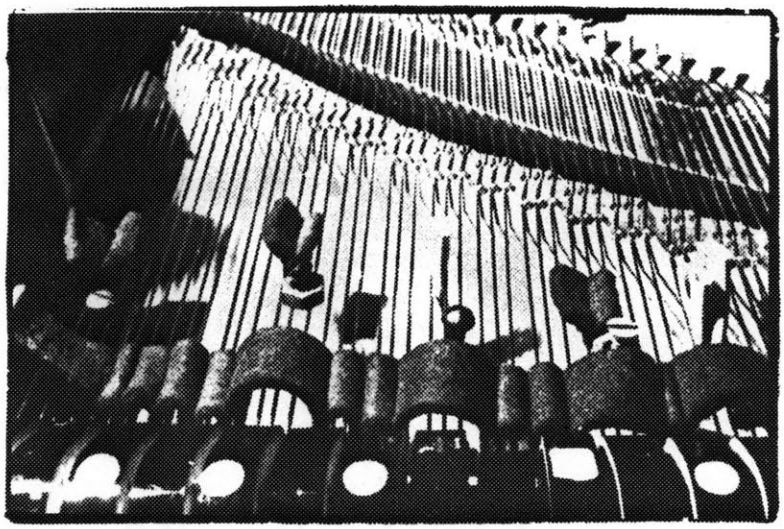
In the late 50's, Cage influenced several composers and artists that formed the movement called Fluxus. Reminiscent of the Dadaists and the Futurists, this group was interested in non-theatrical qualities of a game or a gag in an event setting. Musicians, Maciunas, Brecht, Paik, Kosugi, and artists/poets, Kaprow and MacLow, were some of the Fluxus artists influenced by the teachings of Cage at the New

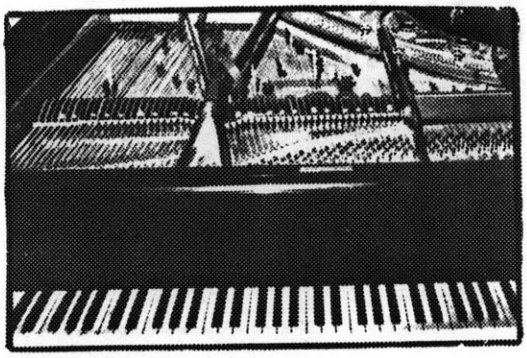
School of Social Research.

George Brecht, originally a painter, became interested in events. Some of his events involved running cars ("Motor Vehicle Sundown", 1960), combs ("Comb Music", 1962) and water (Drip Music, 1962). He also used children's toys, which became a widely used instrument in Fluxus compositions.

La Monte Young, a composer from the West Coast, concentrated on less traditional music qualities than other Fluxus artists. "Poem for Chairs, Tables, and Benches, ect." and "Other Sound Sources" (both 1960), used moving furniture as the instruments (not unlike Satie's "Furniture Music", 1921). Young used a random process for calculating time and duration of each sound by selecting numbers from a phone book, or picking other digits randomly.

The Fluxus Movement began to investigate the possible use of ordinary sounds in a somewhat controlled environment. Traditional instruments were rarely used, except for Charlotte Moorman, who played the cello in extremely untraditional ways, such as playing Nam June Paik as a human cello. The Fluxus artist were continuing the tradition of the Futurists and John Cage in breaking away from traditional musical attitudes. The use of events and collaboration, especially between the arts, was a primary achievement of the Fluxus artists.





Prepared Pianos

Conlon Narcarrow,
John Cage,
and Nam June Paik

Harry Partch was an instrument designer and composer who dedicated himself to the realization of his own tuning systems and instruments. Primarily a self taught musician, he rejected the 12 tone equal tempered tuning system and created a just tuning of 43 tones in the early 1930's. Microtonal tuning systems had been the basis of experiments in the previous century such as R.H.Bosanquet (53 tone), Colin Brown (40 tone), and General Thompson (53 tone). They all used the harmonium (as did Partch) for its stability and ease in tuning changes.

All the pitches in Partch's tuning system are represented by ratio. The 2/1 representing the octave, 3/2 the fifth, 4/3 the fourth, and so on. The unique aspect of this system is the capability of tuning all 43 tones by ear. From the 1/1 (Partch used G- 392), all the ratios could be tuned by eliminating the beating which occurs in the upper mode frequencies. The 3/2 is tuned from the 1/1 and eventually, in a specific order, all the ratios are tuned from one another. After the entire scale has been tuned, there is a system of cross checks to insure the precision of the system.

In the 1930's and early 40's, Partch adapted instruments such as the viola (which Partch played), guitar, and a chromelodeon. The earliest compositions realized with the 43 tone scale monophony were with the viola and the voice. In the early 1950's he began to create his own instruments instead of adapting existing ones. He designed chordophones, idiophones and areophones, to realize his compositions in the 43 tone scale. Not only did the instruments serve as the vehicle to create his compositions, but also had a visual beauty that served as stage sets for his large theatrical productions, specifically "The Delusion of the Fury".

Partch required a strict playing technique that usually pushed the physical stamina of the performer to a maximum.

He often drew his ideas from ancient cultures and in several cases required performers to play an instrument while portraying a chariot racer in the midst of a grueling finish. With certain instruments, such as the "Kitharas", some notes were required to be reached by bending the knees and keeping the back straight instead of a more natural back bending approach. He often said, "Don't bow to an instrument". Even if an instrument were easy to play, he would specify that visually they be most demanding.

A brief description follows of some of the instruments built and adapted to constitute the ensembles which performed the music written in the 43 tone scale. Partch designed a series of chordophones, the "Kitharas", the "Canons", and the "Crychord", and adapted the viola, guitar, and koto. The "Kitharas" were representative of the ancient Greek kithara (except the "Surrogate Kithara" which was horizontally positioned). The "Kithara 1" has 72 strings in 12 columns with pyrex rods which create sliding sounds or different intonations. The strings are plucked by finger or plectrum. The playing area and the spruce soundboard rests on top of large resonators. Notation represents the corrolating ratios which are painted on the playing area in bright colors.

The "Harmonic Canons", originally called a multiple monochord, were horizontally positioned. The playing area of the "Harmonic Canon 1" has an upper and lower set of strings. The upper is played with the left hand, the lower with the right, or both sets of strings at the middle where they intersect. The other "Harmonic Canons" ("Castor and Pollux", and "Blue Rainbow") have just one set of strings divided by a bridge into the left and right playing areas. Playing and notation are both complex. Two staves, one for the right and one for the left, with notes representing a string number, correspond to the ratios painted on the playing area. The building materials were a sitka spruce or

redwood sound board, guitar machine pegs, plexiglass, and oak.

The other chordophones, such as the viola and the guitar, were fitted with longer or wider necks, otherwise they retained their traditional framework. The "Koto" was not altered except for the addition of a base which increased the resonance and increased the playing comfort. The "Crychord" was an instrument built for Partch by a student. It uses the monochord idea and was primarily used in improvisational applications.

There are only two instruments in the aerophones category, the "Chromelodeons" and "Bloboy". The "Chromelodeons" were adapted harmoniums and one of the earlier instruments. They became invaluable as a tuning aid for the rest of the ensemble because of their stability in pitch. Once the reeds had been shaped to the correct pitch they stayed regardless of conditions which constantly affected the other instruments. First designed in the 1940's, they essentially did not change from their harmonium appearance, except to be wrapped in mahogany plywood to better fit into the visual appearance of the ensemble. Several of these instruments had been adapted, differing only in the amount of keys and stops. The ratios were painted on the key, and in sheet notation, were represented by traditional notes on staves (meaning a F# notated and played on the keyboard actually sounds the 11/7).

The "Bloboy" was an instrument which contained bellows attached to three organ pipes and four antique car air horns. When the bellows are thrust upon with the foot, the sound of a distant freight train is heard. This is the primary use for this instrument, although it was used in two other applications, differing slightly from the original sound and image of the freight train ("U.S.S. Highball", 1943).

The idiophones Partch designed ranged from glass to wood

to metal. These are the instruments he is best remembered for, with their rich resonant qualities and their visual beauty. With the wood key, Partch created an entire family of marimbas. The first was the "Diamond Marimba" which had rosewood and pernambuco keys with bamboo resonantors. The range of this marimba was three 2/1's and the shape was derived from Partch's theoretical expanded tonality diamond. The shape was intriguing but caused great difficulty in playing because of the excessive cross stroking required of the performer while hitting the block in the proper method.

The "Bass Marimba" and the "Marimba Eroica" are among the most popular instruments and remembered for their deep tones. Both built in the early to mid 50's, they represent a continued devotion to achieve low resonances. Both used sitka spruce for the massive blocks and organ pipes for the resonators. The range of the marimbas overlapped, meaning the lowest note of the "Bass Marimba" was the highest note of the "Marimba Eroica" (and agian, the highest note of the "Bass Marimba" was the lowest note of the "Quadrangularis Reversum"). The longest block of the "Marimba Eroica" was 90 inches and the shortest was 55 inches. The "Bass Marimba" blocks were shorter but used straight organ pipes causing the instrument to stand 60 inches high. The great length needed for the resonating pipe in the "Marimba Eroica" (about 12 feet for the 22 cycle note) was achieved by using angled sections of organ pipe. The coupling between block and resonator is critical and often needed to be re-tuned due to weather changes. The mallets were also of giant proportions to excite the deep frequencies.

The "Quadrangularis Reversum", built in 1965, represents a period in which Partch experimented with the sculptural possibilities of the instrument. Visually appearing as a Japanese shrine, the "Quadrangularis Reversum" contained 57 blocks made of African padouk with bamboo resonators. A mirror image of the "Diamond Marimba" is located in the

center with two alto sections on each side. Two eucalyptus posts support the tori bar which was intended to give the instrument a feeling of floating.

The "Mbira Bass Dyad" was another idiophone which was designed to reach deep tones. Built in 1972, it used a tongue and resonator system. Two thick blocks of osage orange are coupled with two resonators and played with heavy mallets. There is a small bridge under the block which allows some flexibility in tuning by lengthening or shortening the length.

Partch had a long association with bamboo as a building material. He often used it as a resonator, but also created a group of instruments using bamboo as sounding blocks called the "Boos". They used a tongue and resonator system similar to the "Mbira Bass Dyad", but the tongue and resonator were both created from the bamboo itself. Two grooves were cut into a hollow bamboo cylinder allowing the tongue to vibrate, while the tube itself acts as the resonator. Bamboo is extremely unstable, affected by weather changes, so the metal straps which secure each block can be loosened or tightened to correct pitch.

The "Eucal Blossom" was also a bamboo instrument differing from the "Boos" in that they have no tongue. The piece of bamboo rod is the key and its length establishes the pitch.

Partch began to use glass in the 1950's with the completion of the "Cloud Chamber Bowls". Glass jars found at the Berkley Campus Radiation Shop were cut and suspended, allowing them to ring freely. Breaking was inevitable; the performer was carefully trained in the correct method of playing.

Another instrument using "Cloud Chamber Bowls" was the "Spoils of War". It had six percussive effects, the "Cloud Chamber Bowls", wood blocks, brass shell casings, bamboo tongues, whang guns, and a guiro gourd.

The "Zmo-Xyl" completed in 1963, used glass, wood blocks, and hub caps. The blocks were made from white oak (originally part of one of the "Chromelodeons" before the mahogany casing), and the glass was 17 specific brands of liquor bottles. Researching the pitch relationships in bottles, Partch found a perfect 1/1 in Bristol Creme Sherry and 16 other tonalities conforming to the 43 tone scale. Breakage here was not as crucial as the "Cloud Chamber Bowls" for the replacements were readily available at the local liquor store as long as the correct brand existed.

Another glass instrument built in 1963 was the "Mazda Marimba". Similar to the use of liquor bottles, it incorporated the use of light bulbs with the bases removed. Their arrangement tonally was similar to the "Boos" and tuning was achieved by breaking more glass off the stem or wrapping tape on the stem to create more mass.

The last instrument to be discussed here is the "Gourd Tree and Cone Gongs". It represents one of the more sculptural instruments using a eucalyptus branch to suspend twelve tuned Chinese temple bells with attached gourds to increase their resonance. Airplane gas tanks function as tuned gongs and enhance the sculptural appearance.

Most of the notation for the instruments was written on traditional music paper. More complex applications necessitated the use of different symbols, such as circles, squares, or triangles, representing different parts of the instrument (such as the "Zymo-Xyl" instrument with more than one keyboard). The cone gongs were notated with similar shapes corresponding to different areas of the cone on which to hit. The final notation, once familiar with playing the instrument, is as clear as a traditional manuscript, although the actual pitches are not indicated.

Partch continued to create instruments until his death in 1976. They were predominately small hand-instruments used by performers in "The Delusion of the Fury", for which he

achieved national notoriety in 1969. He made many recordings under his own label (an only source of income) called Gate Five, and later CRI and Columbia. Two recordings exist that best represent each individual instrument, "And on the Seventh Day Petals Fell in Petaluma" (CRI #213) contains duets and quartets of the instruments, and a disc of individual instrument solos available in limited quantity, with the "Delusion and the Fury" (Columbia M2 30576).

Harry Partch designed instruments for his own purposes, unlike anyone before. Playing techniques, instrument design, notation, and performance were all part of his total concept of the art form he pursued, although he never considered himself an instrument builder, rather a "composer seduced into carpentry". He wrote music that created a new approach differing from the 12 tone equal tempered system. His influence is widely felt in both instrument building and tuning systems as seen in the current sound movement in California. The entire collection of instruments is located in the Harry Partch Foundation in San Diego. The instruments are periodically used in performances and have been exhibited in museums.

Partch was one of several people to use microtonal scales. As mentioned earlier, several people experimented with the harmonium in the previous century. In the beginning of the 20th century composers began to use new tuning intervals to realize compositions. Charles Ives' "Chorale" (1903-14), was written for strings, but probably based on the experiments he had done in 1903 with two pianos tuned a 1/4 tone apart. Olivier Messiean also used a microtonal scale in the "Fetes des belles eaux" (1937), using an early electronic instrument called an "Ondes Martenot", which was also used by several composers throughout Europe.

Julian Carrillo was similarly dedicated to creating a microtonal ensemble. In the 1920's, he began building several instruments of his own design. The 1/8 tone

"Octavina" (bass guitar), the 1/16 "Tone arpa citera" (harp), and a 1/4 tone trumpet formed some of the pieces of his ensemble which toured Mexico in the 1930's under the name "Orquesta Sonido Trece".

The largest influencial microtonalist was of course, Partch, who had quite a following in California, especially in the 1960's. Ivor Darreg, a contemporary of Partch's, has assumed the role of critic of equal temperment tunings. Often outspoken in his criticism, Darreg builds several instruments with names like the "Hob Nailed Newlpost" and "The Megalyre", capable of several different tuning systems.

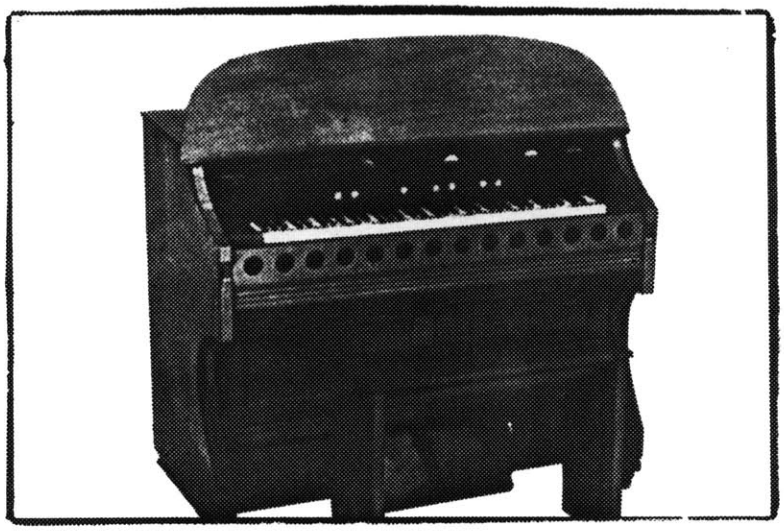
Other Californians who worked directly with Partch are Prent Rogers, Jonathan Glasier, and Cris Foster. They have formed the Interval Foundation in San Francisco which publishes current developments in the world of tuning systems (Interval Magazine). Very few of the newer breed of microtonalists realize compositions, but rather use improvisation with their instruments. David Cope is one of the few who uses a compositional structure (in 31 tones), as is Tillman Schafer who has transplanted himself to the East Coast, and uses compositions involving 53 tones.

Microtonal designs are fewer outside of California. Carrillo had some devoted followers who continued his work in Mexico. David Aviles has built the "Arpas armonicas", with 400 notes per octave, as well as several other large number systems. There are plans to create a Carrillo Museum in Mexico, which will also house Carrillo's students' microtonal instruments.

In the mid-60's, many Gamelon societies were formed, probably due to the work of Colin McPhee and Lou Harrison. Many universities began developing Gamelon orchestras, and became interested in ethnological studies in music. Lou Harrison used Gamelon instruments to bridge east and west music with his own ensemble. Since the early 1970's, Gamelon societies have become very popular, making them one of the

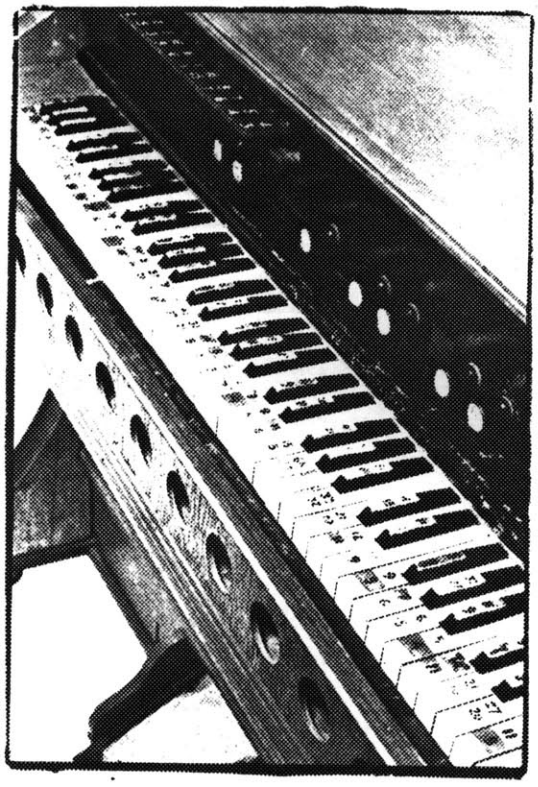
largest groups of instrument makers today. Most of the instruments are made by the members and consist primarily of metallophones. The resonators are often made of coffee cans, and are styled and designed after the traditional Gamelon orchestras. These societies are common throughout the U.S. cities.

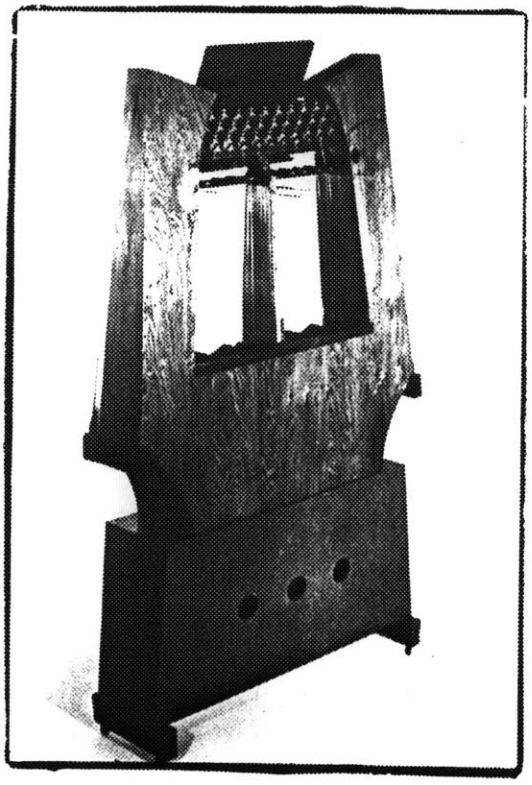
The instruments of Harry Partch



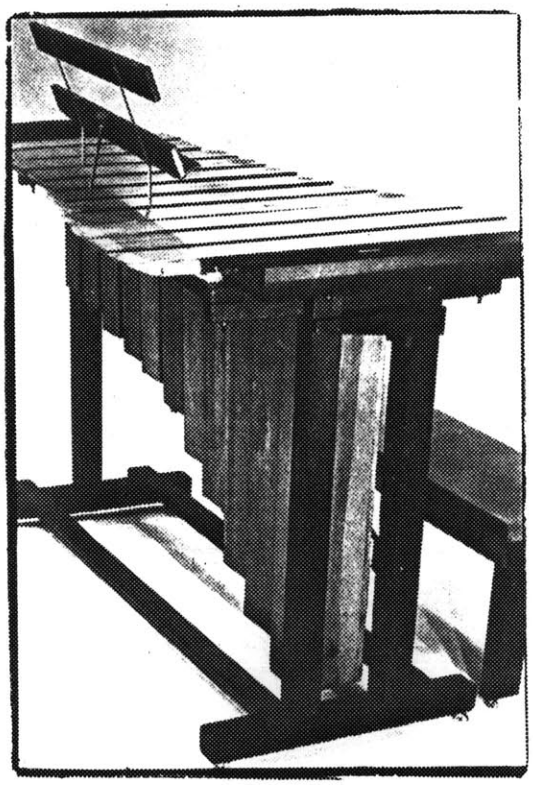
"Chromelodeon 1"

and keyboard >

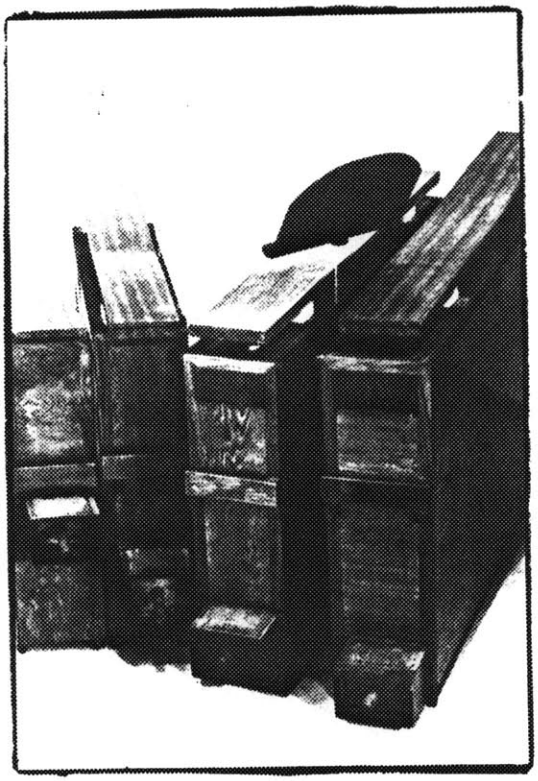




< "Kithara"



"Bass Marimba"



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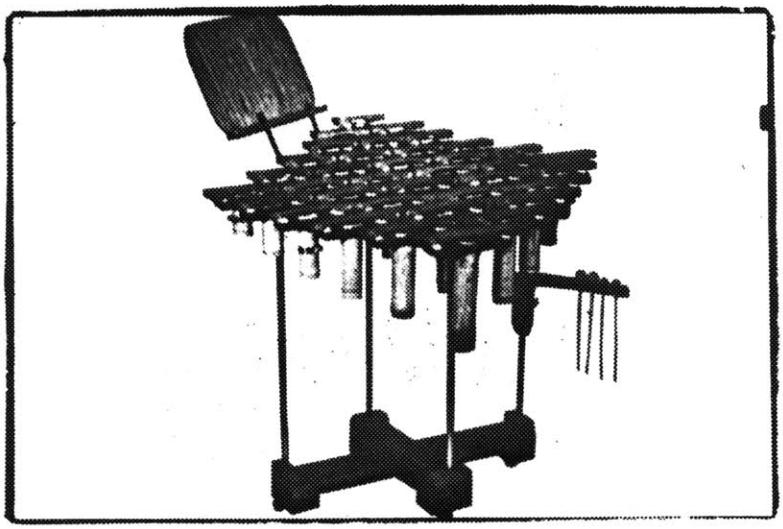
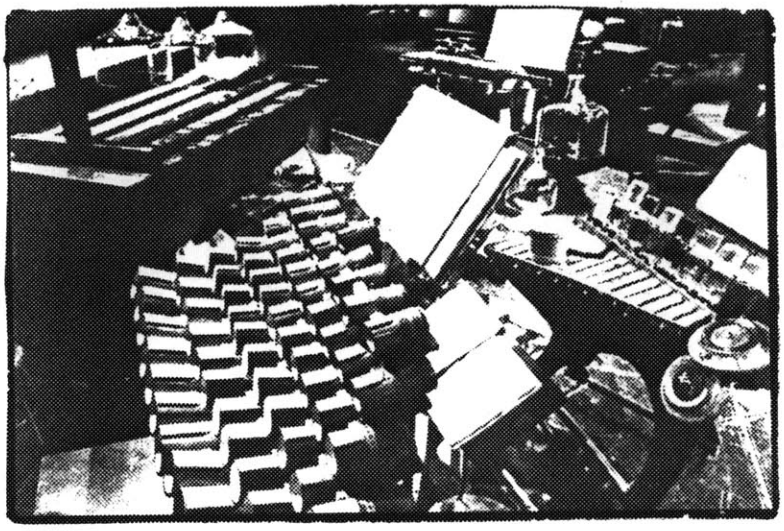
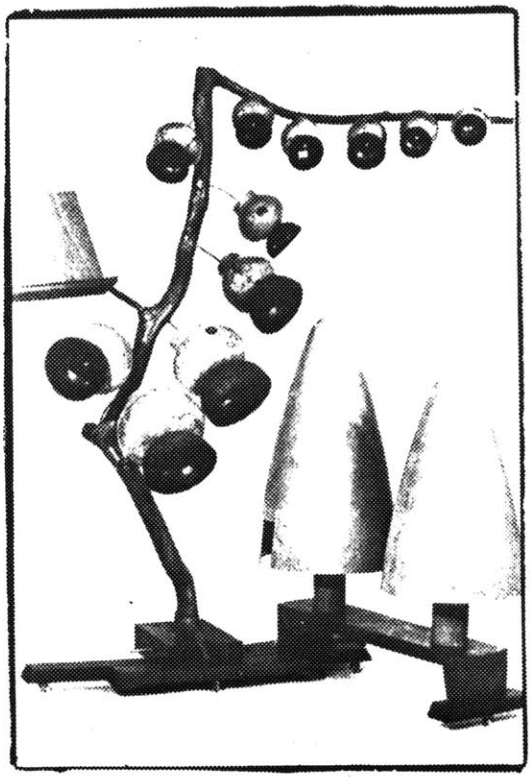


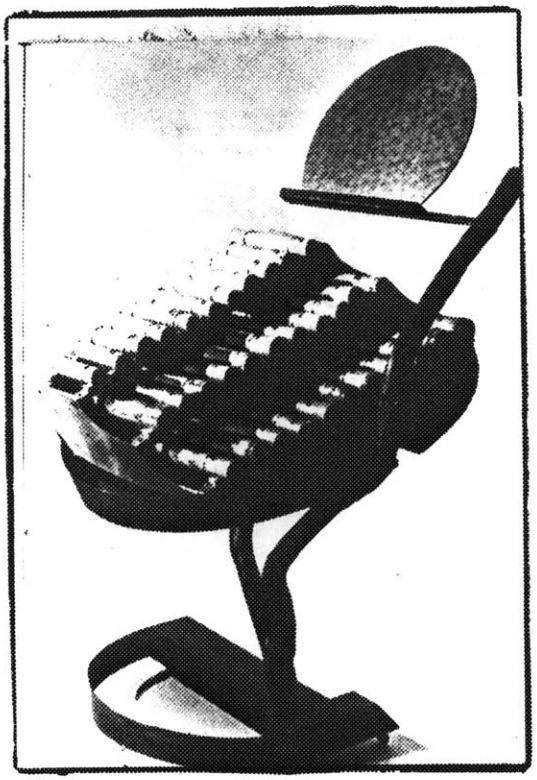
"Diamond Marimba"



Set for "Delusion of the Fury"
"Boos", "Mazda Marimba" shown



"Gourd Tree and Cone Gongs"



"Eucal Blossom"

Bernard and Francois Baschet were two of the first artists dedicated to the use of sound as a medium. Francois was trained as a sculptor and a designer, while Bernard was trained as an engineer. Their interest began in a collaborative effort to research the design and properties of traditional instruments. Their first sound instrument, completed in 1952, was a portable guitar with an inflatable plastic body. That instrument was a forerunner of the "Structures Sonore", a generic name they would give their family of instruments.

The majority of the "Structure Sonore" are based on the friction rod or nail violin system. Vibrations are created by rubbing (usually with the hands) a metal or glass rod which is attached to a large metal resonator (although they have used cardboard, plastic, and fiberglass). These resonators radiate the sound with surprising volumn and have become a trademark of the Baschet's work. The collaboration between the two brothers, in a sense, is a fusion of science and art. By using each other's expertise, they control the timbre and quality of the sound by its form. By changing the shape, or increasing a fold in the resonator, they can alter the acoustic properties of the instrument.

During the 50's and 60's, the Baschets formed a instrumental group called "Structures Sonore", utilizing several of their sculptures. Most of the pieces were based on the friction rod principle, although a few involved strings and wind. Several composers have written pieces for the Baschet's ensemble. Jacque Lasry worked with them from 1954 to 1963, and Toru Takemitsu in the mid 60's.

The Baschet's have recently worked towards creating public sound environments. Much of their current work involves very large structures, including sound fountains and musical clocks. They continue to make small and personal instruments, but have geared most of that work for

interaction with children.

Harry Bertoia, not unlike the Baschets, used his background as a successful designer to make sound sculpture. He groups several metal rods together on a pedestal which when gathered together and allowed to spring back and forth, hitting each other, create a wash of sound. Bertoia controls the timbre of the sound by using different metals and alloys. He has called these instruments "Sonambient".

Several people have used these sculptures in film music. Bertoia also created a "sounding box" barn at his home in Pennsylvania, where a large number of "Sonambient" was grouped together as a large sound environment, created and played by Bertoia. He has, not unlike the Baschets, made large outdoor environments in the form of fountains and wind activated sculpture.

During the 1950's and 1960's, while Cage and the Fluxus group dedicated themselves to new attitudes in music and performance, a group of people dedicated to kinetic sculpture began to emerge. From early influences, such as Moholy-Nagy ("Light-Space Modulator", 1922-35) and Alexander Calder's mobiles, the movement towards kinetic sculpture began a new attitude towards sound. Many of the artists who incorporated movement in their work perceived the potential relationship of that movement to sound. Many of the kinetic artists soon became fascinated with the idea of sound as a medium and continued to explore its possibilities.

A form of sound sculpture can be found historically in the mechanical systems of the music box. Hupfeld's "Phonoliszt-Violina" (1912) is an excellent example of an early kinetic sound sculpture. The mechanical fingers depress the string of a traditional violin as a mechanical bow sets up the vibration. The music box served an important source of entertainment in the previous century until the introduction of the gramophone and the radio. After the

gramophone and radio had become popular, many gained a new respect for the music box and especially the pianola, with composers Hindemith and Stravinsky writing compositions specifically for them. Today, composer Conlon Narcarrow uses the player piano to realize compositions that can only be done on the machine instruments. The Cross-Granger "Free Music Machine" (1945) was another form of early sound sculpture. Although most of their creations were electronically generated, they did build two machines that used harmonium reeds (in a microtonal, 1/8 tone tuning) and were controlled by a paper tape and pneumatic system. Several of the machines have survived and are exhibited in the Granger Museum, Melbourne, Australia.

The mechanisms of the music box interested a young Jean Tinguely. Born in Switzerland in 1925, he began building sound sculptures as early as 1938. His first creation was a percussion machine powered by a small stream, in which revolving water wheels caused hammers to hit tin cans.

Similar to the musical clocks of the 1800's, Tinguely began to build mechanical objects using wire gears fashioned after watches in humorous and unpredictable methods. During the years 1954-55, Tinguely added motors, pulleys, and belt drives, in conjunction with found objects. His work was often compared to "musique concrete", also located in Paris. Composer Toshi Ichiyanagi used the sculptures of Tinguely for the composition, "Music for Tinguely" (1963).

Tinguely's greatest coup was his "Hommage to New York" (1960), in which his sculpture self-destructed in the courtyard of the Museum of Modern Art. He mixed the elements of sound, kinetic action, and humor into a large sculpture/ performance/event. Tinguely did several pieces involving destruction and the sound and force associated with it.

In 1962 Tinguely incorporated the radio into his sculpture. He exposed the inner pieces of the radio creating shapes sometimes resembling animals. All of his radio

sculptures utilized a small motor that continually changed the station. Tinguely's recent work involves the use of very large industrial-style gears and flywheels. The "Meta-Harmonie Series" (1978-80) creates an urban factory roar in a manner that earlier Futurists would have appreciated.

Many other kinetic sculptors used sound in their work. Len Lye used the sound of a metal loop being pulled and realeased to pulsate ("Loop", 1963). He had a unique way of using the natural properties of his materials to achieve kinetic and sonic forms. Lye used magnets and their built-in kinetic potential to achieve the force he needed to start his sculpture.

Takis has also used electromagnets to create kinetic sculpture and sound. He has used small needles which jump about on strings due to a reversing polarity. The strings are stretched across a large metal resonator which sounds the action of the needles ("Electromagnetic Music", 1963-75). He has incorporated solenoids (an electromagnetic plunger) into similar pieces, in which mallets strike the metal resonators, not unlike a gong ("Big Tube Series"). Recently Takis has combined his previous sculptures along with new pieces to create "Trois totems-espace musical" (1981). He uses mercury vapor lamps, electrical apparatus, pendulums, amplified strings, metal tubes, and wood beams in a large sound environment. The wood beams are the latest addition to his sculptures. They are similar to a "Semantron" which is a Greek sounding-plate used to call a congregation to prayer. Takis applies a solenoid with mallets to sound the "Semantron", along with the sounds of his other sculptures.

Joe Jones created several sculptures combining kinetic influences with musical instruments. He completed several pieces that used the violin as the sounding mechanism. ("Four String, Black Painted Violin", 1968, from the "Erector Set Series"). He still uses the violin and similar

sounding devices in current work ("Violin in a Bird Cage", 1981). His juxtaposition of images often evoke a humorous image.

Many of the kinetic artists experimented with sound. Robert Rauschenberg combined sound with several pieces and Yaacov Agam made several sound sculptures. Even the large sculptures of Mark diSuvero can create an eerie sound as the metal structures slowly move in the wind. These are just a few of the artists involved in kinetic sculpture that have used sound. Many of the people mentioned here are still very involved in the creation of sound, as well as the use of kinetic force.

In the 1970's sound was being used as its own medium and several exhibitions were put together of artists concerned solely with sound. The major shows were held in Vancouver, Oakland, Ghent, and Edinburgh. The West Coast of North America and the British Isles were established as the major centers for sound works. They have begun to lose their dominance recently, but are still areas of large populations of sound artists. The movement in Art and Technology also played a significant role in sound work during this period. Many exhibitions were organized involving sound ("The Machine Show", 1972), and often the use of interactive electronic devices was employed to incorporate the audience. Although most of the sound work was electronically generated, it was an important step for sound as a medium.

Stephan Von Huene uses the technology of the early music box. His sculptures are usually run by pneumatic systems and are controlled by perforated tapes. He often pieces the parts of his sculptures together in humorous ways. "Kaleidophonec Dog" (1965-67), uses the body of a dog, lying on its back, playing a xylophone with its feet, producing sound in conjunction with internal organ pipes. His "Totemtones" (1969-70) have been exhibited widely. Punched tape controls blowers attached to organ pipes, usually

grouped in series of three. Automatic valves control different openings and vents which vary the sound of the pipes. When the "Totemtones" are on, they can create sound in the form of composition. Von Huene has also used many percussion devices in his work and has collaborated with composer James Tenney ("Drum", 1975) in the use of a drum surrounded by many sticks for the composition entitled, "Wake for Charles Ives". Von Huene has recently been using glass tubing to create new percussion and tonal sounds.

David Jacobs has used organ pipes and reeds in combination with inflatable sacks. Some of the very large pieces ("Wah-Wah", 1968) take 20 minutes to inflate and sound to a peak, and then another 20 minutes to deflate to silence. As they inflate and unfold, new reeds begin to sound. Similar to Von Huene's "Totemtones", a reed or organ pipe sounds several different partials as the amount of air passing the reed or pipe is varied. When the "Wah-Wah" is inflated, it can produce several pitches from the same pipe.

Reinhold Pieper Marxhausen has created very unique and different sound sculpture. They are sometimes in the form of headphones and become a personal experience as you play them. He has coined the phrase "listening to door knobs", and has combined several found objects into small, personal sound sculpture.

R. Murray Schafer, a Canadian, became interested in the sound of the environment. He made several investigations into the soundscape of different man-made and natural environments. Travelling to different parts of the world, he recorded the different sounds he heard and their related frequencies, in a sound diary. His many books on soundscapes offer a different and philosophical approach to sound sculpture. He is still involved with the same kind of research and currently using radio as an environmental sound medium.

These are some of the people associated with the West

Coast sound movement (involved in exhibitions or teaching and living there). There was also a large group of sound artists in the British Isles. They use quite a different approach to sound sculpture than the West Coast artists. Many of them use found objects as the source of the sound. They are not often modified from their original design ("Stainless Steel Rods", Hugh Davies, 1973). Much of the sound work is intended to be used in improvisational composition, not as visual sculpture, but as a performance tool. Several of the performance groups became well known, such as the "Scratch Orchestra" (led by Cornelius Cardew) and the "Portsmouth Sinfonia" (led by Gavin Bayers). They felt that the performers needed to release the creativity within themselves and therefore traditional ideas of composition were not used.

Hugh Davies has created hundreds of sound sculptures, the first of which he called "Shozyg" (1967). Similar to the later version, "Feely Boxes" (1969), they are self-contained, often in a dictionary or an accordian file, and produce the sound of what ever is inside. They are often amplified, as are most of the found objects used in his work. Recently Davies has become an authority on sound sculpture, working with many institutions involved in cataloging the sound medium.

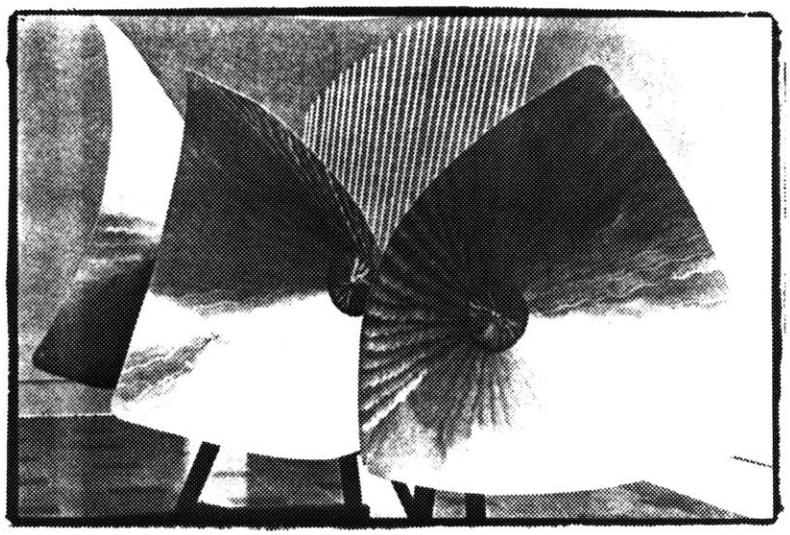
Max Eastly has approached sound in a more sculptural sense than many of his colleagues. He is devoted to creating aeolian harps in new ways other than the traditional methods such as those found all over the United States. His aeolian "Marine Organ" uses the changing tides to change the pitches of large pipes on the beach. The "Hydrophone" (1973), uses the force of water current to sound strings and change their tension as well.

John White has built machine compositions that create sound, similar to Tinguely's creations, but using performers instead of mechanisms. His "Drinking and Hooting Machine"

(1969), in which four performers drink and hoot on bottles, has often been compared structurally to the gradual process music of Steve Reich. Banal everyday sounds are rationalized when put into a machine sequence, and he eventually used actual machines and musical toys in the "PT Orchestra" of the mid-70's.

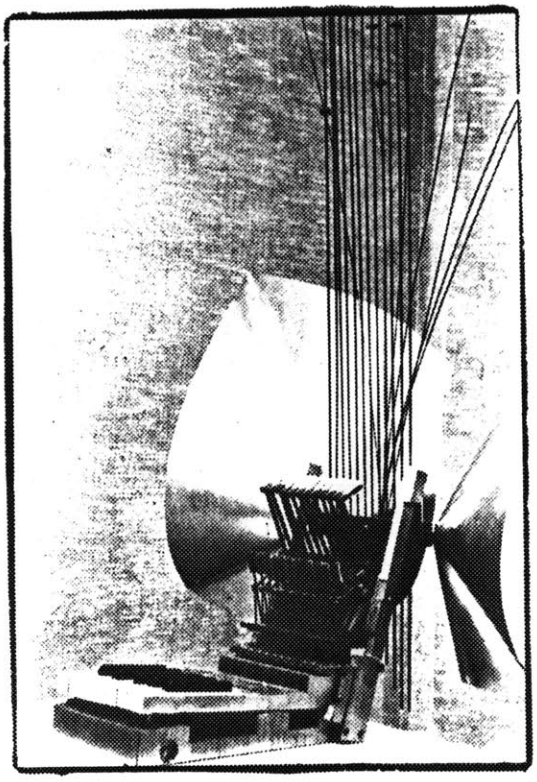
Anna Lockwood experimented with the sound environment. Lockwood made several piano environments, one called "Piano Transplant" (1972). She used an English garden to transplant several pianos in disrepair. They were to be played and admired as they became one with the earth.

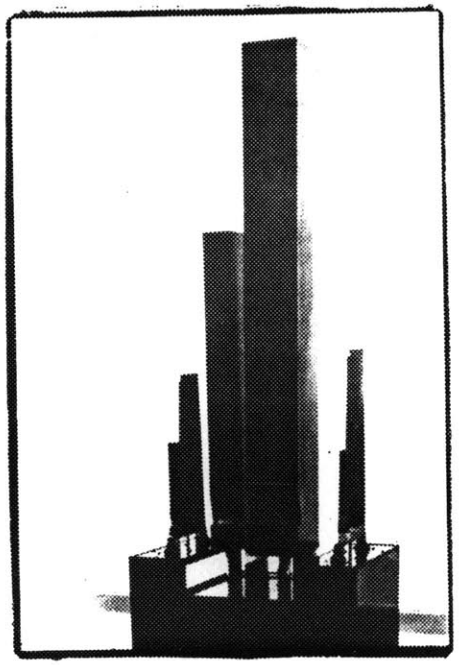
Much of this music and sound work was recorded on the Discreet Record label (now out of print). The label was created and produced by Brian Eno, who felt that this work should not be forgotten.



< The Baschets
"French Monument
on 57th St."

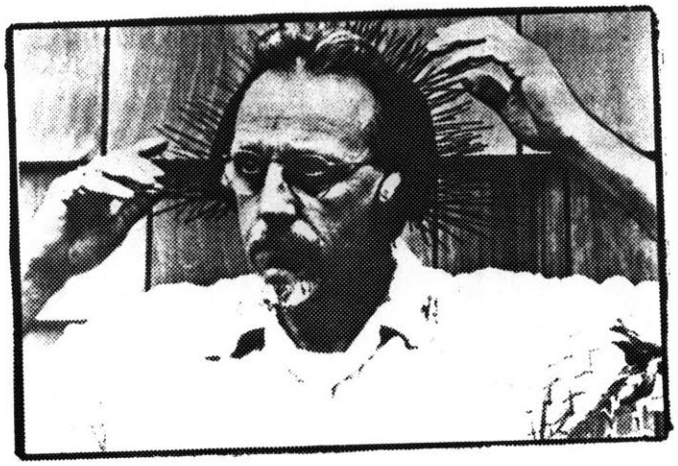
The Baschets >
"Piano with Two Ears"

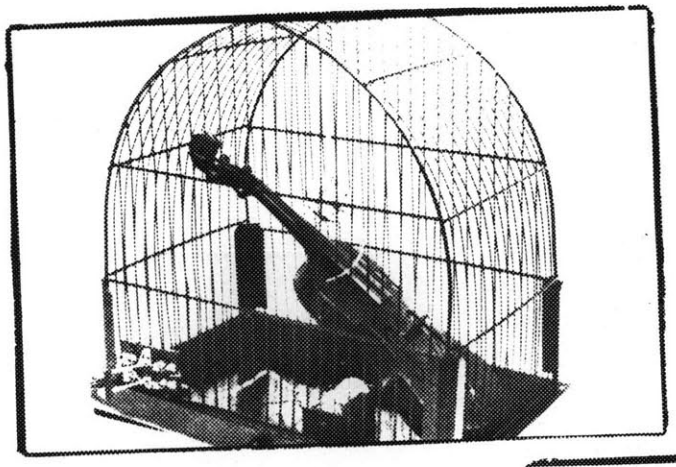




< Stephan Von Heune
"Totemtone III"

Reinhold Marxhausen >
with a headphone





< Joe Jones
"Violin in a Bird Cage"

Anna Lockwood >
"Piano Transplant"

In 1981 I became interested in sound as an artistic medium. Drawing on early musical studies (percussion) and undergraduate studies in the visual arts (photography), I developed the two areas into a unified form. I was prompted to explore this medium by the quantity of sound I was experiencing in the environment in which I was living. New York City is one of the few places which the sonic world is as chaotic as the visual world.

My first attempt at creating sound was a marimba, in which the keys could be positioned into any order. The result was the reduction of cross sticking; an arpeggio could conceivably be played by merely sweeping the mallet up and down the keys. I used Honduras rosewood for the keys, but developed an allergic reaction to the wood oils not far into the project and was forced to make a smaller version than I originally intended.

After that experience I began to think of the kind of sound I really wanted to create. The marimba project did not reflect a new sound, but a new design to change the playing technique. It was also an instrument I had played in the past. I felt that I really wanted new sounds and had always been interested in the sounds of early electronic musicians such as Morton Subotnick, Karlheinz Stockhausen, and Herbie Hancock. I began to realize that I was part of the first generation to grow up with electronic music, commercially as well as non-commercially. The early 60's were a most influential time for spontaneity with electronics, and I developed a sound vocabulary that I still draw upon today, made largely from the early analog electronic sounds.

I was not drawn to creating these sounds electronically as they had been in the past but rather through acoustic processes. My feeling about electronic synthesizers, especially the current models, is that they lack a latitude which is found in most acoustic instruments. Applying more pressure on a bow, or blowing harder on a reed, creates a

personality in an instrument and a latitude of sound that I have never found equalled in an electronic synthesizer.

The first sound piece that really reflected my electronic vocabulary was a "Velcro Walkway". It was an eight foot sidewalk of Velcro (part A) and a pair of Velcro shoes, (part B). The performer simply ripped across the surface, creating a white noise. The creation of noise in an instrument, like Russolo's, reflected the environment in which I was living. As a correlation of man's noise with nature, I performed this piece with the use of electronic amplification and a tape delay. The "Velcro Walkway" was positioned outside, against a steep mountain. The performer took one step to sound the acoustic rip of the Velcro. The tape delay would amplify an electric rip two seconds later, and nature would return a rip in the form of an echo off the mountainside two seconds after the amplified rip, and four seconds after the first step. This piece was also performed in Boston at the Cyclorama, using the acoustics in the architectural space rather than nature's echo.

During the work on the Velcro Walkway I also worked on a sound familiar in electronics and to several Indian instruments. I began using strings to achieve a sympathetic resonance which would result in a very rich harmonic content. My first attempt was a string instrument that used one string to excite the sympathetic strings on the same bridge. It did not result in the manner I had hoped. Although a failure initially, I experimented with a small motor and plectrum and began vibrating the string at a high rpm. The results were very close to what I had been searching for originally. The discovery of the vibrating string began a long process of creating sculptures and instruments using that principle.

I left New York and moved to Boston which gave me more space to create large sculpture using the vibrating string. As I was beginning to create these new pieces, I was also

interested in solar power. The motors I was using to excite the strings were capable of being run by a solar cell. The first completed sculpture contained two strings, two motors and was completely powered by the sun. Although it was a successful sculpture, I felt the need to learn much more about the string and soundboards. What I was hearing, as the string vibrated, was the upper mode frequencies of the string, or the partials. Although I was not sure why this happened, I began new sculptures improving the quality, both in craft and sound.

When I arrived at M.I.T. and the Center for Advanced Visual Studies, I continued to experiment building new sound sculptures and environments. I began to learn about the properties of the string and the acoustics involved in making an efficient soundboard. The first sculpture I worked on at M.I.T. had the shapes of obelisks and I have named them the "Obelisks". I have since completed several sculptures of the "Obelisk" family. The material I used was an inexpensive luan plywood that turned out to be a good soundboard due to its stiffness and small amount of dampening in comparison to a multi-ply plywood. I also attempted to use a ported cavity in the instrument, much in the manner loudspeaker manufacturers do, but due to the higher frequencies of upper mode vibrations, it was an inadequate design.

These sculptures (I built two) were part of a larger sound environment which used several organ pipes and photo switches in an interactive, participatory installation. Laser beams were sent to the photo switches to create a keyboard of light. The organ pipes sounded as the light beam was broken. The "Obelisk" droned in the key to which the pipes were tuned, creating a harmonious resonance. The organ pipes were sounded by a squirrel-cage fan which sounded several partials as it gathered speed, similar in method to the work of David Jacobs and Stephan Von Huene.

After the "Organ Pipe Installation", I decided to concentrate on the strings and in creating an instrument capable of realizing compositions. I began to build an instrument called the "12 Boxes", which were precisely that. Twelve strings were housed in separate rectangular boxes and controlled by a keyboard. The keyboard had speed controls for the motors and on-off switches to turn the boxes permanently on instead of using the keyboard. Upon completion of this instrument, I realized its inadequacies. Twelve pitches were not enough to realize the compositions I had intended. I also felt that twelve separate boxes were too cumbersome to move and store. The sculptural and spatial qualities of the "12 Boxes" were indeed intriguing, but I immediately started to design an instrument closer to my original intention. I designed what was to become "The 37 Strings" (described in the next chapter).

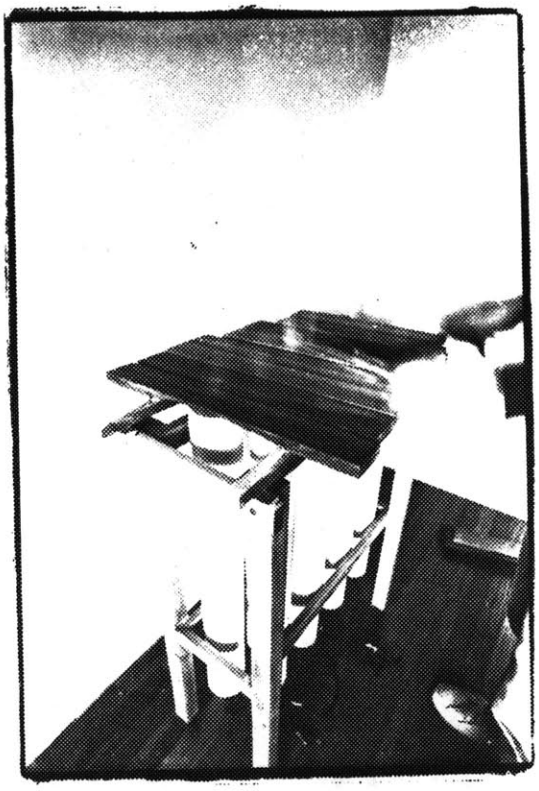
During the time when I was designing "The 37 Strings", I became interested in building an ensemble of instruments. Certain ideas which I had sketched started to become realities. I had come across blocks of walnut with large diameter holes drilled through them. I cut two slits in them making a tongue which could vibrate freely and resonate in its own body (similar to Partch's "Boos"). Although walnut is not normally used in tuned blocks or marimba keys, it was available. After I tuned several blocks I felt that it would be appropriate to form them into a wheel that would rotate, and with small balls inside acting as mallets, it would play itself. I called it the "Marimba Wheel" and have plans of eventually installing it over a stream so the energy of the water current causes the wheel to rotate. Until then, it is rotated by an electric motor and used in my ensemble.

I also became interested in the sound of water in a metal bowl and how the water changes the mass of the bowl when tilted. It is reminiscent of my percussion training as a tympanist. I used two stainless steel bowls with foot

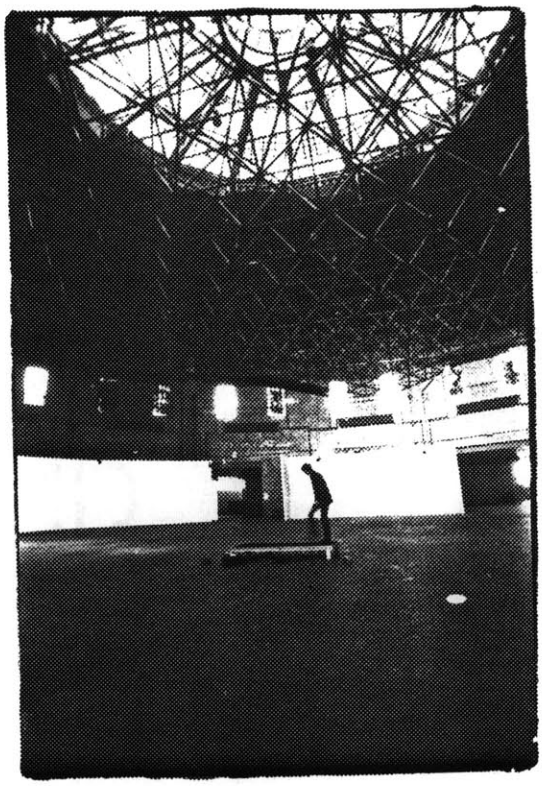
pedals to control the amount of tilt (and pitch). Solenoids attached to piano hammers (as in Takis' "Electromagnetic Music") strike the bottom of the bowl to produce the pitch. I also used a motor with plectrum, similar to the ones I use in the string instruments, to vibrate the bowl constantly and create a drone effect.

The final instrument which I created for use in the forming ensemble was the "Bird Synthesizer". I had used small circuits that sound a "bird call" in a previous outdoor solar installation. Twenty-five "Solar Birds" were scattered about the lawn and when the sun hit them they began to chirp. I took the same circuits and wired them in a fashion such that several different bird sounds could be made and manipulated. Although I have strong opinions about synthesizers, I felt that I was making a humorous statement about the current synthesizer world. I designed the "Bird Synthesizer" as an instrument capable of creating and controlling many different bird sounds through electrical supplies. I had gathered all the materials from surplus outlets, so my final cost of this project was about $30. It is a humorous instrument that turned out to be capable of being integrated with the other pieces in the ensemble.

I have several designs for instruments which are on paper. I am working towards developing an ensemble I believe will be interesting not only sonically but visually. I have been interested in creating instruments that are not only playable, but also can be used as sound sculpture.

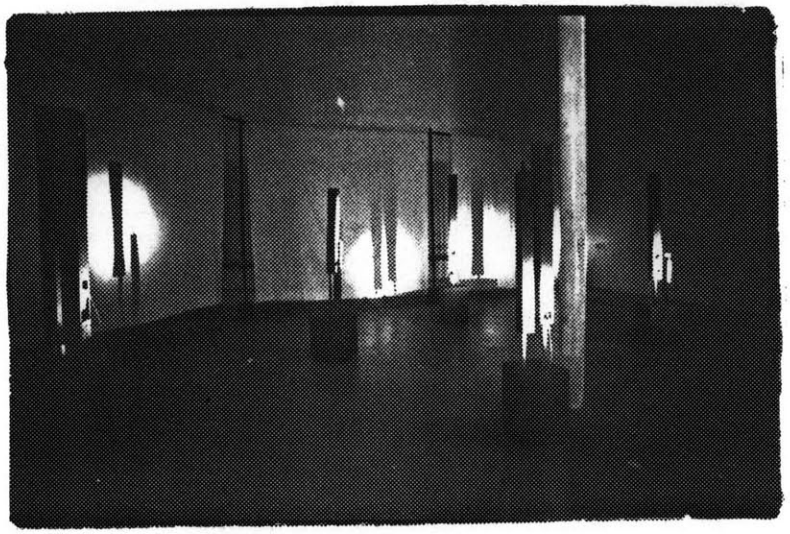


< The "Marimba"

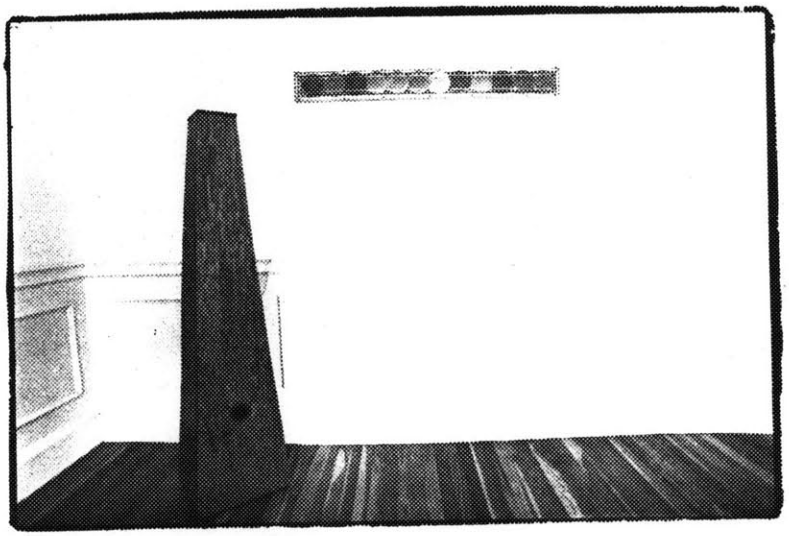


The "Velcro Walkway" >

< The first string instrument

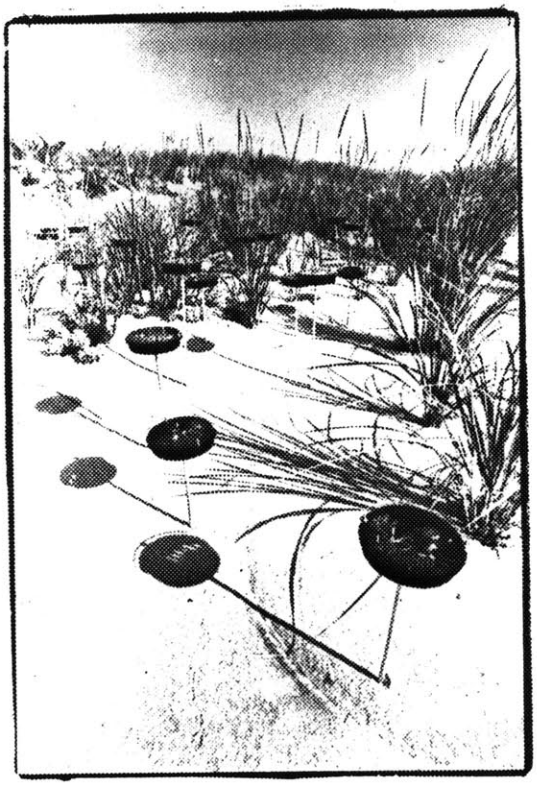


The "Organ Pipe Installation"

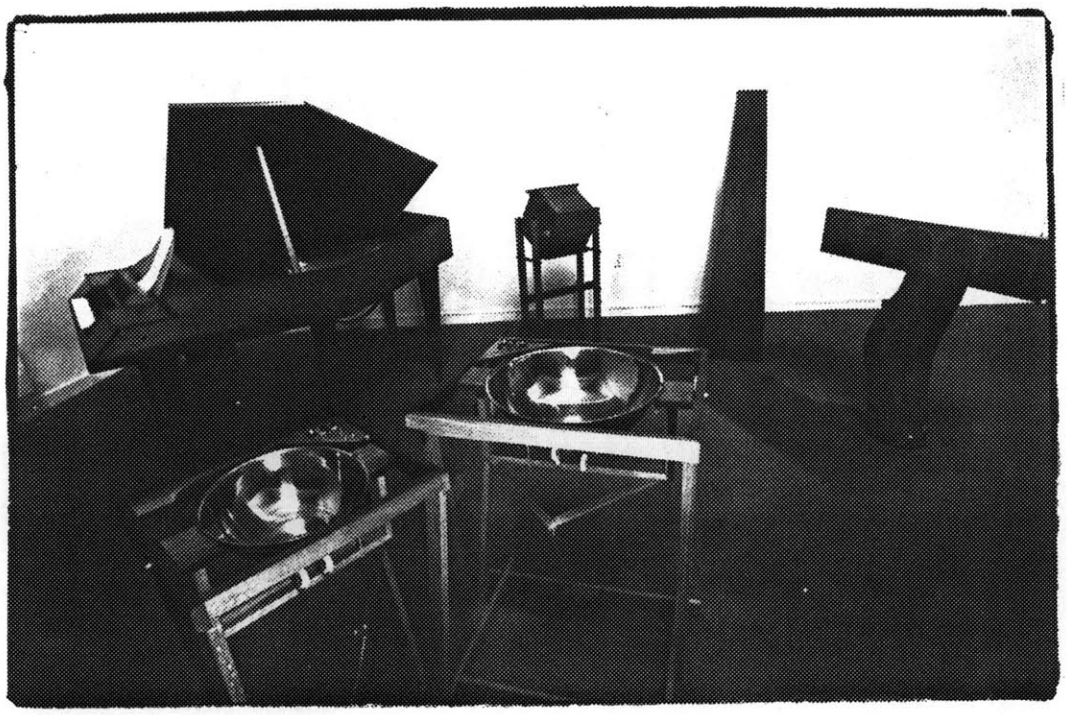


The "Obelisk"

"12 Boxes"



< The "Solar Birds"



The Ensemble
"The 37 Strings", "Marimba Wheel", "Obelisk",
"The Bird Synthesizer", and "Water Drums" (in foreground)

After I had completed the "12 Boxes", I realized they did not reach my initial goals. I found I was immediately making new designs to resolve their problems. The first thing I needed to resolve was the separate housing of the string. Although visually interesting they are not easy to move or to store. I felt the 12 pitches were not adequate for compositions I was interested in and felt three octaves would be more appropriate. Keeping the strings together on one soundboard was the answer to the bulk of the separate boxes, and also my desire to use the sympathetic vibrations that occur with strings sharing the same bridge. I found the piano image visually appealing (especially early harpsichord designs) and began to consider it as a model for my next instrument. I researched piano manufacturing, materials, and process, and was fortunate to find a full description of Bosendofer's manufacturing process. With the aid of a local piano builder and a piano rebuilder's supply house, I began designing "The 37 Strings".

I cut the basic shape out of plywood and built an aluminum frame to support the tension of the strings. Unfinished organ pipes in the obelisk shape, similar to the shape of my earlier sculptures, served as legs. I choose a sitka spruce for the soundboard, and poplar for the supporting struts of the soundboard. Collecting the materials I would need for "The 37 Strings" became a full-time job along with designing. Things in quantities of 37 are sometimes unavailable, especially in the surplus markets I frequent. I found a three octave keyboard, proper motors, transistors, slide pots, motor mounts, switches, transformers, and L.E.D.s, all in surplus supply outlets.

With the frame now standing, I positioned the struts on the frame. Normally, struts are glued to the soundboard in a large press which gives the board a slight curve to increase stiffness. Because I had no press and my soundboard was in ten inch board widths (piano soundboards

are always made to order from the factory), I felt it necessary to shape the struts individually, and glued the spruce boards in the frame. The amount of curve the soundboard has, using my method, is an approximation, unlike the piano rebuilder, who usually has access to a press for an exact soundboard curve.

The bridges are made of poplar. There are two bridges, one for the seven wrapped strings in the bass end, and another for the solid strings. Both are straight and have a brass rod running down the center contact with the string.

The tuning pins were a decision that I felt was best answered with guitar machine heads. Traditional tuning pins require a pin block made from several layers of thin maple boards. The tuning pin is then secured by friction. Pin blocks are expensive and the pins require a tuning wrench to adjust tension. The machine heads are less expensive and can be easily tuned, therefore, I chose them over the traditional pin system.

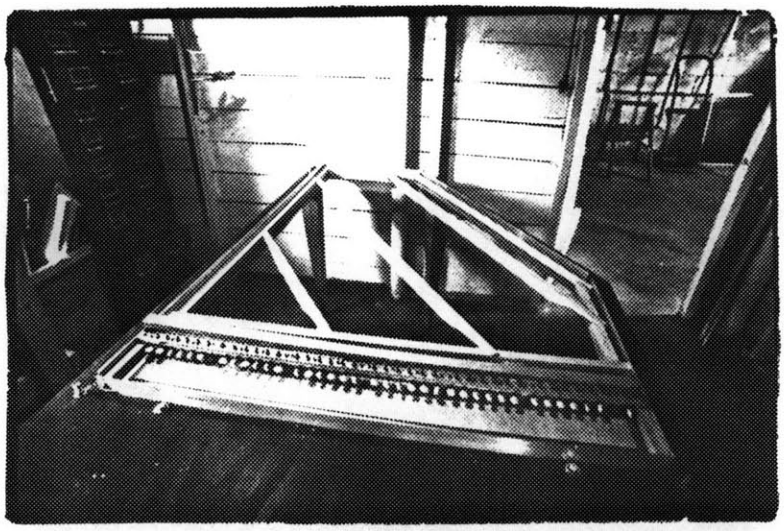
Stringing the instrument is always a momentous occasion. The string lengths were already calculated from a model I built for use in the M.I.T. Acoustic and Vibration Lab. After the strings were tensioned, I noticed the aluminum frame starting to bow under the enormous pressure. I thought a single aluminum angle would be sufficient but was obviously mistaken. Fortunately I had enough room to reinforce it with another piece of angle. It seemed to work but I was quickly learning about the combined tensions of strings and their resulting pressure. I decided to reinforce the tuning pin after I observed the load it was under. Once the frame was secure I found that I had not made a wise choice in using poplar, a relatively soft wood, for the struts. Although I don't anticipate a problem, it would have been preferable to use a rock maple or similar hard wood.

The next step was supporting the motors and their electrical wiring. The motors were to be suspended from two

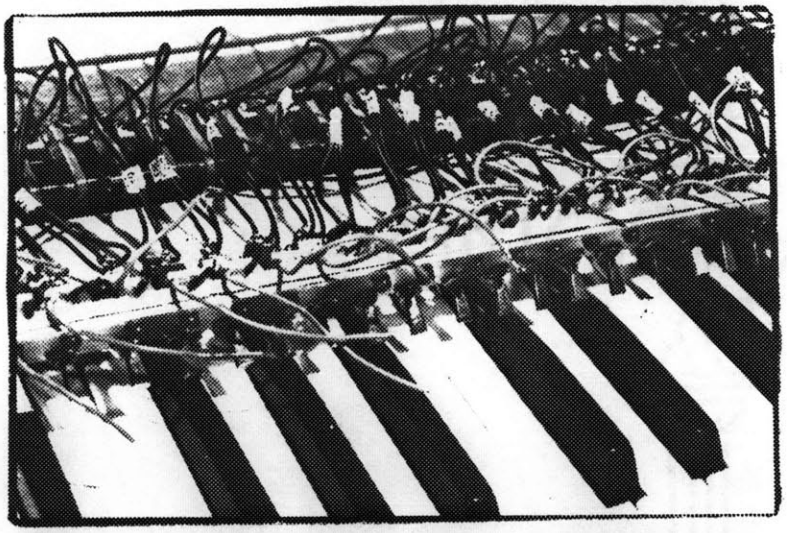
1/2 inch rods approximately four to seven inches from the rear tuning pin bridge. The motors I used are a low inertia DC type. The power supplies are housed under the frame and deliver 6 volts at 150 milliamps. Between the power supplies and the motors is the keyboard with controls. The motor can be turned on and off by depressing the key, or can remain on, using a toggle switch. Whenever the motor is on a L.E.D. glows just above the key. I found this a necessity, after having played the "12 Boxes" and losing track of which box was sounding, and with thirty-seven possibilities I felt the L.E.D. indicators a must. After the power gets switched to its desired route it goes through a transistor and potentiometer to control the electrical output, or the speed of the motor.

The basic mechanics of the instrument were now complete and the wood working and finishing remained. Following the tradition of early harpsichord designs, I used a straight sided case and decided on a natural mahogany finish. Much of the designing was done as I went along. It was easier to visualize the next step when I saw the outcome of the previous one. Once the legs had been veneered and the finish applied, I was ready to begin to learn to play it.

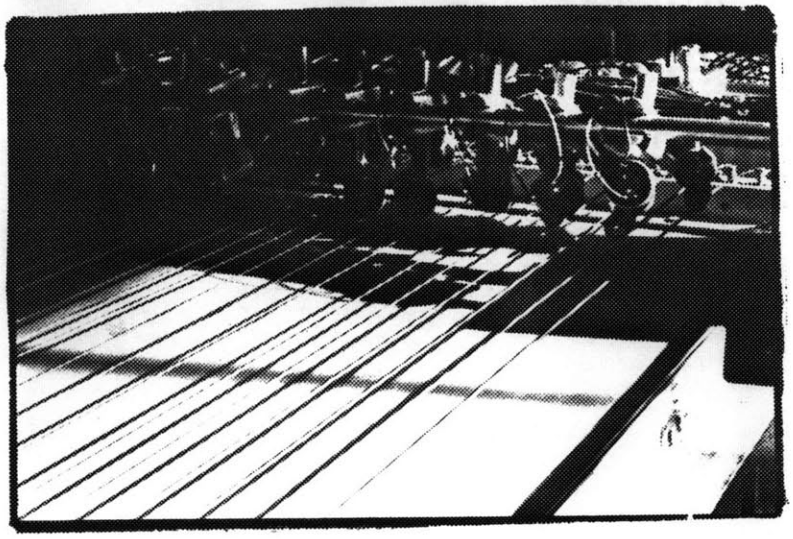
As you build an instrument, the anticipation of playing it is overwhelming. It took two weeks to properly adjust the motor positions and tune the strings. I changed the diameters of some of the strings to compensate for unanticipated tension problems. The soundboard radiated very well and the instrument was much louder than I had expected. The partials sounded with more energy than the "12 Boxes" had, and the sympathetic vibrations of the other strings created a richer resonant sound. Now when I play the "12 Boxes" they lack much of the fullness and quality that "The 37 Strings" has. I will probably only use them in sculptural sound environments rather than as a performing instrument.



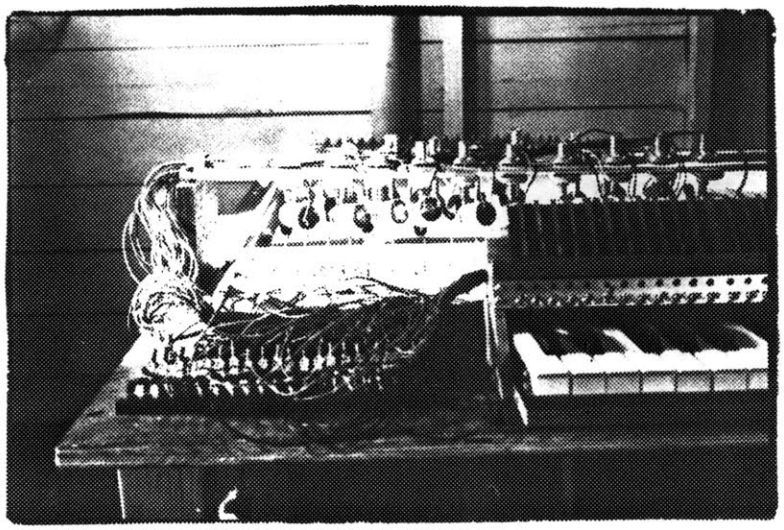
< The struts and tuning machines in place



< Wiring the switches and keyboard



< Motors postioned over the strings



< The wiring from keyboard to motors

< Beginning the finishing

"The 37 Strings"
completed January
1987

The building of "The 37 Strings" was no different than many of the instruments throughout history. One basically plows ahead and examines the physics later. After I had devised a method in which to excite individual partials of the vibrating string, I needed to find out the why and how of what was happening, so I arranged to use the Acoustic-Vibration Lab at M.I.T. to do the research. I wasn't seeking equations to the questions, rather a set of parameters which I could use in making decisions in my creative process.

I built a frame which held a soundboard and two bridges between which a string was stretched. A motor with a plectrum was adjustable over the entire length of the string, and a transducer was suspended above the string to gather information. I used a spectrum analyzer to see the exact energies coming from the string and a stroboscope to mark motor speed. With a large number of variables, such as string diameter, string length, string tension, motor speed, motor position, I had to arrive at a starting point through previous observation. I knew that much of the information I needed concerned motor speed and string tension, so to eliminate some of the other variables I ran tests to see if my observations were correct.

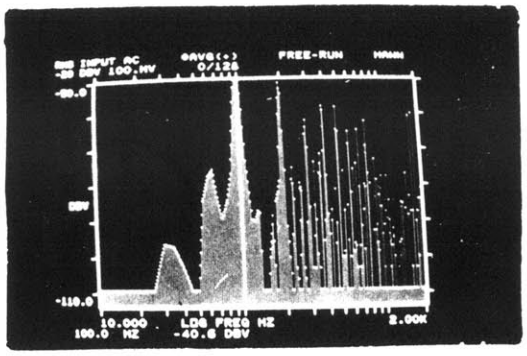
I found that varying the motor position on the string had a wide scope of harmonic response. I decided to place the motor at the 1/7 mark (like the hammers of the piano) to standardize the process. I did find that the response of the string is similar until the 1/4 length mark where it begins to effect the 4th partial. At lengths shorter than the 1/4 mark, the response is harmonically full but requires larger amounts of energy from the plectrum. The closer to the bridge the motor is positioned, the less the fundamental will sound.

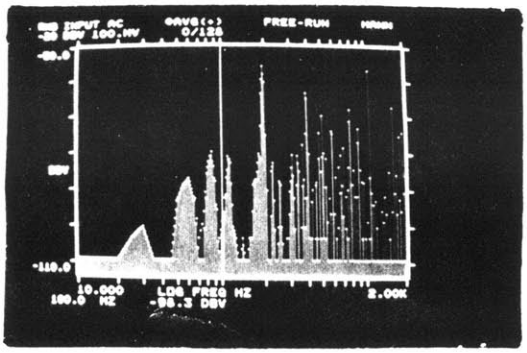
Motor angle, or the angle in which the plectrum

strikes the string, has basically the same response at all positions (except when the motor is perpendicular to the string creating longitudinal pulses). In adjusting the plectrum angle, you listen for the least amount of "noise". In other words, the ideal angle is the one in which one only hear the vibrating string and not the striking of the plectrum.

The string diameter and length are decisions closely tied to string tension. To achieve an ideal tension may require a smaller diameter string or vice-versa (this can often be the saving grace as length is often fixed). Wrapped strings usually necessitate a larger plectrum to excite the deep frequencies. If a fundamental frequency is desired, it must be present when the string is plucked. Both diameter and length decisions were made as logical observations from previous applications.

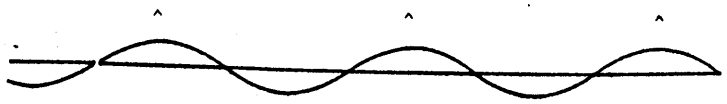
As I was working with the spectrum analyzer I found that tension was a variable that provided answers. With variables constant, so all experiments would be identical, I stretched a #9 harpsichord wire the length of the frame (45 inches). I tuned the string to 100Hz., which is about 16 lbs. of tension. The top speed of the motor is approximately 2500 rpm and the partials start to separate from the full spectrum at 1000 rpm. Within that speed range there were two strong responses with a sequence of weaker upper partials in between. The first response included a full spectrum with the most energy occurring at the fundamental, similar to the spectrum of a plucked string. The second response differed, with a loss of energy at the fundamental and strong energy at the 2nd partial, with an even distribution of upper mode frequencies.



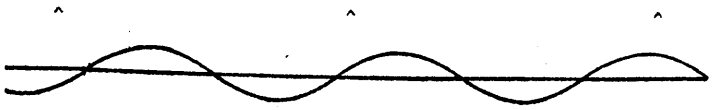


The above photographs represent images taken from the spectrum analyzer. In the left image the large spike represents the fundamental frequency vibrating at a certain rpm. On the right, the rpm of the motor is increased and the fundamental frequency disappears.

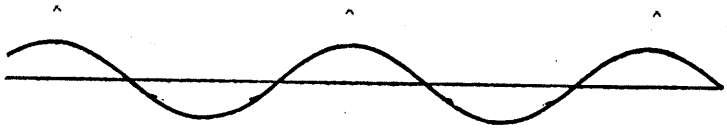
As the plectrum transfers its energy to the string there is a certain amount of displacement. As the displacement is repeated at a certain rate (1700 rpm for example), it sets up a corresponding vibrating mode in the string. If the mode is relatively strong it will set up a standing wave in the string. The relationship between tension and rpm is repeatable, meaning, if the 5th partial is in phase with a pulse of 1700 rpm, under the same tension it will always sound the 5th partial at 1700 rpm. When the string is vibrating there is a speed of pulses which is in phase with maintaining that vibration. The speed of the pulses and the speed of the vibration are in unison. The plectrum contacts the string at the peak of its wave. As the speed of the motor increases the plectrum now hits at different points in the wave cancelling out that partial and sounding one that is in unison with that new speed.



- Plectrum strikes, 1500 rpm - standing wave



- Plectrum speed change 1200rpm, note the eventual phase cancellation of the existing wave



- Same speed with new standing wave formed

With the fundamental vibration being the largest wave, you can actually hear the plectrum go in phase. The sound of the plectrum hitting the string becomes silent. For an everyday example imagine a jump rope "vibrating" at the fundamental. Once it gets up to speed, maintaining the vibration takes less energy. The wrist pulse and the rope become in phase. Imagine a motor pulsing the rope at the speed needed to maintain that vibration. It is the same effect occurring here. The string is under much more tension and becomes much more complex than the jump rope, but it illustrates a relationship between pulses and vibration. Regardless of the amount of force applied through the plectrum, the partial will always excite at the same speed. To find an equation to anticipate the result of a certain rpm or the rpm needed for a certain frequency would only be applicable to that particular experiment and model. Therefore, it would be fruitless to attempt such a chore for an instrument such as "The 37 Strings". The following chart is an example of the frequencies that a string goes through. I used the pitch of C (264 Hz) as an example. This was taken from "The 37

Strings", not the experimenting model. Due to factors such as different string characteristics and the soundboard's natural frequencies, this only pertains to the string being used, although the stronger vibrations will repeat their pattern in different strings. The sequence is in ascending order which would be slightly different than a descending order.

C - fundamental, 264 Hz 1200 rpm
Bb - 930 Hz, 1350 rpm
E - 1330 Hz, 1420 rpm
G - 1590 Hz, 1510 rpm
B - 1980 Hz, 1560 rpm
G - 792 Hz, 1630 rpm
F - 2819 Hz, 1710 rpm
Bb - 3785 Hz, 1770 rpm
G - 1584 Hz, 1870 rpm
C - 1056 Hz, 1990 rpm

This was a group of partials that occurred with a #15 piano wire at 38 inches. Playing C an octave higher (528Hz) there are similarities but they are by no means the same. The position of the motor changes as the different string's length increases or decreases changes. At the bass end, it may be positioned 1/12th of the length, while at shorter strings it may be 1/4 of the length. The stronger frequencies, such as the fundamental, the 2nd, and the 3rd partial are easily repeated in all the strings regardless of the characteristics that influence the string. The most subtle change in speed will change the order of the upper mode frequencies creating new ones that may have been missed previously. The group was taken from "The 37 Strings". The soundboard has a natural resonance around G (198 Hz). Many of the strings will resonate at that

frequency even if it is not a strong partial. When the G string is excited it resonates wildly and must have the plectrum adjusted to compensate. The partial response in the G string (198Hz) is "limited" because of the coupling between the string and the soundboard's natural frequency. The fundamental of G (198Hz) could be excited from 1200 to 1800 rpm for example. This problem can be lessened by using a different diameter string to change the tension.

After the experiment I realized that earlier sound sculptures, which operate on solar power, never "settle" into a strong partial. The speed is constant and there should be a corresponding partial sounding. The fact is that the strings of the earlier sculptures are under a large amount of tension, similar to that of a piano or guitar. With that amount of tension the plectrum comes in contact with the string for a much shorter duration; it does not allow the string the freedom to vibrate at its lower partials. Only the upper modes can vibrate because of their short wavelengths that don't require much energy. They fluctuate and create slowly changing pitches. I speculate that the minute differences in every rotation of the plectrum causes enough variation to change the string's mode. Tuning by means of speed to an upper mode frequency and holding it there is very difficult. The slightest change in speed, even changes caused by the flexibility of the plectrum, are enough to make the frequency change.

In conclusion, I feel that I arrived at parameters which will influence my building. I reached answers to many questions involving the nature of the vibrating string and the ability to alter the partial response I need for a particular application.

As I have discussed some of the history of sound works, it is important to keep up with the current happenings in the medium. History, for example, may not always record things the way you remember them, and I have often imagined the many things that have gone unrecorded. The popularity of sound works has grown immensely in the past two decades. Although both the West Coast and British Isles are still centers for sound related media, many other locales have become prominent. Groups of sound artists have established themselves in Australia and produce the Australian Music News, as well as artist located all over Europe, producing a network of experimental sound galleries. Many of the people associated with California and Vancouver have moved to other parts of the continent, spreading their influence in the sonic arts.

It is difficult to see any trends in sound works because the scope of the medium is so large. The rapid growth of the last decade in the directions of sound environments and sound sculpture, new instruments, composition, and electronics, has been exuberant.

Sound environments have often utilized the kinetic forces of nature to make a sculpture sound. Ocean currents and tides are used in John Latham's "Big Breather" (1980) and wind activates the many aeolian harps of Doug Hollis and Jacques Dudon. Richard Lerman amplifies bicycles in "Travelon Gamelon" (1979-87) to create a moving soundscape.

I have seen a developing attitude in instrument makers to rely on physics for problem solving. This is especially evident in the work of Roger Pytlewski and his "Bi-level Guitar" (1984). This guitar has been developed with a bi-level soundboard to eliminate the bridge and its inefficiencies. This results in a guitar capable of much more volume than a traditional guitar.

One trend in instrument building that I have seen, and am interested in, is the formation of an ensemble of

instruments for performance. This is the direction in which I have been heading, as others have, such as Robert Rutman and his group the U.S. Steel Cello Band, Richards Waters and his Gravity Adjusters Band, the Canandian based Sonde, and the Glass Orchestra, one of the several groups who perform with glass. These groups have all made recordings of their ensembles.

Probably the largest growth in sound-related media has been in electronics. Although I have not gone into the electronic sound processes, it has recently formed into the largest area of commercial and non-commercial sound works. Electronics existed earlier than the '50s, but have recently become more affordable, as have their components. One such component is the contact microphone. This has opened the door to creating sound that is normally inaudible. Tom Nunn has used the contact mike to create instruments that make a variety of sounds. Without the difficulty in designing and building a soundboard, Nunn uses combs, beakers, nails, and prepared surfaces, forming an ensemble of sound. The performer sits at a table with the objects attached in various ways, and becomes the conductor to the ensemble before him. The use of the contact mike has provided the vehicle for exploration of "unheard" sounds. Many other artists (John Cage and Takis, already mentioned), have used contact mike systems for sound environments and composition.

The work I have done with the vibrating string has interesting correlations to contempoary artists. It is also interesting to find that one is a composer and others (actually two collaborators) are visual artists working with sound in similar techniques. We have used the vibrating string as a source for sound; they both use the contact microphone or a magnetic pickup for amplification.

Paul Panhuysen and Johan Goedhart are from the Netherlands. Both were visual artists with some musical

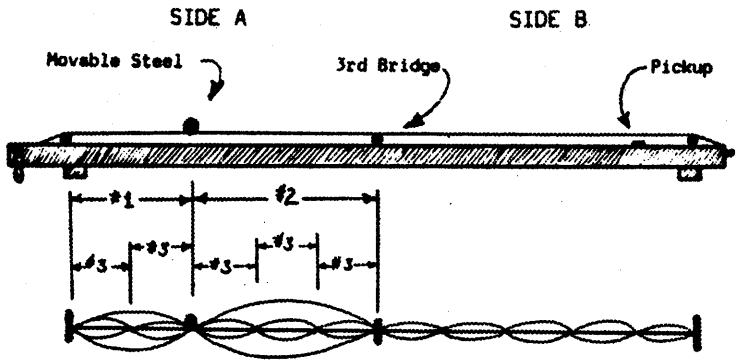
background. They began their sound work in 1982 with a series of long string installations. The approach to the installation was concerned with architecture and the creating of an instrument within that architecture. Strings (metal, gut, or even dental floss) sometimes 30 feet long were strung throughout the space, making the architecture a sound box and placing the audience inside the instrument.

The performance is improvisational composition and the strings are bowed or struck, with sound amplified through piezo pickups. In 1983, they began to apply different motors with plectrums to vibrate the strings and create sound sculpture that did not need performers. Because of the length of the string, the fundamental and, in some cases, the first several partials, are inaudible due to their low frequency. Higher partials are the resulting sound. Many of the motor pieces use fairly slow revolving speeds. In some cases a high rpm motor and a variety of different plectrums are attached. One interesting development is the use of long pieces of filament as the plectrum ("Julian Gast", 1985 and "The Third Ceiling", 1985). The variety of the plectrum's energy, in relationship to the string, creates an always changing attack, resulting in timbre and pitch changes.

Panhuysen and Goedhart are concerned with the visual and sonic properties that evolve in the architecture. Reviewing the approach that I have taken, carefully trying to control the string's properties, it is refreshing to find people letting the string become uncontrollable. Each installation they do is treated entirely differently, and they have managed to keep their developing ideas from stagnation by letting the architecture of the space collaborate as an integral part of the whole. As one reviews their last 37 installations, the development is without repetition.

Glenn Branca has composed several works using electric guitars. In 1982, he began to write orchestral works for a pure tuning system. To realize the works, he conceived a new

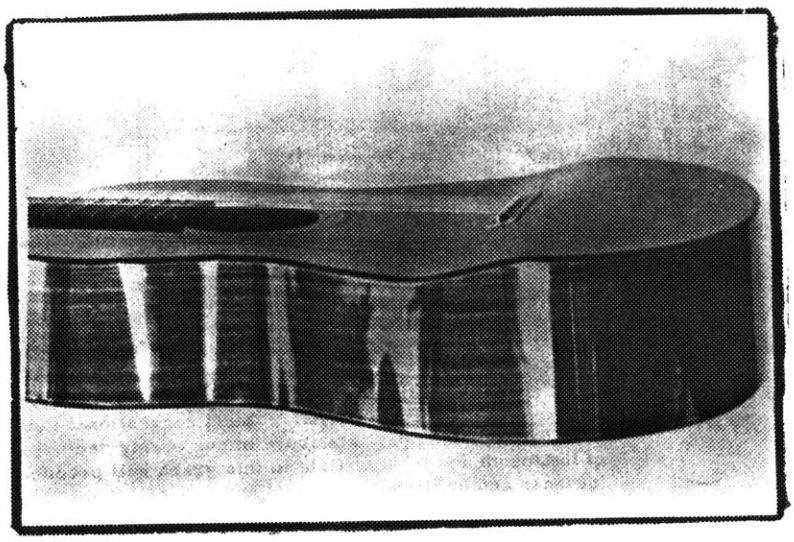
instrument, which I feel is probably one of the most inventive designs in utilizing the electric pickup. He uses a third bridge, which is positioned in the middle of a string's length.



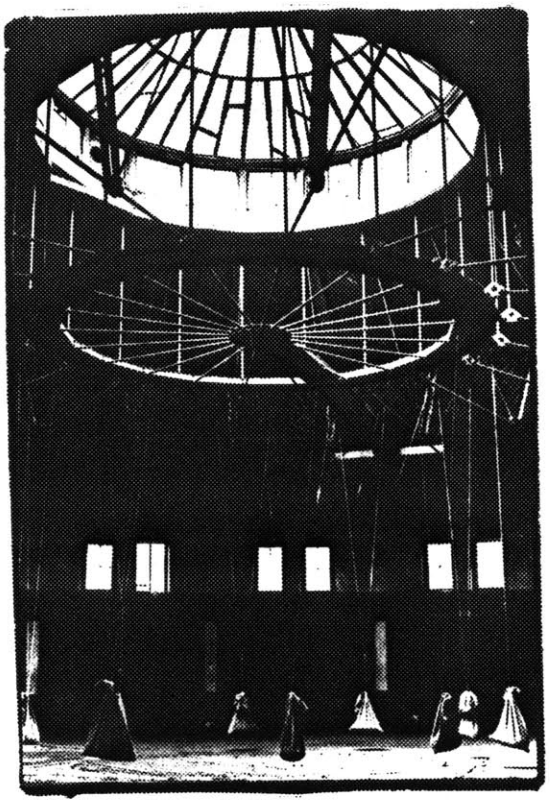
If a moveable steel bar (like a bottleneck or Hawaiian guitar) is used to vary the pitch of the A side, let's say dividing the string on that side into 2/5 (#1) and 3/5 (2) segments, then the common dominator is X/5 (#3), and that X/5 is transferred across the bridge because the B side string is sympathetic with that wavelength, which is sensed by the pickup and sounds the 5th partial (also multiples of the 5th partial). Because #1 and #2 on side A do not have corresponding frequencies on side B, only the partials that are relative to both sides sound.

Branca designed several harpsichord-style instruments for his "Symphony No.3 (Gloria)" (1986), which were built by David Quilian. He uses a traditional harpsichord striking method as well as a small leather disc on a motor which lightly rubs the string in the correct location. Because of the electric pickup, the instruments need no sound board and are supported on plywood and 2X4's. Visually, the instruments are the exact opposite of my intentions, and to a certain extent, those of Panhuysen and Goedhart. Branca's chief concern is the sound. The visual beauty traditionally associated with instruments is not considered in the least.

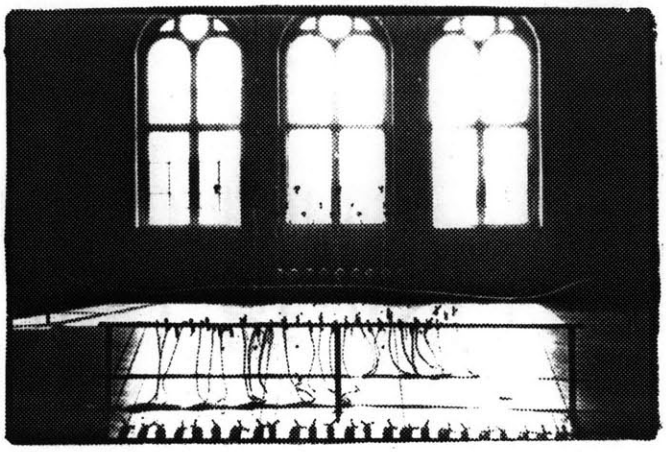
I have been fortunate to find different ideas involving similar principles. We evolved our process at about the same time and have come up with very different products. It is intriguing to find such a difference in three approaches to strings, harmonics, and motors. I think our backgrounds have influenced the course we have pursued. I am interested to see what will happen next.



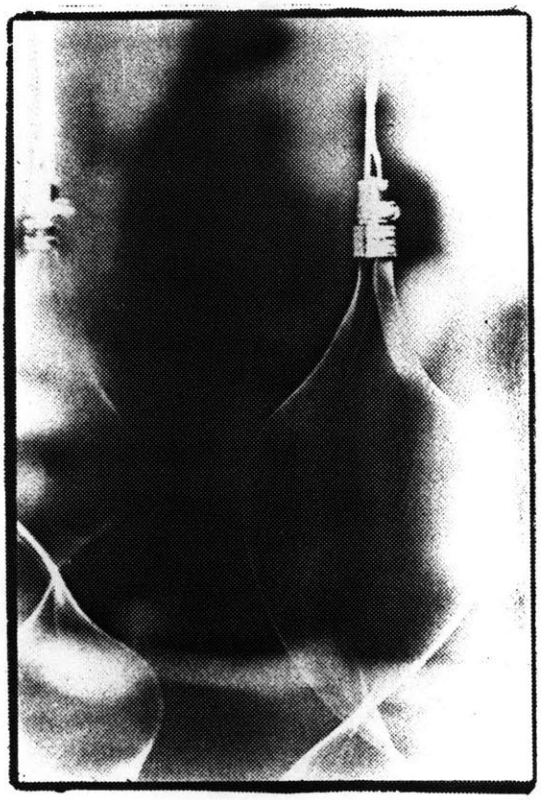
Roger Pytlewski "Bi-level Guitar"



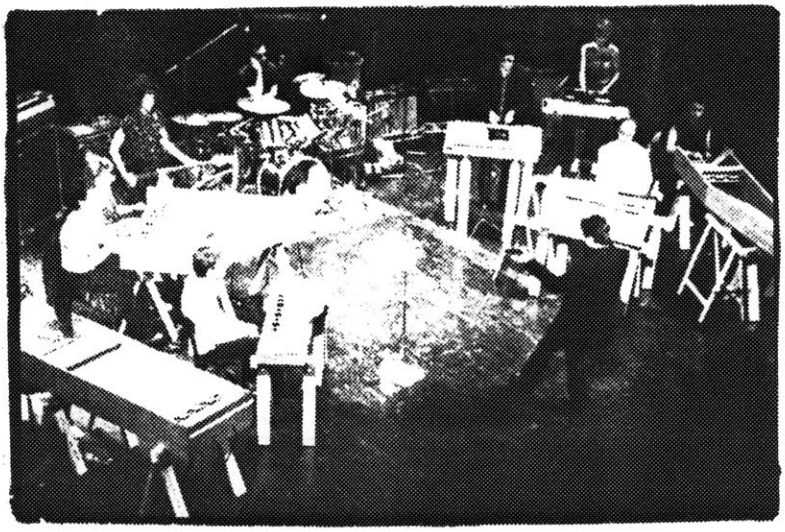
< Panhuysen and Goedhart
"Circus" installation



Panhuysen and Goedhart "Julian Gast" installation



< Detail of motor and plectrum "Julian Gast" installation



Glenn Branca with his ensemble
performing
"Symphony No.3 (Gloria)"

In conclusion, the medium of sound has progressed in great strides. This year two sound artists were awarded Guggenheim Fellowships. That recognition was received from the visual arts' practitioners rather than musical groups. I hope that proper recognition by musical institutions will follow in the future, i.e. recognition of sound resulting from collaborations of the two media.

FOOTNOTES

1: DICTIONARY OF MUSICAL QUOTES
Ian Croffon, page 68

2: Ibid.: page 28

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PHOTOGRAPHS

Page 10- all photos taken from FUTURISMO 1909-1919

Page 16- Prepared pianos taken from THE WELL PREPARED PIANO
Nancarrow, Cage, and Paik taken from KEYBOARD

Pages 26 thru 28- All taken from the liners notes of
DELUSION OF THE FURY except the set of Delusion
taken from GENESIS OF A MUSIC

Page 37- all photos taken from SOUND SCULPTURE

Page 38- Marxhausen taken from SOUND SCULPTURE
Joe Jones taken from SOUND
Lockwood taken from KEYBOARD

Page 63- illustration taken from EXPERIMENTAL
MUSICAL INSTRUMENTS, Vol. 1, #3

Page 65- Pytlewski taken from EXPERIMENTAL MUSICAL
INSTRUMENTS, Vol. 2, #5
Panhuysen and Goedhart taken from
APOLLO RECORDS

Page 66- Panhuysen and Goedhart taken from
APOLLO RECORDS

Page 67- Glenn Branca taken from KEYBOARD Jan. 87

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