sculpting space through sound

by

Junko Nakagawa

Bachelor of Science in Architecture
Washington University, 1997
St. Louis, Missouri

Submitted to the Department of Architecture in Partial Fulfillment of the Requirements for the
Degree of Master of Architecture
at the Massachusetts Institute of Technology
February 2002

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Bachelor of Science in Architecture
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Submitted to the Department of Architecture on January 18, 2002 in partial fulfillment of the requirements for the Degree of Master of Architecture at the Massachusetts Institute of Technology, February 2002.

How does one experience space?

What kind of information do humans collect in the process of constructing space in their mind? How does one begin to understand volume, light, texture, material, smell and sense of space?

The focus of this thesis investigation is on the basic parameters of space, specifically on sound. What leads to this study is my previous experience performing musical instruments and my fascination in discovering how one acoustically experiences space. It is especially crucial to understand how acoustic influences spatial experience in a time when optical media dominate, and the sense of sight and visual perception have a greater significance. It seems that the elementary relationship between sound and space has been neglected.

So, what does it mean to experience space acoustically?
Can one choreograph spaces with sounds to change the spatial experience?
Can one invent spaces that are formed using sound as building material?

The goal of the proposal is to transform one's understanding of space and it's relationship to the surrounding environment by acoustically shaping space.

Thesis Supervisor: Peter Testa
Title: Associate Professor of Architecture, MIT

sculpting space through sound

Title icon.

When I was stuck with a drawing, my drawing teacher often told me to rotate the drawing 180 degrees. Ground becomes sky, background becomes foreground and negative becomes positive. The familiar drawing is transformed into an unfamiliar drawing. Perhaps this unfamiliar drawing embodies new possibilities I didn't witness before. Like the simple trick used in a drawing class, I always prefer to search for different ways to approach a site.

Acknowledgements:

I would like to thank many people beyond this list who have encouraged me and supported me throughout my study. Without the support of all of you, I would not be able to accomplish half of what I was able to do.

To my committee:

Thank you very much for all your support throughout the semester. My project started with very little definition and direction, but your positive encouragement throughout the semester has enabled me to complete the project.

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Thank you very much:
To my friends, who in my opinion are the most generous, thoughtful and brilliant thinking people. I cherish each thought and conversation we shared. This semester would not have been as enjoyable without you.

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To Zach Kramer for answering my random questions at random times. (...How to fix my bike brakes, how to use the 3dprinter, how to make movies, how to use the Premier program and helping me recover my computer with DOS)

To the SMArch students in room 3-415. Thanks for creating a relaxing atmosphere and being supportive of the three MArchs sitting at one side of the room.

To Imdat As for helping me whenever I needed help with computer programs. I apologize for constantly asking for your help.

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Thanks to many other people who may not be mentioned here, but still helped me by randomly stopping by my desk and getting stuck giving a deskcrit.

Last, but not least, I would like to thank my father, mother, brother, grandmother and my aunt in Japan for worrying about my health and always being there for me. I apologize for all the last minute troubles I unintentionally caused when transitioning between the two countries. Because of your help and constant support I've gotten this far.

I also like to mention my grandfather and grandmother, who are no longer with me, but who have always waited for my visit and listened to all my adventures in life. I especially thank my grandfather who most valued my hard work and encouraged me to study architecture. They will continue to be with me in my heart.

1.0.0 introduction

Intention:

How does one experience space?

What kind of information do humans collect in the process of constructing space in their minds? How does one begin to understand volume, light, texture, material, smell and the sense of space?

Scientifically humans have five basic senses. Sight, hearing, smell, taste, and touch are the basic senses. Our receptors enable us to receive signals from outside the organism to orient and direct oneself. In addition, kinesthetic senses (sense organs in muscles, tendons and joins) and a sense of balance or equilibrium are being further studied. It is the accumulation of numerous signals and information from these sensors that allows humans to have an awareness of space. But which signals in particular are most responsible for constructing a 3 dimensional experience of space?

One of the senses less explored in architectural and spatial study is hearing. This sense interests me the most because sound and the ear do not just respond to the material and proportion of a space, but sound and its movement through air constructs the 3 dimensional volume of space.
Buckminster Fuller pointed out that, at the atomic level, solid bodies are actually composed of different states of vibration.
In other words, all bodies are in a state of constant transformation. This way of perceiving space changes one's relationship to the surrounding environment.

The focus of this thesis investigation is sound as a basic parameter of the experience of space. What leads to this study is my previous experience performing musical instruments and my fascination in discovering how one acoustically experiences space.
It is especially crucial in a time when optical media dominate, and the sense of sight and visual perception have an enormous significance, while sense of hearing is attenuated, and even has negative connotations of noise and noise pollution.
While architectural spaces are de-emphasizing acoustic space, we also need to be aware of the new emphasis placed on sound through new technologies today. We are surrounded by technologies such as MP3s, cell phones, streaming media, XM satellite radio and highly sophisticated speaker systems in automobiles. The last decade can be characterized by the dominance of sound related technology. In this case, people

often use sound to disconnect themselves from the space they inhabit to enter the spaceless environment. In both cases the elementary relationship between sound and space has been neglected.

So, what does it mean to experience space acoustically? Can one choreograph spaces with sounds to change the spatial experience? Perhaps sound itself can be understood as a building material, as an architectural and sculptural material, as a form-producing material like wood, stone and plaster. Recent technical advancements in sound production and reproduction offer previously inconceivable opportunities to invent space with sound.

As a method of experiencing space, an investigation of acoustically shaped space can transform one's understanding of space and its relationship to the surrounding environment.

Proposal:

The test site for the project is situated in the Flushing Meadows-Corona Park in Queens, NY. The park is nearly 1,500 acres, which makes it one of the largest park areas in New York City. Many travel from all regions of NY City to use the park for larger team sports or other events and activities not easily available in the inner-city park such as the Central Park.

The experience of the park can not be characterized without relating to the acoustic quality of the site. The park's close relationship to major infrastructure and it's unique location close to LaGuardia Airport makes the location of the park acoustically intriguing. In addition, the sound experience of various sports and leisure activities in the park also adds to the liveliness and excitement of the park. However, when one is walking in the park, one hardly notices the acoustic richness and complexity of the park.

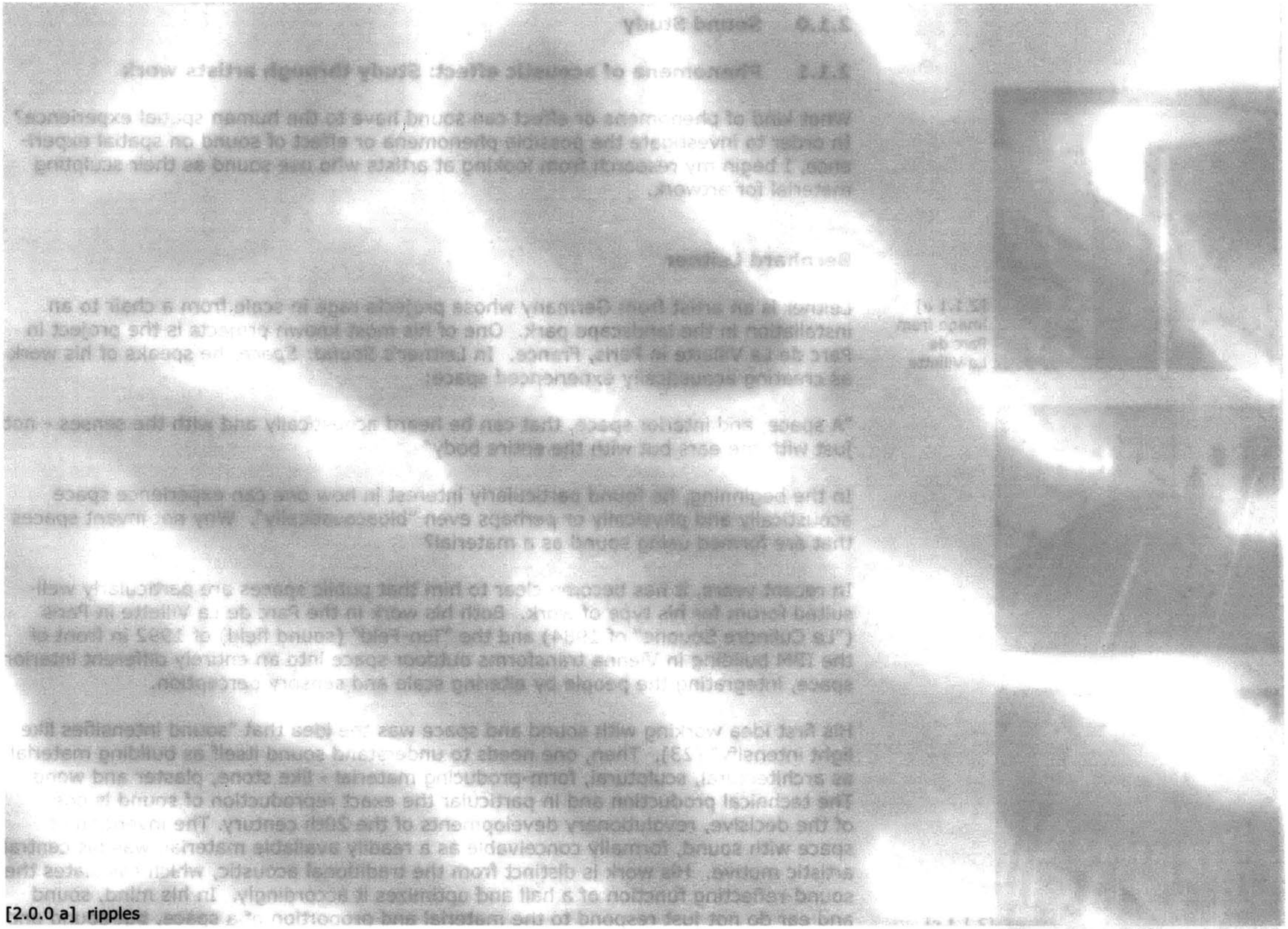
The goal is to explore a way to design using sound as the leading architectural and building material. Designing from a non-physical material such as sound addresses some of the basics of physical architectural design differently. Issues of dimension/scale, boundary conditions and relationship to the landscape are some of the key questions leading the design process. The focus of the thesis will be the explorative process of developing a set of design tools and design processes through sound in order to give another reading of the park through experiencing a sequence of acoustically choreographed spaces intrigued by various people initiated events in the park.

3.0.0 design method

4.0.0 design development

5.0.0 final proposal

2.0.0 design foundation

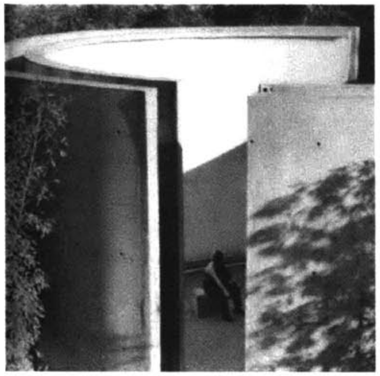


[2.0.0 a] ripples

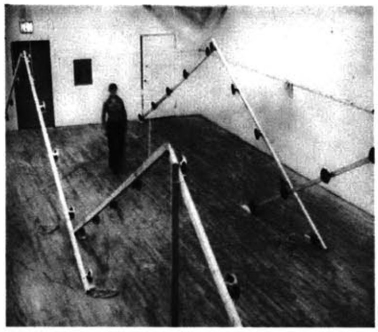
2.1.0 Sound Study

2.1.1 Phenomena of acoustic effect: Study through artists work

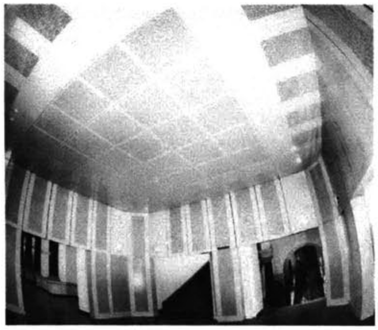
What kind of phenomena or effect can sound have to the human spatial experience? In order to investigate the possible phenomena or effect of sound on spatial experience, I begin my research from looking at artists who use sound as their sculpting material for artwork.



[2.1.1 a] image from Parc de La Villette



[2.1.1 b]



[2.1.1 c]

Bernhard Leitner

Leitner is an artist from Germany whose projects rage in scale from a chair to an installation in the landscape park. One of his most known projects is the project in Parc de La Villette in Paris, France. In Leitner's *Sound: Space,* he speaks of his work as creating acoustically experienced space:

"A space, and interior space, that can be heard acoustically and with the senses - not just with the ears but with the entire body"

In the beginning, he found particularly interest in how one can experience space acoustically and physically or perhaps even "bioacoustically". Why not invent spaces that are formed using sound as a material?

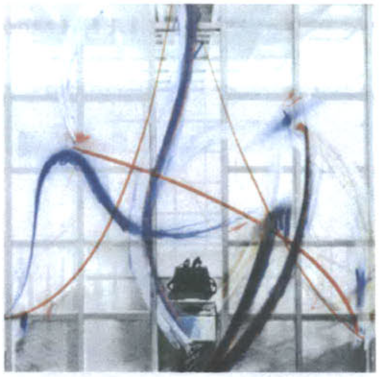
In recent years, it has become clear to him that public spaces are particularly well-suited forum for his type of work. Both his work in the Parc de La Villette in Paris ("Le Culindre Souone" of 1984) and the "Ton-Feld" (sound field) of 1992 in front of the IBM building in Vienna transforms outdoor space into an entirely different interior space, integrating the people by altering scale and sensory perception.

His first idea working with sound and space was the idea that "sound intensifies like light intensify" (23). Then, one needs to understand sound itself as building material, as architectural, sculptural, form-producing material - like stone, plaster and wood. The technical production and in particular the exact reproduction of sound is one of the decisive, revolutionary developments of the 20th century. The invention of space with sound, formally conceivable as a readily available material, was his central artistic motive. His work is distinct from the traditional acoustic, which calculates the sound-reflecting function of a hall and optimizes it accordingly. In his mind, sound and ear do not just respond to the material and proportion of a space, but sound and its movement are the space - a new type of acoustic space.

"sound cube" 1981

This device allows him to work with space sculpturally. When he draws a line in space, it is almost as if sketching. This action has a certain set of characteristics, which can have a body-space function. For example, a diminuendo line that rises in space has an experience of almost lifting the body up. On the other hand, the crescendo line that descends in space, moving from top to bottom, through the body, has a spatial experience that is almost like being compressed.

The physical, acoustic, relationships are very important for Leitner. The sound space, or space in general are measured acoustically by the entire body and not just the ears.



[2.1.1 d]
sketch of
sound cube

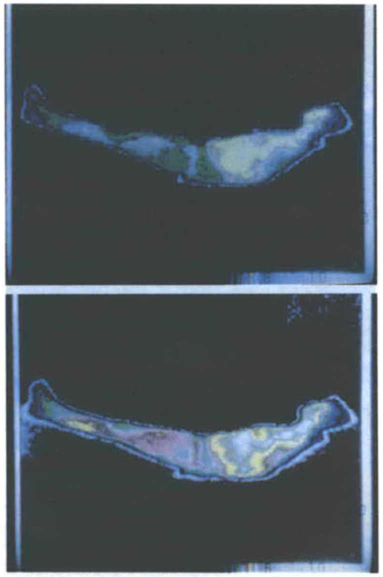
"sound chair" 1991

The sound chair is a work of art but it can also be seen as a means of psychophysiological therapy. From testing, it shows that by positioning the body in the reclining position enhances relaxation and provokes new modes of perceiving and experiencing one's own body.

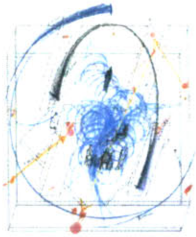
This project was tested 64 times at the Department of Clinical Neurophysiology at the Bonn University Clinic, mainly with pain patients. The average time of testing was 20 minutes.

Psychophysiological parameters were measured before and after in some cases even during the application of the sound chair. Registration of the breathing frequency demonstrated a reduction in frequency of at least 1 per minute. Systolic blood pressure was in most cases reduced by about 10mm.Hg. Pulse frequency did not change significantly in either direction. Electromyographic registration showed diminution of muscle activity in the sense of relaxation. The Brain electrodes showed the person in sleep stages even III and I. Registration of skin surface showed increase in temperature. This indicates stages of dreaming.

One of the starting points of Leitner's work was that sharpening our ears had become essential again. And he believes that it is not just the ears, but our entire acoustic sense of space. For certain people it isn't easy to enter into an acoustic -spatial work; they need training. In many exhibitions he has found that people who are

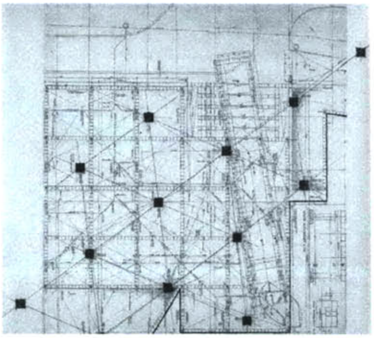


[2.1.1 e]
image from
the testing of
sound chair

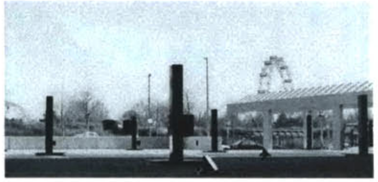


[2.1.1 f] Leitner

[2.1.1 g] Leitner



[2.1.1 h] "Ton Feld" by Leitner



[2.1.1 i] "Ton Feld" by Leitner

aware of their bodies, who work with their bodies, for example, dancers, people who have no inhibitions with respect to their bodies understand the work quicker.

In Leitner's mind, he believes that acoustic spaces have other conditions and are perceived differently than visual spaces. In our time, the optical, visual sense of space is more developed and decisive.

Terry Fox

Fox is interested in finding sounds that make energy palpable and that convert the listener and his physical surroundings. In this he stands closer to Buckminister Fuller. Starting from the discoveries of physics, Fuller pointed out that, in reality no solid bodies exist but merely various states of vibration. All bodies are in a state of constant transformation.

In some of his work, the discovery in 1970s is deeply influenced. Fox realized that vibration of meter-long, strung piano wires call up sound particularly suited to spatialization. He used these strung piano wires in various contexts on most various sites.

Throughout his work, Fox usually relates sound to the given spatial conditions. He activates and vitalizes the space and thus changes the perception of its architecture. He also makes the entire architectural space vibrate and turn it into a resonance body, into a co-player, even into an instrument. In Terry Fox's Works with sound arbeiten mit klag he speaks of his art piece as:

"I transformed the space, that was the point of the performance. I felt musically part of the environment."

To speak of the time aspect of traveling sound, he says he has a different sense of time, and so do his performances. They are not didactic. The extended length of time works to get one into the piece.

"tronic" 1986

In this work, he played a lowest key of the church organ consistently for a long time. Through this consistent low sound of the organ, one felt the entire space resonate, especially if one is sitting on the chairs on the floor. This resulted in making people spatially aware.

Drawn from the following sources:
Fox, Terry. *Terry Fox - works with sound arbeiten mit klag.*
Leitner, Bernhard. *Sound:Space.*

[2.1.1 j]
piano wires
by Fox

[2.1.1 k]
sound project in an
abandoned
church by
Fox

2.1.2 Phenomena of acoustic effect: Study through sound manipulative technology

In continuously searching for the acoustic phenomena or effect that alters human spatial experience, I also looked into the field of sound manipulative technology.

My search starts from looking at concept of sound cancellation. What happens to acoustic spatial experience when there is no sound to situate one in a space? Furthermore, what will be the spatial experience if this technology that is most effective through earphones is applied to the architectural scale. I further proceeded in this idea of sound cancellation in architecture by looking into pietzo material as the building material.

While still being interested in creating acoustic space with sound cancellation and understanding the technology, one of readers criticized me on my direction of research. He told me the content similar to the following:

I am not a scientist whose goal is to invent a technology and develop them to perfection. Instead, I am a designer whofinds an application for that technology.

From this point, I continued to look for the possibility of sound manipulation technology for my interest, but not caught up deelpy in the detail of the technology.

The following are some of the other interesting sound technologies I discovered through the research.

"Surface Sound" a speaker system using "exciter"
By NXT Technology

"Sound spotting"
By MIT Media Lab

"Dialtones: a telesymphony
A concert performed entirely through the ringing of the audience's mobile phones.
By Golan Levin, Scott Gibbons, Greg Shaker, Yasmin Sohrawardy
and Joris Gruber, Jorg Lehner, Gunther Schmidl, Erich Semlak

Sound Cancellation

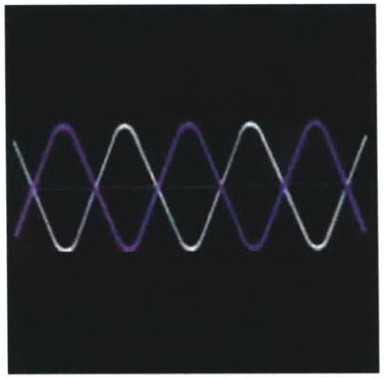
As the first process in deforming 3D spatial experience acoustically, I looked at the possibility of Sound Cancellation technology.

Some people have to work in noisy environment. For this reason, a device is developed in order to protect their hearing and allow them to concentrate on what they are doing without the distraction of sound. This device is called sound suppression device or electronic noise cancellation.

The scientific concept of sound is the following:

Adding waves
If one adds two waves together that are in the same direction, and if those waves are in phase - that is when the peaks and valleys of the waves line up - then the amplitude or height of the waves will double. This results in doubling the volume of sound as if two sources of the same sound are combined.

Canceling waves
On the other hand, if one adds two waves together that are going in the same direction but completely out of phase - that is when the peaks of one line up with the valley of the other - then the amplitude or height of the waves cancel each other out. This is the essential concept of sound cancellation.

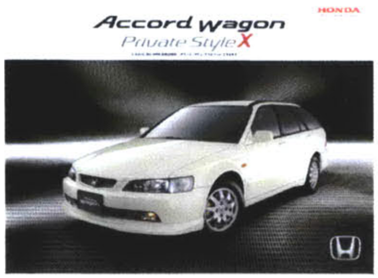


[2.1.2 a]

Canceling out sound waves is done electronically. There are now special noise suppression headsets that have a microphone and electronics built in it. The microphone detects the noise, changes it to an electrical signal and relays it to the speaker in the headset. This then turns the signal back into sound.

This is how any microphone-speaker system works. What is different is that the electronics put the recorded signal exactly out of phase with the actual sound. The sound from the electronic noise cancellation headset then is creating the same sound as loud as the noise. The only difference is that it is completely out of phase with the noise, thus canceling the sound. Therefore, in one sentence, adding two loud sound that are simply out of phase creates silence.

[2.1.2 b]



[2.1.2 c]

ることからオーディオシステムの新たな機能として採用した。また、
防ぐ目的で使用しているボディ補強材を軽減できるため、車両の

ブノイズコントロールの構成図

聞きやすさを示す概念図

[2.1.2 d]

[2.1.2 e]
sound cancellation
headphone by Bose

The following are some of the applications for sound cancellation technology currently on the market:

Headsets
Headsets created with sound cancellation technology to protect hearing of workers in airports and noisy factories.

Honda cars
Noise canceling sounds waves are sent through the stereo speakers, along with music. This technique reduces the low frequency vibration noises in the car while improving the sound of the car audio system.

Headphones
Headphones used inside aircraft and automobile interior to reduce low frequency vibration noises.

From my understanding of the concept of sound cancellation, there are currently two reasons for using this technology. This technology is most commonly used in order to protect one's hearing ability from being damaged through excessive noise levels. This is in the case of various working environment such as airport, factory and construction sites. Another case is to cancel the surrounding sounds for one to concentrate on their work or studies. It is a form of a relief from background noise. In both cases they are used as a solution to the "noise" problem. Instead, I am interested in using this technology as a sound controlling technology that has the powerful effect of completely altering the spatial experience.

Drawn from the following sources:
Bose Corporation at: http://www.bose.com/noise_reduction/personal/qc_headset/index.html
Japan Honda Motor Co., Inc., Accord Wagon
Kurtus Technologies at: http://www.scholl-for champions.com/science/noise.html
Gernsback Publications at: http://www.headwize.com/projects/noise_prj.htm

Pietzo-electric material

Learning about the powerful effect of sound cancellation, I searched for a way to create an architectural space with this effect.

The Pietzo-electric material research is initiated by its potential as a material to function like the sound cancellation headsets to emit the out of phase sound wave to cancel sound in an architectural space.

To explain this process more clearly, one needs to understand the unique quality of Pietzo-electric material.

Pietzo-electric

This is a material which electric charge is generated when the material is pressed. The reverse is also true: an applied electric field will cause a change in dimensions of the piece of material. This process is somewhat like thermal expansion and contraction, but since electric field is used instead of temperature, a quick reaction is achieved in response to commands easily generated with electronic circuits.

Using Pietzo-electric, I imagined a situation where a large panel of Pietzo-electric material can vibrate frequently enough to emit out of phase waves to cancel the sound of the space surrounding it. If this is possible, the sound cancellation technology will advance into another dimension and scale. Furthermore, it will introduce an acoustic spatial experience that has never existed before. If it is possible to create an technology embodies many interesting possibility.

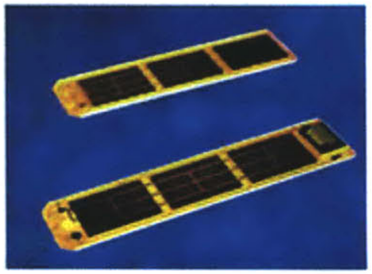
The following are some of the products where pietzo-electric material is currently applied for reduction of vibration.

- Ski - reduction of vibration
- Fighter jets
- Flat speaker
- Smart bat
- Snowboard
- Omni transducer
- Electric water-ski

Drawn from the following sources:
Active Control Express: http://www.acx.com

[2.1.2 f]

ACX custom-designed QuickPack actuators installed on the vertical tail of an F/A-18 airframe. The IFOSTP ground vibration test rig is seen in the background.
Photo courtesy of AMRL.



[2.1.2 g] pietzo electric ski boards

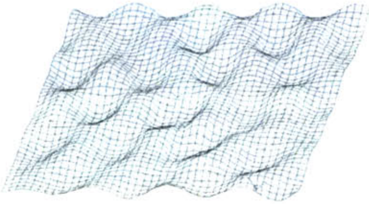
[2.1.2 h]

NXT technology

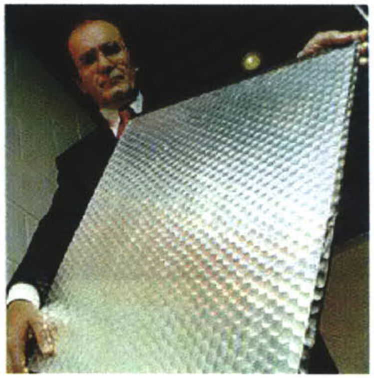
A London-based company called NXT began licensing technology for new kind of flat-panel speakers. While flat speakers have been around for nearly 50 years, NXT's technology is the first to use multiple, chaotic vibrations instead of pulsating diaphragm to create sound. The result is an expensive, lightweight and flexible speaker that can reproduce high to mid-range frequencies better than regular speakers.


[2.1.2 i]

Conventional speakers use a pair of magnetic fields to make a membrane vibrate as a whole. By contrast, NXT's speakers use electronic impulses to produce multiple vibrations across a single surface. The basic idea behind this technology is the same as tapping a drum. If one taps the drum, the sound vibrates across the drumhead, starting at the point at which one tapped. It one taps it softly, the volume is lower. If one taps along the edge, one will get a different tone than if one taps the center. With the NXT's speaker, an electronic "exciter" on the back of each speaker send the electronic "taps" along the surface of the panel. By changing and regulating each electronic tap, the exciter creates different volumes and frequencies that vibrate through the panel.


[2.1.2 j]

The resulting vibrations are heard as sound. The exciter sends multiple taps along multiple paths. This results in an overlap of sound waves across the panel that makes it look like a pond in a rainstorm. The vibrating membrane on the current NXY speakers is made of a woven paper composite. According to the company, the material one uses for the panel does not make a significant difference. One can use cardboard if one opts to do so. However, the better the material, the better the sound.


[2.1.2 k]

NXT has licensed its technology for use in ceiling tiles, picture frames, car door panels and cinema screens. The technology is even being used for the new speaker system at the Greenwich station of the London Underground.

Note about the speaker is that the driver is clamped to the panel and produces wave like vibrations within the panel. By controlling the parameters such as the stiffness, density and area of the panel, position of the driver and the method of suspension the speaker can be made to perform as a loud speaker. It is important to note that this technology however does not have the capability to absorb or deaden sound. The technology is developed as an amplifier at this moment.


[2.1.2 l]

The following is the list of advantages with the NXT technology in contrast to the other flat speaker system.

It is able to evenly disperse sound throughout any space, as oppose to conventional speaker.

The design is compact. It can be easily installed on ceiling because of its lightweight.

The panel can carry images and pictures by spray mounting it directly on to the surface.

The panel also works like a musical instrument.

The product also works very well in strange shaped rooms without the interference patterns usually associated with speakers. This is because the waves produced are incoherent.

Material size is up to 500 GSM canvas but 200 GSM is recommended.
SIZE 25 cm^2 to 100 m^2
WIDTH 3mm to 25mm

The speaker is multi-sided. It is possible to have both front and back of the surface to work in phase. This means that there is no need for enclosures. It can be hung in a room and act as two speakers radiating in 2 different directions.

It has a competitive price to conventional moving coil speakers.

The NXT's research facility has also developed another technology called SoundVu. SoundVu uses transparent panels instead of opaque panels to conduct sound. The company has made a laptop with SoundVu - the entire screen is a speaker.


[2.1.2 m]


[2.1.2 n]


[2.1.2 o]

The following is the use of NXT technology SoundVu in the various areas of application.

advertisements
picture frames
kiosk
automobile rear glass, door panels(Chrysler and Mercedes)
house interior
airplane interior for engine sound dampening
cinema screens
new speaker system at the Greenwich station of London underground
open plan office sound masking system "i-ceiling system"

Drawn from the following sources:

NXT Surface Sound Technology at: http://www.kodel.com/flatpanel.htm
NXT Surface Sound Technology at: http://www.uclan.ac.uk/facs/destech/epd/students/speakers/nxt.htm
NXT Surface Sound Technology at: http://www.nxt.co.uk/
NXT Surface Sound Technology at: http://www.nxt.co.uk/www/corp/press/pr010809.htm
NXT Surface Sound Technology at: http://www.techtv.com/print/story/0,23102,2454059,00.html
NXT Surface Sound Technology at: http://abcnews.go.com/sections/tech/CuttingEdge/flatpanel990402.html

[2.1.2 p] plan view of the site

[2.1.2 q] site of the testing on MIT campus by the Media Lab

Soundspotting

Hear&There
1999 Sociable Media Group at the MIT Media Lab

Soundspotting is a system developed at the MIT Media Lab, initiated by Joseph Rozier. The title suggests the concept of the system, to virtually drop sound at any location. During the demonstration, one will experience sound to "appear" to be coming from a particular location in space. One of the examples is to make a bird fly in air with sound. The audience will not see the bird flying, but they will hear the bird flying, as if it actually exists. (The system used spatialized audio, using Java3D)

Apparently, the interface allows for precise control over where a sound exists in space, how large it is, and various properties of the audio.

The authors hope this system will be used to build a sense of community in a location and to make places feel more alive. A situation where one can use Soundspotting technology in the future proposed by the authors is the notion of temporal information (soundspot changes over time), augmented communication channels within a space, and moving sounds.


[2.1.2 r]
the system used during testing

Joseph Rozier's Masters of Engineering Thesis Proposal called Hear&There: An Augmented Reality System of Linked Audio states that:

"I will use audio overlays to give members of a community the ability to leave audio imprints in a real-world space. These "imprints" will be groups of related sounds that represent the author in some way."

Notes

Software and hardware required:
Java 2, JDK 1.3
Audio Software for creation of sound files
Desktop computer for authoring/simulation system
Notebook computer for In-Field system
Palm computer for simple In-Field UI
Magellan Z-Sensor GPS for location tracking
Microphone for recording audio
Headphones for In-field listening
Backpack for carrying In-Field components

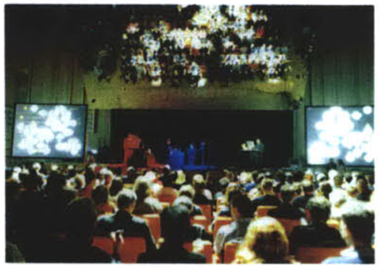
Drawn from the following sources:

Joseph Rozier at: http://smg.media.mit.edu/projects/HearAndThere/

Dialtones: a telesymphony
A concert performed entirely through the ringing of the audience's mobile phones.


[2.1.2 s]

Dialtones is a concert performed entirely through the ringing of the audience's mobile


[2.1.2 t]


[2.1.2 u]


[2.1.2 v]

phones.

The intention of this project is to revile the technology's possibility to invert one's understanding of private sound, public space, electromagnetic etiquette, and fabric of the communications network that connects one to the world.

In http://www.flong.com/telesymphony, the author describes the project as the following:

"During the concert itself, the audience's mobile phones are brought to life by a small group of musicians, who perform the phones en masse by dialing them up with a specially designed, visual-musical software instrument. Because the audience's positions and sounds are known to Dialtones computer system, the performers can create spatially-distributed melodies and chords, as well as novel textural phenomena like waves of polyphony which cascade across the crowd; these musical structures, moreover, are visualized by a large projection system connected to the performers' interfaces. Towards the end of its half-hour composition, Dialtones builds to a stunning crescendo in which nearly two hundred mobile phones peal simultaneously. It is hoped that the experience of Dialtones will permanently alter the way in which its participants think about the cellular space we inhabit."

I find it intriguing that the individually/privately owned cell phone with the least welcoming sound can transform into the musician's instrument and become an actual sound of performance. Sound becomes the transitional media from private to public.

Another appealing element of this concert project is it's centrally controlled but distributed sound source. In other words, the musician may signal the sound, but the sound is produced among the audience. The audience is literally actively participating in the concert. This kind of choreography of space through sound gives another meaning to acoustically experienced space.

Drawn from the following sources:

Golan Levin, Scott Gibbons, Greg Shaker, Yasmin Sohrawardy
and Joris Gruber, Jorg Lehner, Gunther Schmidl, Erich Semlak at:
http://www.flong.com/telesymphony

2.1.3 Ideas on sound sculpted space: Space sculpted with non-physical material

At the end of the summer of August 2001 before school began, I listed a series of the unique character of sound shaped space I intend to pursue in the thesis project. Although the characters listed below were projected from the basis of a sound cancelled space, the unique possibilities of space sculpted with non-physical material are clear.

Ideas of architectural application:

Pietzo-electric material as sounds cancellation media

First condition = phase waves, or sound cancelled space.

In the case of out of phase waves, one can imagine the following scenarios:
(Note: in an outdoor situation, the sound will not completely cancel out to the state of silence, but background noise will be reduced.)

The effect has a potential to question public/private space. In other words, the space shaped by sounds can transform outdoor space into entirely different experiential interior space, for example.

The effect also has the deforming acoustic sense of space different from the visual sense of space. The sense of boundary and distance is deformed.

The effect has the potential as a therapeutic device. It is known from the work of Terry Fox (artist working with sound), that certain sound has the ability to relax the listener.

The effect can also have a problem solving option of sounds cancellation in an space restricted in material (smooth reflective surface) where conventional sound absorbing method is not appropriate.

Using the background sounds cancellation effect, one can imagine the possibility of conducting meetings and events, which normally take place indoor or outdoors.

[2.1.3 a] image shows condition of overlapping programs

[2.1.3 b]

When occupying an event space: In the case of a sports match, the sound canceling structure can lower the background noise for the athletes to concentrate on their match.

When occupying before an event: By suppressing the sound before an event, if one experiences a sound suppressed space before an event space, then the experience in an event space will be amplified and add more excitement.

Second condition = in phase waves or amplified and recreated sound condition.

In the case of in phase waves, one can imagine the following scenarios. The important concept in this condition is the ability to transport sound in space and time.

One of the amazing aspects of this technology is not only to cancel sound but to also amplify sound. Furthermore, depending on the configuration of the sound controlling devices, one can also record the 3D acoustic space and acoustically recreate the same space in another occasion and time. In other words, the space keeps an acoustic memory of the space. (This effect has been demonstrated through the sounds cancellation headsets)

One possible application is for a professional athlete to practice under the atmosphere of many visitors. This way, one can recreate the atmosphere acoustically, and practice under those acoustic conditions. This application is interesting but does not interest me because of its very specialized application.

Another application will be to add more excitement to an event. Application of this technology can change the atmosphere by acoustically modifying the space.

Last possible application is to simply experience of the surrounding environment. I would like to call this effect a pure experience of space through sound. Using the amplifying aspect of the technology, one can begin to highlight the acoustic sound of the surrounding environment and transform one's understanding of the surrounding environment.

2.1.4 What is sound? : Science of sound

Sound manipulated space has an ability to create physical texture in space through a non-physical material. As another step to understand the possibility of acoustically shaped space, I felt the need to review my knowledge of the scientifically defined sound itself.

A vibrating object will produce a sequence of compressions and rarefactions in the air surrounding it. These small fluctuations in air pressure travel away from the source at relatively high speed, gradually dying off as their energy is absorbed by the medium. What we call sounds is the vibration produced by the ear when stimulated by fluctuation in the air pressure.

Another definition:
"Consider the air close to the surface of some vibrating object. As the surface moves outwards the air molecules next to the surface are pushed closer together. The air cannot move back into its original for the moment as the space is occupied by the advanced surface of the vibrating object and therefore a movement of air occurs from the object."

terms
The wave motion of sound can be described in the following terms:

Amplitude
This term refers to the difference between maximum and minimum pressure of the sound wave.

Wavelength
This term refers to the physical distance of sound wave between successive compressions. Thus this is dependant on the speed of sound in the medium divided by its frequency: V=l*f (velocity =wavelength*frequency)

Frequency
This term refers to the number of peak-to-peak fluctuations in pressure that pass a particular point in space in one second.

Velocity
This term refers to the speed of travel of the sound wave. This varies between mediums and is also dependant on temperature.

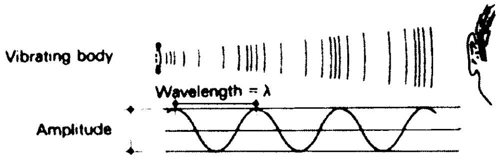


Image taken from S.V. Szokolay. Environmental Science Handbook.

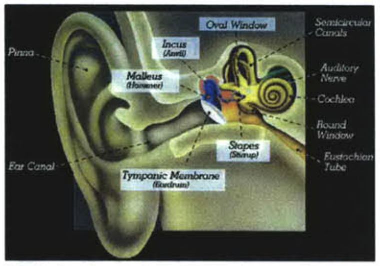
[2.1.4 a]

Assuming air acts as an ideal gas, its velocity (V in m/s) relates to temperature (T in C) as follows: V=331.5 + (0.6T) (m/s)

In other materials, the speed of sound can vary quite substantially. The following shows the speed of sound in a number of different materials.

Material = speed of sound (m/s)
Air = 343 m/s
Steel = 6100 m/s
Timber = 5260 m/s
Brick = 3650 m/s

Properties of sound in Air
Temperature (T): 20.0 C
Velocity (V): 343.7 m/s
Frequency (f): 500 Hz
Wavelength (l): 0.6874 m



[2.1.4 a]

The human ear

Sound waves approaching the ear enter either directly or are reflected by the pinnae down the meatus and are conducted to the cochlea by the three auditory ossicles. The ossicular chain produces a pressure amplification of about 20:1. Their vibrations are conducted up the cochlea by the basilar fluid, which excites about 30,000 small hair cells on the surface. It is from the motion of these hair cells that the brain interprets sound.

Direction Perception

The human brain is able to detect relative direction of sound using the following mechanisms:

Interaural delay

This depends entirely upon time delays between similar excitement levels in each ear. The distance between each ear can be on average 150mm, so there exists a vertical plane, running through the center of the head, within which sound reach each ear simultaneously.

Effects of the Pinnae

These are designed to collect frontal sound and reflect it down the aural canal.

Sound entering from above and behind must have been diffracted by the pinnea and as a result, slight spectral changes to the sound will have occurred.

Distance Perception
The brain is also able to perceive the relative distance of a sound source as follows:

Loss of intensity in sound due to inverse square law and molecular absorption.

Changes to the spectral content resulting form molecular absorption and diffraction around objects.

The level of direct vs. indirect sound - the age old trick of increasing reverberation as a song finishes in order to give the impression it is facing away into the distance, sounds like its in a large cave.

P.H.Parkin & Humphries, Acoustics, Noise and Buildings.
http://www.squ1.com

The shape of ears to come: dynamic coding of auditory space.

Although vision might be our dominant sense, the author emphasizes how much we reply on hearing as our only panoramic, long-range sensory system. If I rephrase this statement, I believe one can understand hearing to be the only sense, which allows one to experience space in an architectural scale.

In this article, the author continues on to how we make use of variety of spatial cues that arises from the direction-dependant manner in which sounds interact with the head, torso and external ears to location of a sound source.

Accurate sound localization relies on the neural discrimination of tiny differences in the values of these cues and requires that the brain circuits involved be calibrated to the cues experienced by each individual. It is important to know that there is growing evidence that the capacity for recalibrating auditory localization continues well into adult life. Many details of how the brain represents auditory space and of how those representations are shaped by learning and experience remain elusive. However, it is becoming increasingly clear that the task of processing auditory spatial information is distributed over different regions of the brain, some working hierarchically, others independently and in parallel, and each apparently using different strategies for encoding sound source location.

Drawn from the following article:
TRENDS IN COGNITIVE SCIENCES JUN 2001.

Traces of learning in the auditory localization pathway.

Human spatial experience is constantly altered through changing sound. Does this suggest that the nervous system adapts and grows as one ages?

The author states that one of the fascinating properties of the central nervous system is its ability to learn: the ability to alter its functional properties adaptively as a consequence of the interactions of an animal with the environment. The auditory localization pathway provides an opportunity to observe such adaptive changes and to study the cellular mechanisms that underlie them. The midbrain localization pathway creates a multi-modal map of space that represents the nervous system's associations of auditory cues with locations in visual space. Various manipulations of auditory or visual experience, especially during early life, that change the relationship between auditory cues and locations in space lead to adaptive changes in auditory localization behavior and to corresponding changes in the functional and anatomical properties of this pathway. Traces of this early learning persist into adulthood, enabling adults to reacquire patterns of connectivity that were learned initially during the juvenile period.

Drawn from the following article:
PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES OF
THE UNITED STATES OF AMERICA 97, OCT 24 2000.

Animal Spatial Recognition

The human brain is able to detect relative direction and distance of a sound source resulting into spatial experience as stated in the earlier part of this chapter. There are examples of other animals that are particularly known for their acoustic sensory reception I would like to look closely.

According to Britanica, among the most highly refined applications of auditory sense are those found in such animals as bats and dolphins. These creatures are able to discern objects around them by a process called echolocation. With echolocation, the animal sends out a cry, and by the nature of the echo, is informed of the presence of obstacles or potential prey. For these animals, the sense of hearing provides a service in the dark that closely approaches the reliability of vision in the perception of objects and spatial relationships.

On the topic of the central nervous systems ability to learn, it is believed that humans learn projection in space where as it is innate for most animals.

Drawn from the following source:
Sensory Reception
Macropaedia Britanica 27

2.2.0 Sound related Architecture

Acoustics and the effect of sound in space have not been the primary focus in most architectural design. However, one can find basic acoustic languages used to describe spatial experiences in the text book. There are also precedents one can learn valuable design methods in it that became helpful. In both cases, it is the first step in starting to learn the existing techniques or ways to represent acoustical spatial experience.

2.2.1 Sound Language

In Leo Beranek's Concert and Opera Halls - *How they sound*, he describes the acoustic spatial experience through a set of sound languages. This set of language he has developed is valuable and helpful as the first step to describe or represent acoustical spatial experience, a non-physical and non-visual condition.

Common Language

The following are a few selected terms used between musician and acoustic experts to describe the impression of acoustic space.

Intimacy or Presence
When music is played gives it the impression of being played in a small hall.

Reverberation or liveness
"Reverberation" refers to sound that persists in a room after a tone is suddenly stopped. "Reverberation time" is the number of seconds it takes for a loud time to decay to inaudibility after being stopped. A hall that is reverberant is called "live" hall. A room with a short reverberation time is called "dead" or "dry". "Liveness" is related primarily to the reverberation times at the middle and high frequencies, above 350Hz. A hall can sound like it is balanced and still be deficient in bass. If a room is sufficiently reverberant at low frequencies, it is said to sound "warm".

Spaciousness: apparent sound width (ASW)
A concert hall is said to have one of the attributes of "spaciousness" if the music performed in it appears to the listener to emanate from a source wider than the visual width of the actual source.

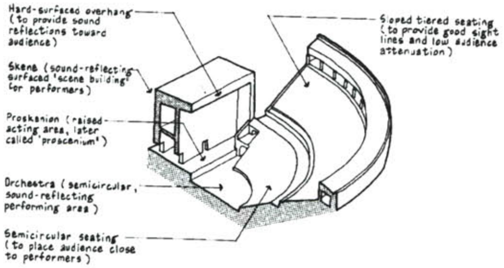
Clarity
"Clarity" is the degree to which the discrete sounds in a musical performance stand apart from one another.

Warmth
"Warmth" in music is defined as liveness of the bass, or fullness of the bass tones relative to that of the mid-frequency tones.

Brilliance
"Brilliance" in music describes a bright, clear, ringing sound that is rich in harmonics. In a brilliant sound the treble frequencies are prominent and decay slowly.

Drawn from the following source:
Beranek, Leo. *Concert and Opera Halls - How they sound.*

2.2.2 History of Acoustic Design and principles of sound behavior



[2.2.2 a]

P.H.Parkin & Humphries' Acoustics, Noise and Buildings talks about how the history of acoustic design started from the amphitheatres constructed by the ancient Greeks. They needed a space to listen to a single orator or small group of actors in open air.

There is a limit to the audibility of the human voice. In order for the amphitheatre to work, the ancient Greeks used acoustic techniques to project the human voice for the 2000 people housed in the amphitheatre to hear. Acoustic design of auditoria progressed until the end of the nineteenth century by a mixture of empirical data and trial & error.

The first significant attempt to determine the fundamental parameters of acoustic design was in 1895, when the auditorium of the Fogg Art Museum was found to have intolerable acoustic problems. Upon examining the auditorium, a Harvard physicist, Wallace C. Sabine determined that the biggest problem was the incomprehensibility of speech due to the excessive sound reflection back and forth between internal surfaces of the auditorium. He tested this by bringing in cushions from a nearby theatre and noticed an immediate improvement.

Consider a sound source situated within the bounded space. Sound waves propagate away from the source until they encounter one of the room's boundaries. At this moment, some of the energy will be absorbed, some will be transmitted and the rest will reflect back into the room. This sets up a complex situation where 3D pressure fluctuations bounce about a room in much the same way as 2D ripples of water.

Sound arriving at a particular receiving point within a room can be considered in two distinct parts. The first part is the sound that travels directly from the sound source to the receiving point itself. This sound that is independent of room shape and materials, but dependant upon the distance between source and receiver is known as the direct sound field. After the arrival of the direct sound, the sound reflected from the room surfaces begins to arrive. These form the indirect sound field, which is independent of the source/receiver distance but greatly dependant on room surface properties.

[2.2.2 b] Fogg Museum at Harvard University

Based on the understanding of direct and indirect sound field, one can assume that the cushions added to the Fogg Art Museum auditorium reduced the amount of indirect sound field by absorbing the direct sound field using the absorptive properties of the cushion.

Furthermore, there is another sound behavior, which also supports Sabines' successful result. This is the growth and decay behavior of sound. When a source begins generating sound within a room, the sound intensity measure at a particular point will increase suddenly with the arrival of the first sound. It will continue to increase in a series of small increments as indirect reflections begin to contribute to the total sound level. Eventually equilibrium will be reached where the sound energy absorbed by the room surfaces is equal to the energy being radiated by the source. This is because the absorption of most building materials is proportional to sound intensity, as the sound level increases, so too doest the absorption.

If the sound source is abruptly switched off, the sound intensity at any point will not suddenly disappear but will fade away gradually as the indirect sound field begins to die off the reflections get weaker. The rate of this decay is a function of room shape and the amount/position of absorbent material. The decay in highly absorbent rooms will not take very long at all, while in large reflective rooms, this can take quite a long time.

Both the reflected sound effect and the growth & decay effect are basic and also primary behaviors of sound. They are two of the several important sound behaviors, which enable me to develop the thesis project.

drawn from the following source:
Square One research PTY. LTD at: www.squ1.com

2.2.3 Experiencing Architecture

In one of the rare books writing about acoustics in architectural space, Steen Eilen Rasmussen posed a question if architecture can be heard? Since architecture does not produce sound, therefore most people would agree that architecture can not be heard. However, neither does it radiate light and yet it can be seen. One sees the light it reflects and thereby gains an impression of form and material. In the same way one hear the sounds it reflects and they, too, give one an impression of form and material. Differently shaped rooms and different material reverberate differently.

People are seldom aware of how much one can hear. One receives a total impression of the things by visual sense and thinks less of the various senses that also contribute to that impression. For instance, when a room is told that it is cold and formal, it seldom means that the temperature in it is low. The reaction probably arises from a natural antipathy to forms and materials found in the room. In other words, something one feels. Or it may be that the colors are cold, in which case it is something one sees. Or finally, it may be that the acoustics are hard so that sound - especially high tones - reverberate in it; something one hears. If the same room were given warm color or furnished with rugs and draperies to soften the acoustics, one would probably find it warm and cozy even though the temperature was the same as before.

As an example, Rasmussen gives two structures where one experiences the space more acoustically.

Barrel - vaulted passage to Copenhagen is not a visually stimulating space, but the reflectivity of the space is very high.

At the Thorralden's museum, in order to play chamber music, one needs upholstery to dampen reverberation. However, when there is a performance of chants, it sounds well in the stone hall of the museum because of its high reverberation. The idea of adjusting the way of performance using the acoustic character of the space is interesting.

On the other hand, today's favorite interior seems unnatural as a rooms with one wall entirely of glass and other three smooth, hard and shiny and at the same time with a resonance that has been so artificially subdued that, acoustically speaking, it does not make a difference what the building looks like. There is no interest in producing rooms with differentiated acoustical effects. They all sound a like. Yet the ordinary human being still enjoys variety, including variety of sound. For instance, a man tends to whistle or sing when he enters the bathroom in the morning. Though the room is small in volume, its tiled floor and walls, porcelain basin and water filled tub, all reflect sound and reinforce certain tones so that he is stimulated by the resonance of his voice. If this is true, why are there little examples of acoustically shaped space?

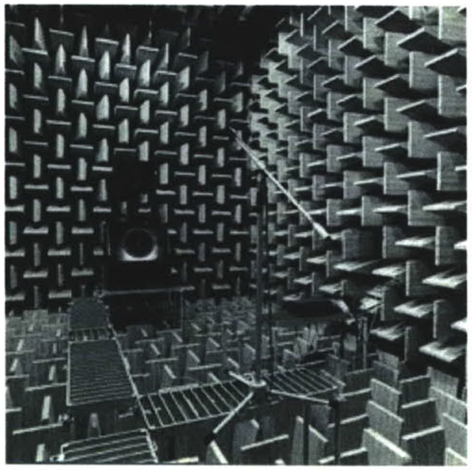
drawn from the following source:
Steen Eilen Rasmussen. *Experiencing Architecture.*

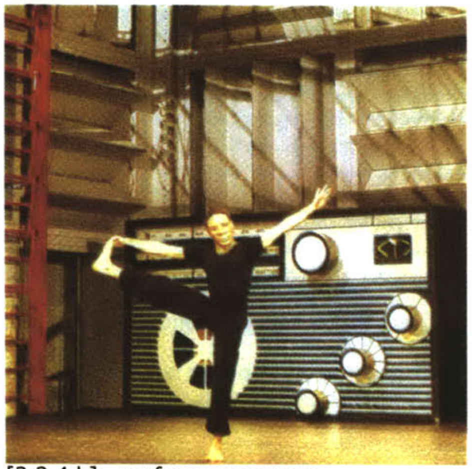
2.2.4 Precedent Architecture case study

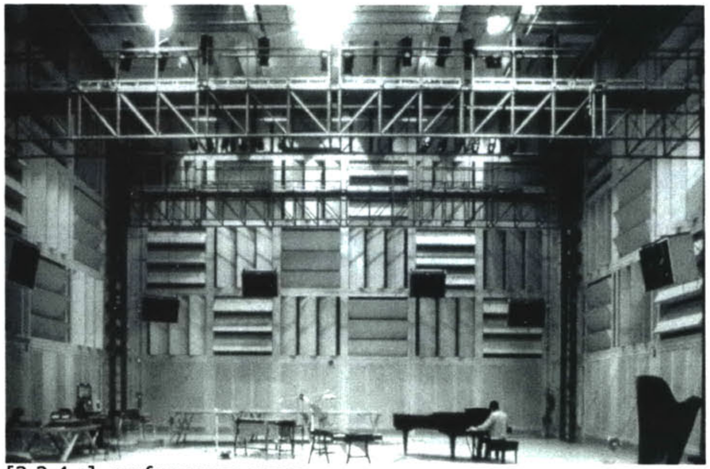
IRCAM, Paris

L'Institut de Recherche et Coordination Acoustique/Musique
Designed by the Renzo Piano Building Workshop

This is a music research center where they experiments on sound composition and music. The underground complex occupies the space underneath the fountain next to the Centre Pompidou. The institute is composed of various rooms to control, manipulate and test sounds. One of these rooms is a performance space where there are rotating panels all along the surface of the wall to vary the reflectivity and absorption of quality of the space. The space can have the acoustic quality of a stone cathedral one time and the quality of a small concert hall another time.


[2.2.4 a]


[2.2.4 b] performance space


[2.2.4 c] performance space

The Swiss Sound Box

Designed by Peter Zumthor
The Swiss pavilion at the Hanover Exposition 2000.

The idea underlying the project is to express human activities of eating and performance through sound. The construction of the installation is an assembly of square section lumbers creating series of walls that divides spaces for different habitation and entertainment. Acoustically, the wall structure becomes a separator or an amplifier of sound created from various events.

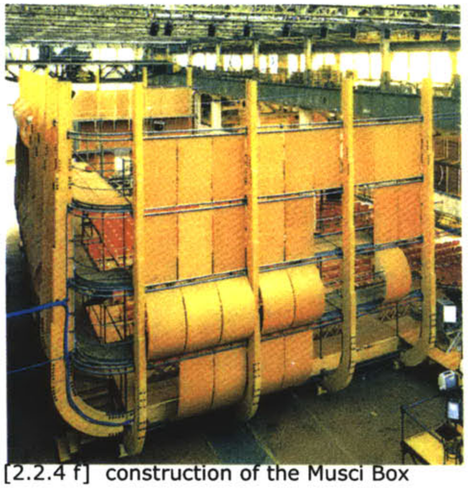

[2.2.4 d]


[2.2.4 e]

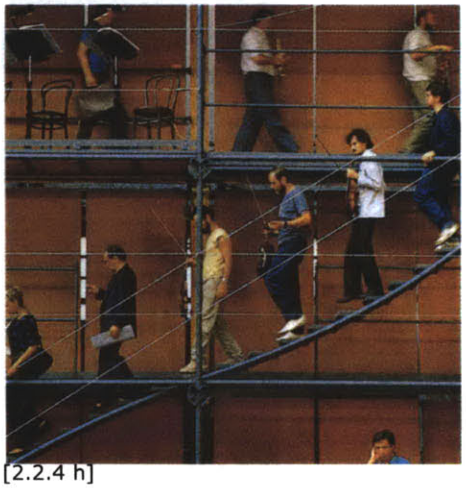
Music Box, Venice Biennale

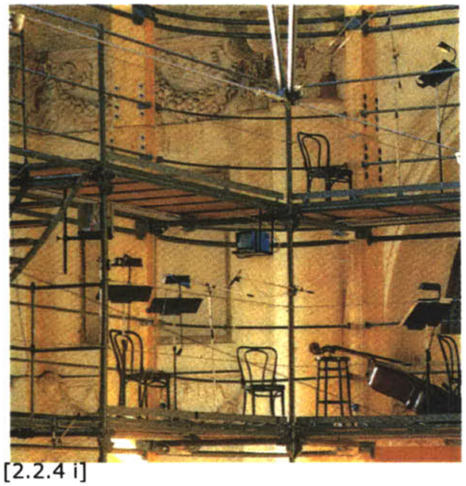
Designed by the Renzo Piano Building Workshop

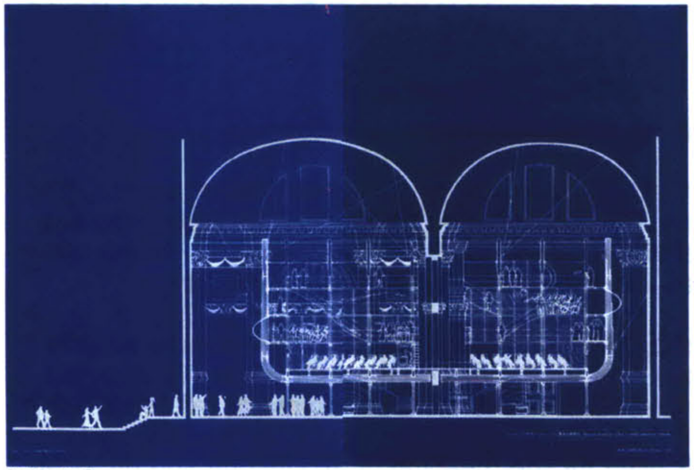
This is a small-scale project in the Venice Biennale, where a laminated wood structure envelops a music performance space inside an old Baroque building. This design resulted in the performance and audience space floating in the middle of the space, only touching the existing building with its supporting structures. Inside the structure, are the audience sitting on the bottom section of the "box", while the musicians surround the audience on the sides of the "box" along its balconies.
In other words, the entire construction becomes a music box.


[2.2.4 f] construction of the Musci Box


[2.2.4 g]


[2.2.4 h]


[2.2.4 i]



[2.2.4 j]

[2.2.4 k]

2.3.0 Landscape Design

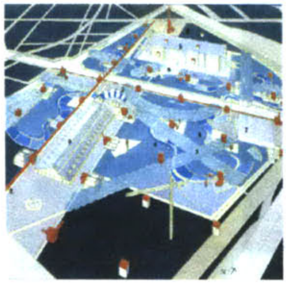
What make this thesis project different from architectural acoustic design is the site and its program. Architectural acoustic design assumes it is an interior space with walls and ceiling enclosing the space. However, the site of the thesis is in a park, where the program contains outdoor activities. Therefore, the acoustic design must take a different consideration in landscape design scale, material and method. Furthermore, one needs to keep a note that the concept of sound behavior does not change. However, the environmental condition alters the sound behavior and adds a different effect on the acoustic spatial experience in an outdoor condition. This idea will be further developed during the design development stage of the thesis project.

2.3.1 Landscape design concept

What are some of the ideas behind park design? The interesting context of the Flushing Meadow park and its potential to create a different function and experience in the park from the urban parks in Manhattan interests me to learn some of the main concepts leading park design. The following is some of the key parks I looked for guidance.

"Paris as a Laboratory for the park of the 21st century"

In this article, the author states that a park should be a refined cultural object. The more refined the culture of the city, the more refined the park. The ideal condition is when the city and nature blend into an ideal relationship in the park. In the urban park, nature is adapted, cultivated and thus made productive for the city.


[2.3.1 a]
Parc de la Villette

In the example of Parc de la Villette in Paris, France the park is not conceived as a green oasis of tranquility within the city. In the design the programme is intended to be open and interdisciplinary. The cultural and symbolic points of reference are pluralism. Words such as urbanism, pleasure and experimentation are keywords in the design. The word pluralism is used for the meaning of disjunction and dissociation. The fragments thus created are reassembled into simple autonomous patterns consisting of three formal systems: points, lines and surfaces. Super imposing these systems produces unpredictable and stimulating combinations of facilities. From this design method, one can see plan that it generates new activities and uses, such as the unexpected encounter between music, sports, and technology in the piano bar intersected by the running track inside the tropical greenhouse. In addition, a grid of striking red structures, "folies", provides focal points throughout the park for both spatial coherence and orientation as well as the functional distribution of facilities and activities.

"Greenway and games: The Volkspark of the future"

Polls on why people go to the parks reveal that they do so to "get out for a bit". This proves that urban dwellers need somewhere to go for a change of scene, a place where they can leave their everyday worries behind, more about, meet other people and let their children play. The statistic shows that the most frequent visitors are elderly, young people, women and foreigners.

Volkspark
The author says that the design of Volkspark is more than just a case of designating open space and positioning infrastructure facilities. It is a matter of fulfilling the physical, aesthetic and spiritual needs of the people. The park is like a colorful planting. It has large open space to erable activities for adults and children, but also provides secluded corners and places for quiet and contemplation that remove visitors from their everyday world.

drawn from the following source:
Topos magazine: June 19, 1997

2.3.2 Sound related Landscape Design

People are seldom aware of how much acoustic design is integrated in park design. In order to pursue what kind of acoustical technique is influential in a landscape design, precedents studies were made with a focus on the acoustic spatial experience in parks.

I began by choosing parks where I remember the acoustic experience being a large part of my experience of the park. Then the source of the sound is pursued, which circles back to how one will acoustically experience the park. A palette of methods, ideas and materials emerged from this investigation that proved to be helpful to me when constructing a design method.

Here are the list of methods, language and material that have an acoustical impact on one's acoustic experience of the park:


[2.3.2 a]
Paley Park, NY


[2.3.2 b]
Greenacre Park, NY


[2.3.2 c]
Bryant Park, NY

Water sound
The sound of the water acts as a masking function to dampen the environmental sound.

Ground texture
Temples and park often have the user-initiated sound to give a masking effect. Use of pebbles, wood blocks and textured surface materials are common. Furthermore, the use of ground material as a sound manipulative element is effective especially in the case where the square area is large. A simple grass field for example acts as an effective sound dampened area using its sound absorptive properties.

Trees, and vertical planters
They act as Sound buffering and sound absorbing elements.

Other activities
(Ex: tables and chairs for eating, reading, writing, etc.)
Creation of sound from other activities has a sound buffering effect because of its different sound quality compared to the street sound (transitional sound qualities) in many urban park examples.

In larger scale sound manipulation:

Terracing/elevation change
Changing land elevation by creating various landforms is an effective method to direct sound. As a basic concept, if one can see the sound source, on can also hear it because there are no obstacles to stop sound from traveling.

Multiple Trees, and vertical planters in large numbers
Multiples and rows of trees and planters act as borders and sound buffering wall.

Pockets of space
Sound quality controlled in intimate spaces, somewhat protected physical barriers has a similar acoustic condition as interior space.

Use of unconventional ground surface materials
Sound reflective character, sound absorptive characters are different with each material, which changes the sound quality of the environment. (For example, children playground uses plastics, rubbers, steel poles, etc.)

Here are the list of parks studied, and the methods and acoustic languages each used for its landscape design.

Paley Park in New York, NY
Water sound used for masking effect.
Trees, and vertical planters used for absorptive effect.
Creation of sound through other activities used for sound buffering effect. (ex: tables and chairs for eating, reading, writing, etc.)

Greenacre Park in New York, NY
Water sound used for masking effect.
Trees, and vertical planters used for absorptive effect.
Creation of sound through other activities used for sound buffering effect. (ex: tables and chairs for eating, reading, writing, etc.)

Bryant park in New York, NY
Trees, and vertical planters are used for Sound buffing and sound absorption effect.
Water sound used for Masking effect.
Creation of sound through other activities used for sound buffering effect. (ex: tables and chairs for eating, reading, writing, etc.)
Method of directing sound through changes in elevation or land forming is effective.


[2.3.2 d]
Bryant Park, NY


[2.3.2 e]
Fountain by Centre Pompidu, Paris France


[2.3.2 f]
Heian shrine, Japan


[2.3.2 g]
Parc de Sceaux, outdie of Paris, France


[2.3.2 h]
Sumida riverside park
Tokyo, Japan


[2.3.2 i]
Boboli Garden
Florence, Italy


[2.3.2 j]
water park by the Science Center
Harvard University, MA


[2.3.2 k]
extention of cemetery in Isola, Spain

Centre Pompidou water-park in Paris, France
Water sound used for masking effect.
Creation of sound through other activities used for sound buffering effect. (ex: tables and chairs for eating, reading, writing, etc.)

Parc de La Villette in Paris, France
Use of unconventional ground texture initiating sound is used for masking effect.
Creation of sound through other activities used for sound buffering effect. (ex: tables and chairs for eating, reading, writing, etc.)
Method of directing sound through changes in elevation or land forming is effective.

Heian Jingu(shrine) in Kyoto, Japan
Water sound used for masking effect.
Ground texture initiating sound is used for masking effect.
Trees, and vertical planters are used for Sound buffing and sound absorption.

The Boboli Garden in Florence, Italy
Water sound used for masking is used for masking effect.
Trees, and vertical planters are used for absorptive effect.
Method of directing sound through changes in elevation or land forming is effective.

Sumida riverside park in Tokyo, Japan
Water sound used for masking effect.
Trees, and vertical planters are used for Sound buffing and sound absorption.

Parc de Sceaux outside Paris, France
Water sound used for masking effect.
Ground texture initiating sound is used for masking effect.
Trees, and vertical planters are used for Sound buffing and sound absorption.
Method of directing sound through changes in elevation or land forming is effective.

Water park by Science Center, Harvard University in Cambridge, MA
Water sound used for masking effect.
Grass is used for ground material to dampen sound because of its sound absorptive properties.

Extension of the Cemetery of San Michele in Isola in Isola, Spain
Trees, and vertical planters are used for absorptive effect.
Ground texture initiating sound is used for masking effect.

2.3.3 Porous asphalt for acoustic landscape design

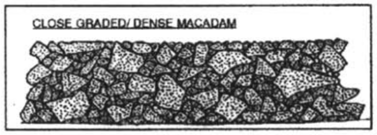
One of the researches I continued after the acoustic study in parks is searching for a ground surface material that has interesting acoustic properties. In a landscape scale design, one of the most effective manipulations of acoustic spatial experience is the ground surface acoustic property. The reason is simple. The ground surface is the largest surface one will occupy in an outdoor park.

Porous asphalt
The increasing traffic volumes on Ireland's Road network together with the wet climate has led to an increased need for adequate surface drainage. Porous Asphalt has been successfully used within Europe over the past decade particularly in France and Belgium and was introduced here within the past 5 years. Porous asphalt consists primarily of gap-graded aggregates held together by a polymer modified binder to form a matrix with interconnecting voids through which water can pass.
The main difference between stone mastic asphalt and Porous Asphalt is in the percentage of voids. Porous asphalt contais at least 20 % voids compared with 3-6% for stone mastic asphalt. In effect this increase in void content means that the porous asphalt acts as a lateral drain and greatly improves the rate of surface water drainage, thereby reducing spray and headlight glare in wet weather and improving the skid resistance.

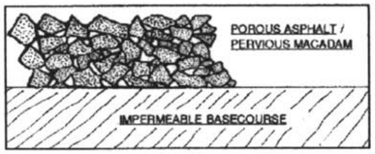
The second main advantage of porous asphalt is in its sound reducing properties. The inverted texture allows for acoustic absorption and the level of sound emitted at the tyre/road interface by porous asphalt is generally lower than for other wearing course materials. The only porous asphalt used in Ireland has a nominal aggregate size of 14mm and several of our country's primary routes to date have been surfaced using porous asphalt.

The main benefits of using porous asphalt are:
Significant reduction in sound levels.
Reduced splash and spray in wet conditions.
Reduction in tendency to aquaplane.
Improved wet skid resistance.

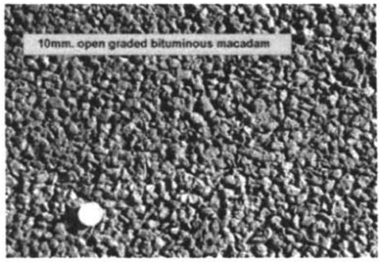
Drawn from the following source:
Roadstone at:
http://www.roadstone.ie/Products/BituminousProducts/PorousAsphalt.htm



[2.3.3 a] diagram of closed asphalt



[2.3.3 b] diagram of open/porous asphalt



[2.3.3 c] image of open/porous asphalt

2.4.0 Previous projects

Prior to this thesis project on acoustically shaped space, I have created some projects based on sound and the acoustical spatial experience. The all come from different discipline of design, however it was from these projects that my interest grew towards acoustically shaped space.

2.5.1 Danahey Park project

A design project during a Visual Art class at MIT called Art in the Landscape taught by Prof. Ed Levin.
Fall 1998

2.5.2 Acoustic and Light Canopy system

A design project during a Design Technology class at MIT called Integrated Kinetic Systems taught by Michael Fox, researching scholar.
Fall 1999

2.5.3 Transportation of sound

A project during a Visual Art class at MIT called Performance Art taught by a performance artist Joan Jonas.
Fall 2001

2.4.1 Danahey Park project

Art in the Landscape class at MIT taught by Prof. Ed Levin.
Fall 1998

Location: Danahey Park, Cambridge MA.

The intension of this project is to become an instrument to experience the park in a different way, through sound.

The interesting experience walking through the park is the ability to hear the sound of the surrounding neighborhood. Park can be a place to escape from the urban context. However, instead of escaping from the urban context, the landscape shape of the Danahey Park immerses one in the neighborhood context through the sound.

The project emphasizes this effect by using sound from the neighborhood and amplifying the acoustic experience through an instrument. The sound from the neighborhood is first picked up by the sound reflector placed periodically in the marsh lands of the park. The reflected sound is then focused towards the space embedded in the ground. This is the seating space where one can occupy to become immersed in the sound of the neighborhood with out seeing the neighborhood.
(Note: A concave plate has the ability to pick up the surrounding sound and focus the sound down to the space underneath.)

The goal of this project is to highlight and make one aware of the unique acoustic spatial experience of the Danahey park.

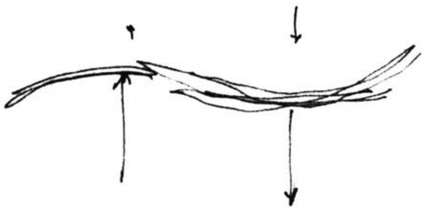

[2.4.1 a]

2.4.2 Acoustic and Light Canopy system

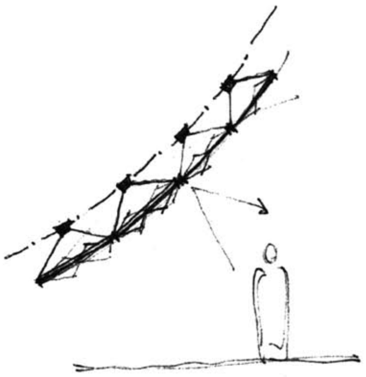
Integrated Kinetic Systems class at MIT taught by Michael Fox, researching scholar.
Fall 1999

Space can be created by the experience of sound in space. Then, changing sound experience will alter how one perceives space. I am interested in creating a fabric that changes it's shape that allows change in spatial experience by redirecting sound. The goal of the design is a flexible structural system, which has the ability to deflect sound in various scale and degree, while also varying the lighting condition of the space.

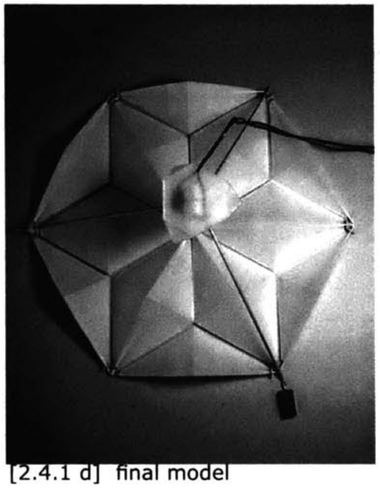
The following are the process in which the project is developed:
Exercise01 physical model
Exercise02 computer model
Exercise03 LEGO model
Exercise04 Application
Exercise05 Final Kinetic model



[2.4.1 b] concept sketch

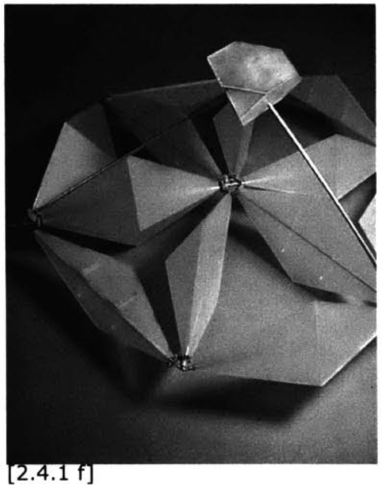


[2.4.1 c] sound reflective system

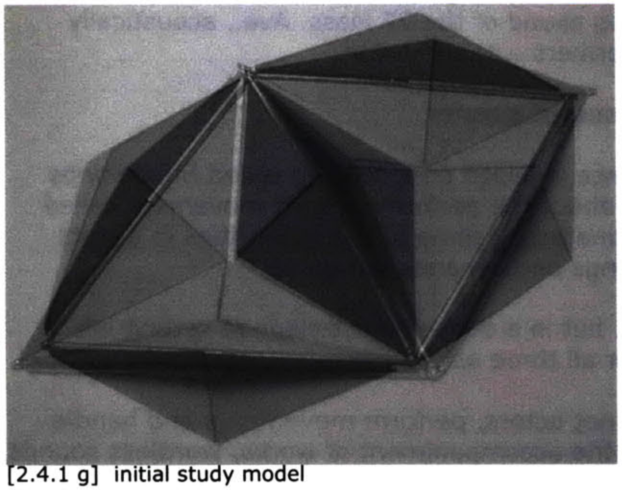


[2.4.1 d] final model

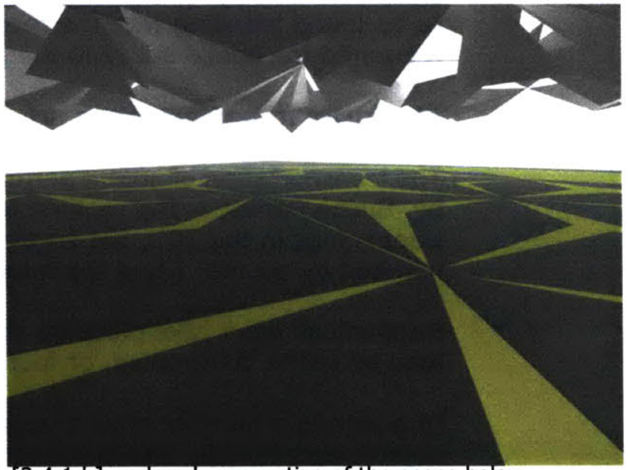
[2.4.1 e]



[2.4.1 f]



[2.4.1 g] initial study model



[2.4.1 h] redered perspective of the space below

2.4.3 Transportation of sound

Performance Art class at MIT taught by a performance artist Joan Jonas.
Fall 2001

The intention of this performance art is to experiment with the idea of transportation and Relocation of space through sound.

I asked the students who are both my performers and audience to spread out in the room. While they are standing, I then asked all of them to close their eyes and practice to make a sound "tu-tu" as I demonstrate the sound. Then I asked to wait to make the same sound only after I tap their shoulders.

In the meantime, I prepared a recording of the "tu-tu" pedestrian signal sound at the crossway at 77 Mass Ave. in front of MIT. I knew this is a familiar place for anyone going to school. The recording consisted of 3 minutes of various sound of the space. It was a mixture of "tu-tu" sound of crosswalk as well as the sound of trucks stopping, accelerating and passing, people passing by while having a conversation, cars and motorcycle sound.

I believe the project was successful in bringing the space of 77 Mass. Ave into the classroom through the performers. The interesting acoustic effect of the performer's tu-tu sound blending with the recording sound of the 77 Mass. Ave., acoustically recreated the space between the performers without vision.

Similarity in performance art and sound events

The transportation of sound performance is based on a reading called *Happenings* by Susan Santec . The reading talks about the performance art movement called Happenings in the 70's, but I was fascinated by some of the similarities in events initiated by sound. I find the Happenings performance intriguing.

Happenings don't take place on stage, but in a dense object-clogged setting which may be made, assembled, or found, or all three above.

In a setting a number of participants, not actors, perform movements and handle objects antiphonally and in concert to the accompaniment of works, wordless sounds, music, flashing lights, and odors.

The Happening has no plot, though it is an action, or rather a series of actions and events. It also shuns continuous rational discourse, through it may contain works like, "Help!", "Voglio un biochiere diacqua", "love me", "car", "one, two, three..." Speech is purified and condensed by disparateness (there is only the speech of need) and then expanded by ineffectuality, but he lack of relation between the persons enacting the Happenings.

Duration of Happenings is unpredictable. The unpredictable duration, and content of each individual, Happening is essential to its effect. Happenins has no plot, no story and therefore no element of suspense.

Happenings state their freedom from time by deliberate impermanence.

Happenings are always in present tense. The same actions are frequently repeated throughout a single Happening. Occasionally the entire Happening takes a circular form, opening and concluding with same act or gesture.

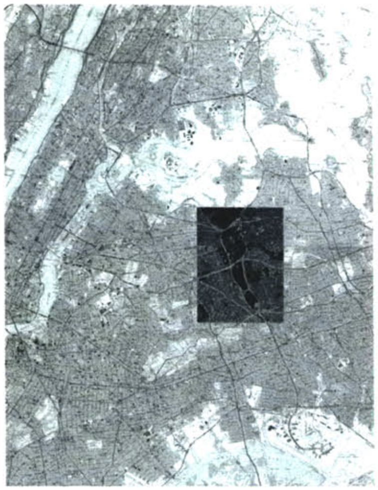
One cannot buy a Happening (like a painting).

Happenings use persons as materials, and not characters.

[2.4.1 i] 77 Mass. Ave. in front of MIT. site for the recording

2.5.0 Site study

2.5.1 Site background
Flushing Meadows-Corona Park


[2.5.1 a]


[2.5.1 b]

Flushing Meadow Park is nearly 1,500 acres making it one of the largest park areas in New York City, almost twice the size of Central Park. The Park is located in the predominately residential Borough of Queens, which is the largest borough in the city, with a growing population of almost 2 million persons. The borough is distinguished as being the most ethnically diverse county in the United States.

Site history:

This park has been through several radical transformation processes. Until 1927, it was a large meadow with a serpentine shaped river in the central part of the site, which collected water drainage and flowed into the Flushing Bay. There were very little residents in the area except for several village clusters that grew in the hill area surrounding the meadow. This is when the northern portion of the park was called valley of ashes, also evident in the quote by the Great Gatsby:

> The Valley of Ashes
> About half way between West Egg and New York the motor-road hastily joins the railroad and runs beside it for a quarter of a mile so as to shrink away from a certain desolate area of land.
> This is a valley of ashes - fantastic farm where ashes grow like wheat into ridges and hills and grotesque gardens, where ashes take the forms of houses and chimneys and rising smoke and finally, with a transcendent effort, of men who move dimly and already crumbling through the powdery air. Occasionally a line of gray cars crawls along an invisible track, gives out a ghastly creak and comes to rest and immediately the ash-gray men swarm up with leaden spades and stir up an impenetrable cloud, which screens their obscure operations from your sight...

The valley of ashes is bounded on one side by a small foul river, and when the drawbridge is up to let barges through, the passengers on waiting trains can stare at the dismal scene for as long as half an hour.

This land however, was completely transformed after it was chosen for the site of the 1939 World's Fair. The large amount of physical transformation of the land was unbelievable.

Earth moved --- 1400,000 truck loads
Railways installed --- the total length of bridges equal to length of George Washington Bridge.
Installed roads --- 12 miles
Installed pedestrian walkways --- 31 miles
Installed bicycle paths --- 5.8 miles
Installed fences --- 10 miles
Installed storm sewers --- 36 miles
Installed water pipes --- 26 miles
Installed piles --- 600 miles

Some of these transformations were of course installed to improve their current condition permanently, and not for temporary exhibition. When the 2nd World's Fair came in 1969, many of the old infrastructures were reused and readapted for the new installation.

Current condition:

The existing park is consisted of large sports facilities, pieces of the old World's fair infrastructure, large lakes and the vast open space for many types of sports activities.

Despite the sound of the airplane over the park every 5 minutes (the park is in the flight path of LaGuardia Airport) because of it's large expanse of land, many drive from far to spend the day at the park on weekends.

The park is not easily accessible to the surrounding neighborhoods because of various boundaries created by above and ground level highway infrastructure, fences and ground level changes.
Furthermore, the park is functioning in a very inefficient way because of its ad hoc

placement of sports field and other activities on the traditional Beaux Arts layout of the park from the old World's Fair. In other words, the existing infrastructure was designed for a specific function (the two World's Fair) and unable to accommodate for new function and needs of the park.

During large sports events in the Shea Stadium and the US Open Tennis Stadium, many use either the highway or the #7 subway train. This subway line is located in the northern part of the park where most people entered the park through the main entrance.

[2.5.1 b] site photo

2.5.2 Same Site, Different Projects

Project 1:

I have designed a master plan on the same site when I joined a Landscape Architecture Design Studio at Harvard University in the spring of 2000.

Conceptual Site by author

The unique character of the site is it's almost incomprehensible scale to human scale when walking through the site. One's experience of the park is filled with impression of fragmentation and isolation from vastness. This effect seems to be created by the visual presence of several large isolated objects of the QMA, Shea Stadium, US OPEN tennis courts, zoo, Science museum and soccer fields as well as the large monuments from the past (Unisphere, NY theater structure and water basin)

To focus on the negative space of the park (vast expanse of open land), one needs to begin by understanding it's influence on the layout of the park. The open space filters through the isolated freestanding objects and trees/grounds the isolated objects in the site. It sweeps and expands throughout the park to speak to its scale as a whole.

With this in mind, the vast expanse of the warping plane or conceptual skin material becomes the core idea of the conceptual site. The conceptual skin is an infiltrating infrastructure, which supports the existing/potential future events and activates public space. It lacks directionality and orientation. It can also be called the keloidal skin, the word adds another meaning that of a tissue which does not mend seamlessly after a tear, but leaves a scar or a mark registering the change.

As an overriding strategy, I began my investigation through studying skin and it's definition.
(This is an investigation instigated from the first project of re-representation of the site, a "non-site" project)

Studies	material possibility of the skin Characteristics diagramming Skin manipulation in fashion

After reviewing the master plan of the site in the existing condition, the final proposal was presented with a series of processes that project one scenario to accommodate the current and future demands.

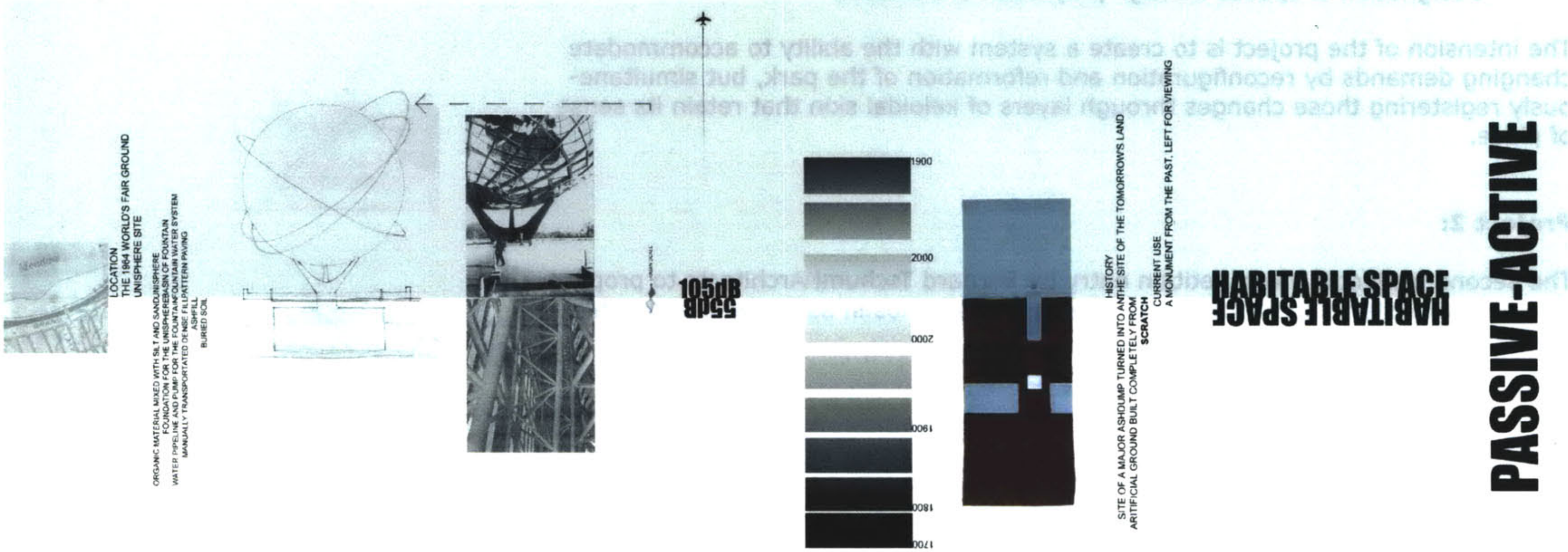
Issues directing the process:

Existing building structures and vegetations
Historical infrastructure - old river footprint
Idea of infrastructure (by Stan Allen)
Circulation and experience through the site
Grid that structures the various levels of ground manipulations - skins
Designation of spaces through projection of activities

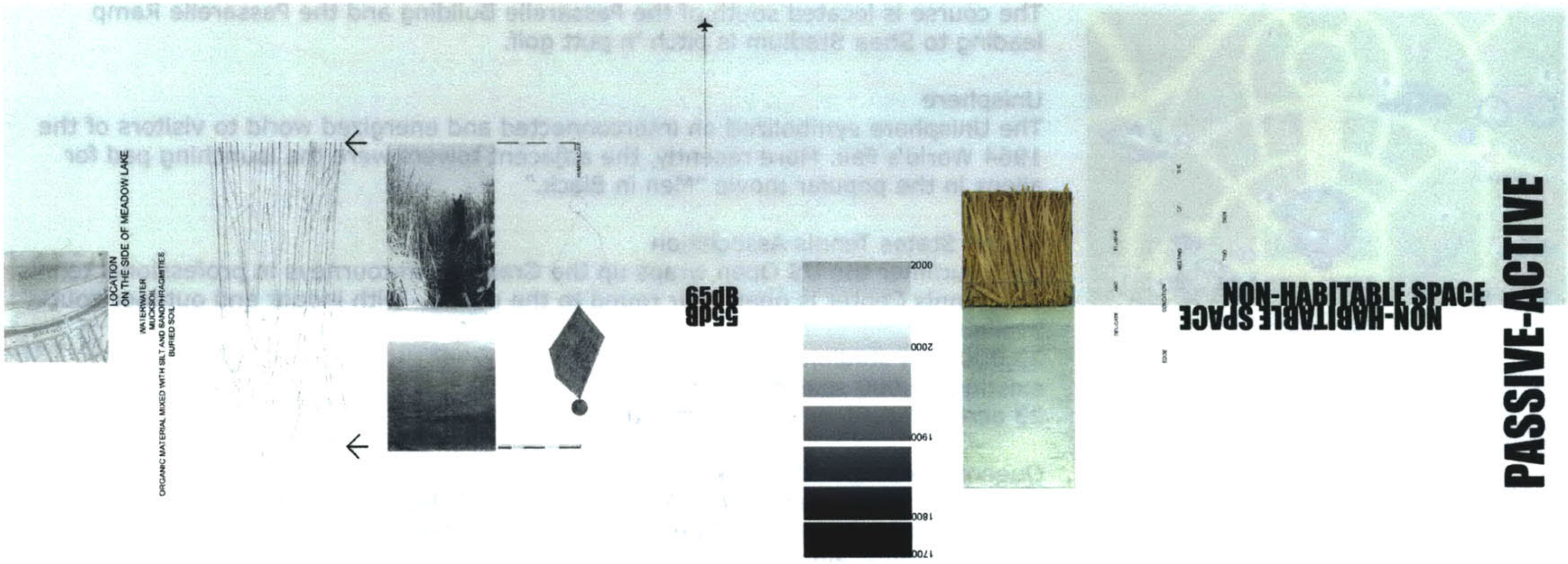
The intension of the project is to create a system with the ability to accommodate changing demands by reconfiguration and reformation of the park, but simultaneously registering those changes through layers of keloidal skin that retain its sense of place.

Project 2:

The second project is a competition entry by Bernard Tschumi Architects to propose also a new master plan for the park. The entry was chosen as the winner for the ideas competition.



[2.6.2 a] concept panels from the Landscape Architecture design studio



[2.6.2 b] concept panels from the Landscape Architecture design studio

[2.5.3 a] Map of activities in the park

2.5.3 Existing Park Activity List

Shea Stadium
Home of the NL Champion New York Mets
Capacity: 56,521. Parking available.

Bike Rental
Bikes are available to cruise around the park.

Pitch & Putt Golf
The course is located south of the Passarelle Building and the Passarelle Ramp leading to Shea Stadium is pitch 'n putt golf.

Unisphere
The Unisphere symbolized an interconnected and energized world to visitors of the 1964 World's Fair. More recently, the adjacent towers were the launching pad for aliens in the popular movie "Men in Black."

United States Tennis Association
Each summer the US Open wraps up the Grand Slam tourneys in professional tennis. The Tennis Center is open year round to the public - with indoor and outdoor courts available.
23,000 seat stadium
existing 10,000 seat stadium
23 acres of outdoor support facilities

Queens Theatre in the Park
Located in the former New York State Pavilion of the 1964 World's Fair, and designed by Philip Johnson, Queens Theatre in the Park presents theater, comedy, dance, children's entertainment and a film series in its Main State Theater and its small cabaret / block box Studio Theater.

Queens Botanical Garden
The botanical garden is located at the north end of the park. 39 acres support a variety of herbs, trees and flowers, and a host of educational programs.

Playground for All Children

Carousel
Antique Carousel is located near the playground.

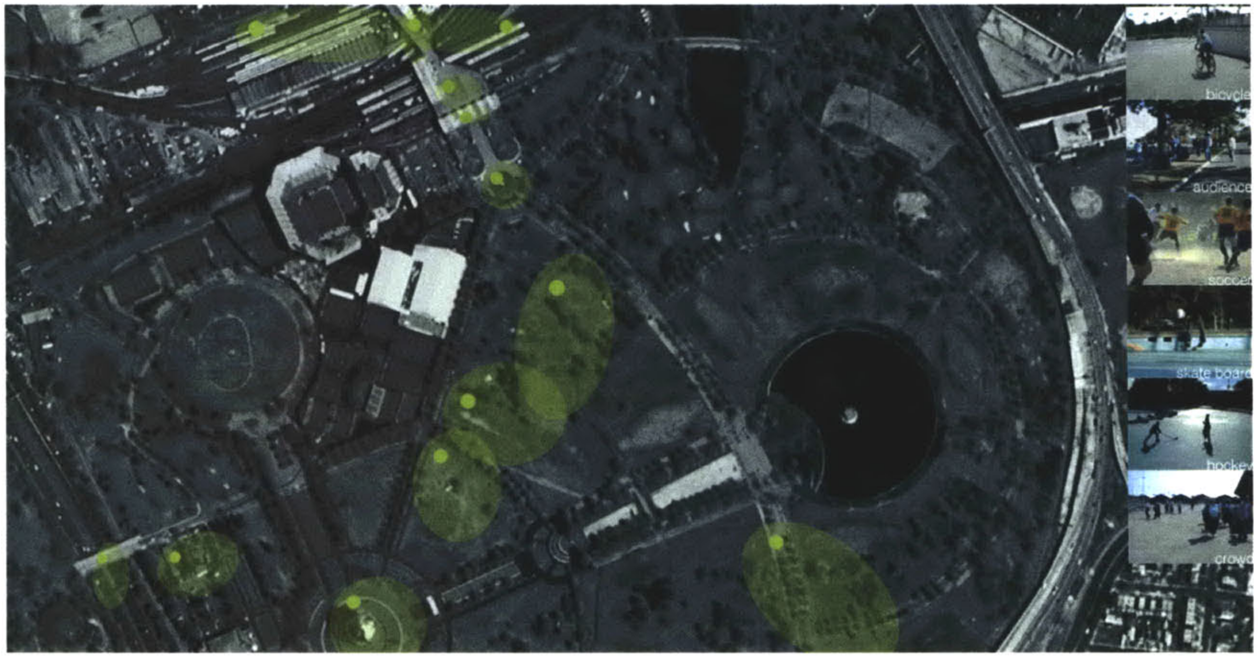
Queens Wildlife Center
Animal exhibits in natural settings provide programs for schools, family, scouts and the public.

Queens Museum of Art
The museum presents exhibitions of contemporary art and photography throughout the year. It also contains one of New York's best exhibitions - the Panorama of New York City, a meticulously rendered model of all five boroughs that encompasses an entire gallery and is observed from above.

New York Hall of Science
Ranked as one of the country's top science museums, the New York Hall of Science opened in 1964 and is New York City's only "hands-on" science and technology museum.

Ice Skating
This 18,000 sq. foot indoor rink is located in the New York City Building, opposite the Queens Museum of Art.

drawn from the following source:
The Office of the Queens Borough President at: *http://www.queens.nyc.ny.us/depts/cultural_affairs/corona_park.htm*



[2.5.4 a] site video clip panel image used on the web with links on each yellow circle and on each activity box.

2.5.4 Site Video Clips

The first step in starting the thesis project was to start with the acoustic information extracted from the site. In order to record the acoustic condition of the site, I made a series of video clips recording the acoustic condition of the existing site and various activities in the park. These video clips eventually become the sound samples for the final sound animation movie of the design.

[2.6.3 b] bicycle

[2.6.3 c] soccer audience

[2.6.3 d] soccer player

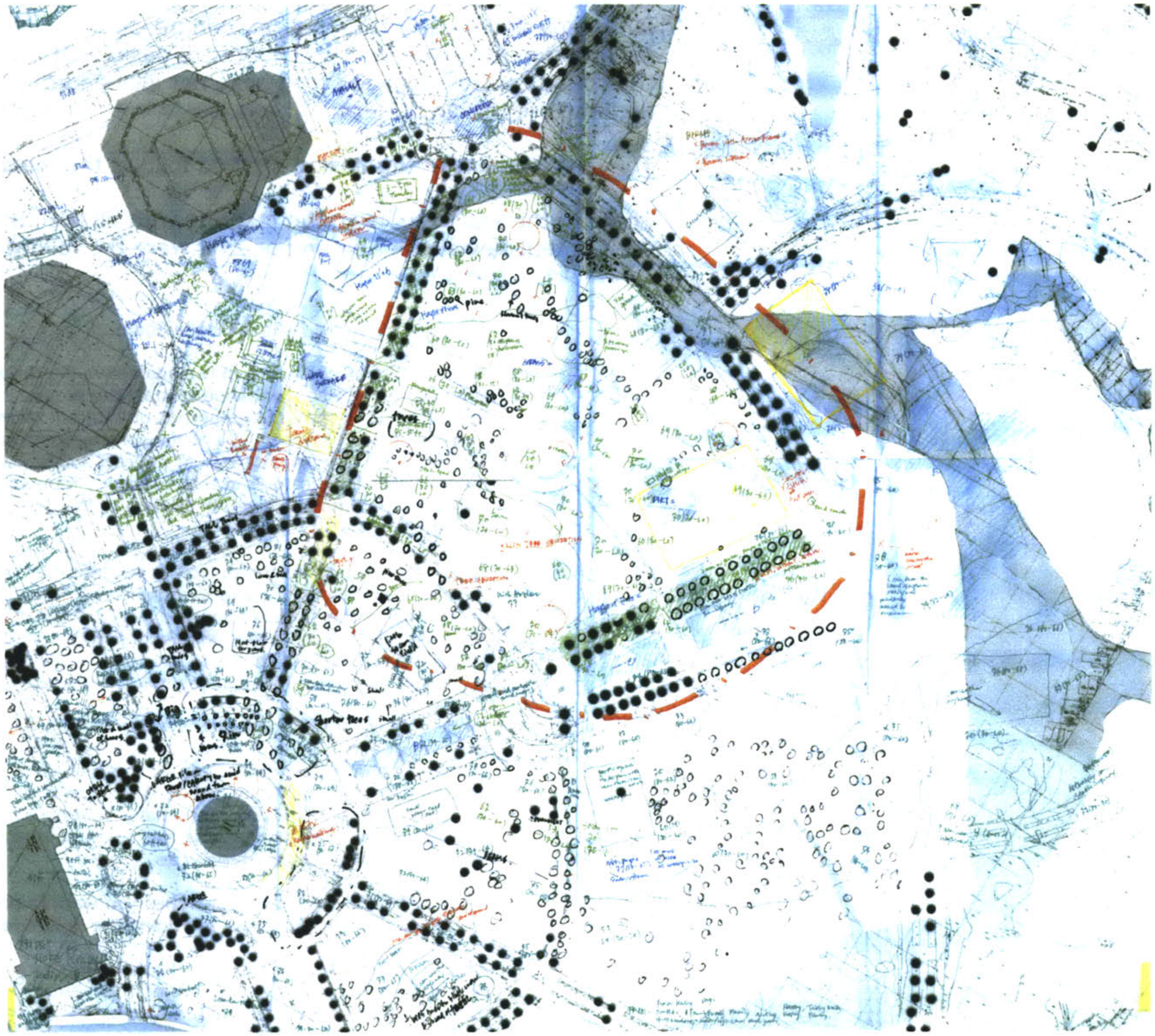
[2.6.3 e] skateboarder

[2.6.3 f] hockey player

[2.6.3 g] crowds

[2.6.3 h] train

3.0.0 design method



[3.0.0 a] map with sound level information

In order to create a project with equal attention on three fields of design, acoustic, landscape and architectural design, one needs to define the essential characters of each design language that contributes to design. It is especially crucial to define the sound control language for I have not included this language in my previous architecture design project.

The development of the design method follows the meeting with the advisors.

Some of the key ideas from the meeting with all the advisors immediately following the Content Review on September 21st were the following.

01.09.26 meeting @ Small Stella Room

Peter: The project stays in the qualitative impression of the site and lacks a quantitative foundation to start the project. Also we need to look at different material properties of different elements on the site (artificial or natural) and look at the sonic properties. Perhaps some elements can amplify, intensify or redirect sound just like the Sound manipulative technologies in the research. Trees, bushes,,, what kind of sound effect does it have, in relation to the person moving through the site.

Axel: It may be helpful to look at pavement or surfaces around the site. People may be able to make sound with certain surfaces. Then, what is the surface's sound quality? What is the sound quality of gravel, grass, etc? Also think about whether trees can also make sound in the wind? Then record the sound of all those surfaces. This can result into a map of sound samples, a sound map.

John: Make sure to compare 2 zones with the same dB but has different quality. Think of what makes those different acoustic ambiances. Then maybe create a plan of these acoustic analyses. Start with 10 different conditions and different quality of acoustic space. Maybe sound reverberation can make a difference in the quality of acoustic space. The point of this exercise is to direct subjective quality relate to specific acoustic properties.

Nico: I think the list of researches you want to precede and the list of various thought processes are going the right direction.

Peter: Have you ever thought of this project as a Visual art project? Or is it an Architectural design project? If you think of this as a Visual art project, you can instrumentalize the entire site. Think of the Unisphere as an instrument. Perhaps the creaking sound of the steel of the Unisphere, contracting or expanding with temperature can

be the sound of the instrument. Of course, you will need a recording technology or method in order to do this project.
In whether you proceed with this or not, I think it's important to start by picking up clues from the site. Think of architecture as a material form that makes sound.

John: I think the combination of the two elements of the architectural design and visual art project will be interesting.

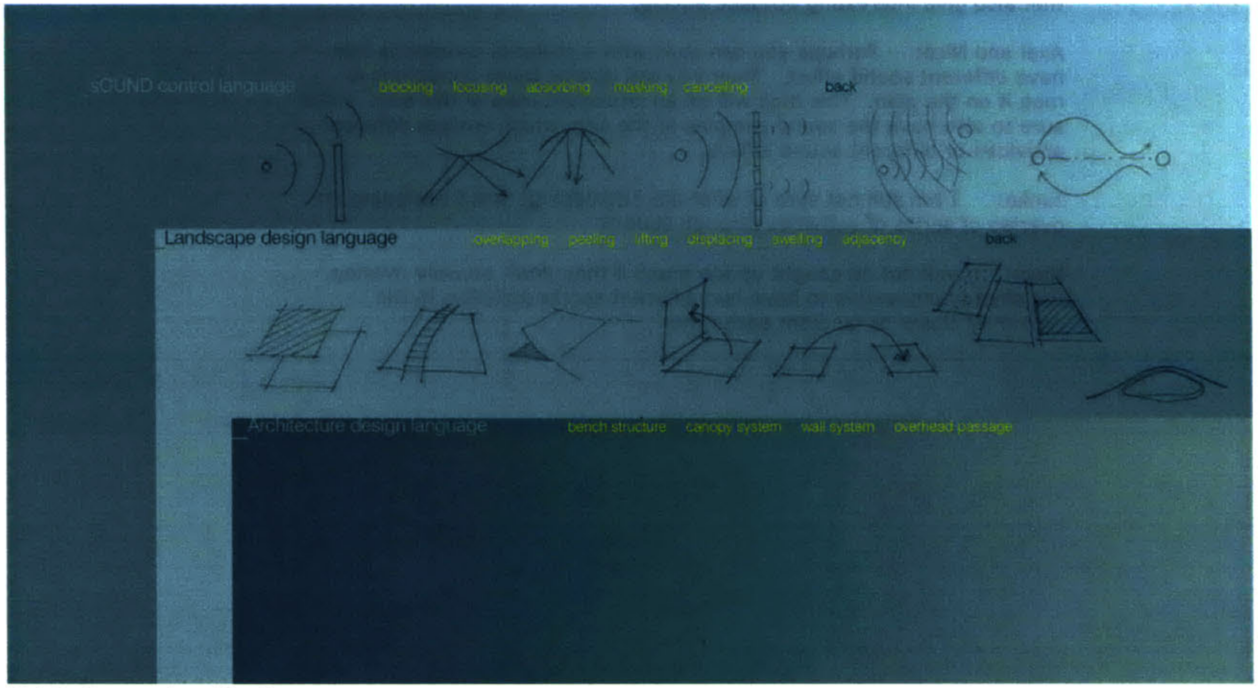
Junko: The scope of the project is still not clear. The idea of a Visual Project is interesting, but I sill would like to proceed with the idea of an architectural design thesis project.

The idea of sound mapping is a great idea. I can look for reflective surfaces that give a certain acoustic space or look for significant contours that also give interesting acoustic effects.

Axel and Nico: Perhaps you can start with 4 material conditions that have different sound effect. Then you can iconize these conditions to map it on the plan. This map will be an important map of this site. Make sure to also have the sound samples of the site, which creates different activities or different sound effects.

Junko: I am still not sure of what am I designing! Am I designing an overlap of series of activities through sound?

Nico: I will not be caught up too much if they don't actually overlap. It's already innovative to have two different sports activities in the proximity closer or far from each other.



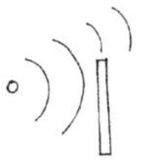
[3.1.0 a] sound and landscape design language panel

3.1.0 Design Tool Development

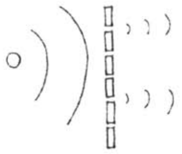
After carefully analyzing the key behaviors of each design discipline, I concluded with the following aspects of each language to use and apply for the design development.

Sound control Language

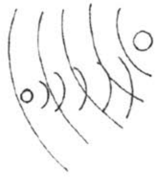
Blocking
The process of obstructing the natural sound pattern. The solidity and the size/dimension of the material reflect on the sound level measurement.
Solidity refers to the density of the material to enable sound to penetrate through the material. The equation $h^2/r > 1$ guides the height and width of the material.


[3.1.0 b]
blocking

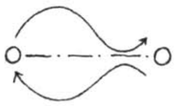
Absorbing
The process where the existing sound condition is dampened through absorptive material. The absorptive quality and surface area of the material makes significance to the sound level measurement.


[3.1.0 c]
absorbing

Masking
The process of adding other sound to de-emphasize the existing sound condition. This gives a quieting effect depending on what kind of sound is added.


[3.1.0 d]
masking

Canceling
The process of adding an out of phase sound wave which effectively cancels the sound condition.


[3.1.0 e]
canceling

Focusing
The process in which the sound is directed. The reflective quality and the shape/angle of the material (concave= focus effect, convex=distribution effect) need to be considered.


[3.1.0 f]
focusing

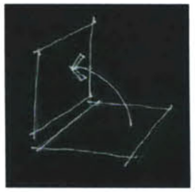
Landscape design Language

overlapping
ex: jogging paths = canopy for soccer audience

[3.1.0 g] overlapping

[3.1.0 h] over and under

[3.1.0 i] peeling



[3.1.0 j] lifting

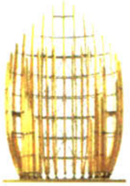
[3.1.0 k] displacement

[3.1.0 l] adjacency

[3.1.0 m] swelling

[3.1.0 n] concrete bench structure

[3.1.0 o] tall grass



[3.1.0 p] porosity

[3.1.0 q] structure

peeling
ex: soccer audience benches flattened/collapsed=>expands the size of the open space

peeling2
ex: soccer audience benches lifted=>sound projective space is created

lifting
ex: performance stage =>when lifted vertically it becomes a movie screen - also becomes a sound block

displacing
relocation of activity

swelling
ex:berm condition

adjacency
ex: soccer field + performance stage + movie screen

merging
overlapping of programs in the same location

Architectural Design Language

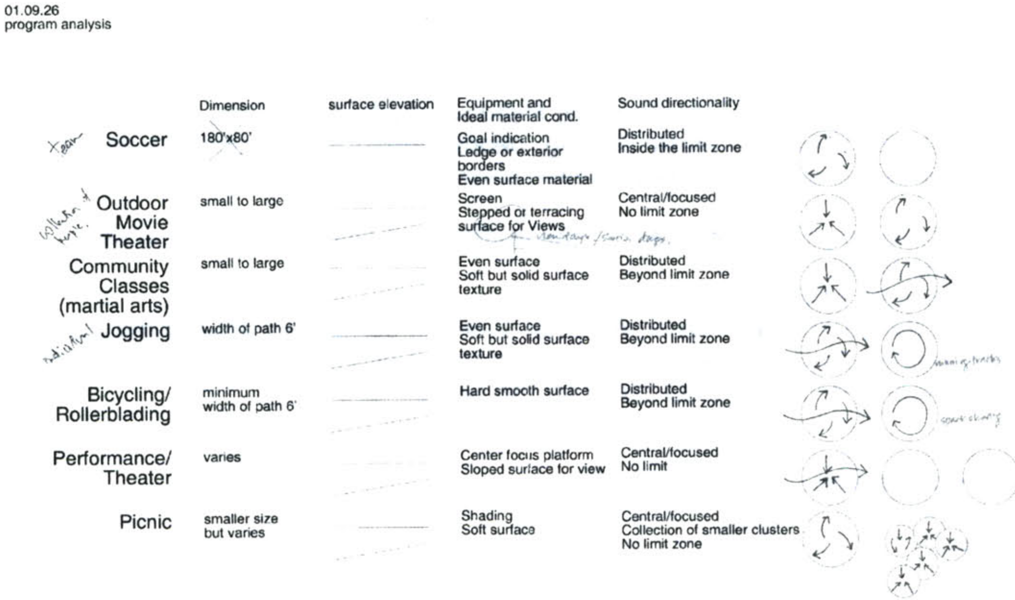
Soccer field
Performance space
Interior space for Lockers, showers and field maintenance space

Bench structure
Canopy system
Wall systems
Overhead passageways

3.2.0 Programmatic studies

At the end of the meeting on September 26th, the project stilled lacked clarity in the kind of design intervention. This initiated the idea of designing a series of several different programs on the site as a sequence of various acoustic experiences. Some of the programs proposed at this stage of the projects are the following: Soccer, Outdoor Movie Theater, Jogging paths, (reorganization of Bicycling/Roller blading to the existing), Performance stage, Community classes, Picnic and skateboarding or biking.

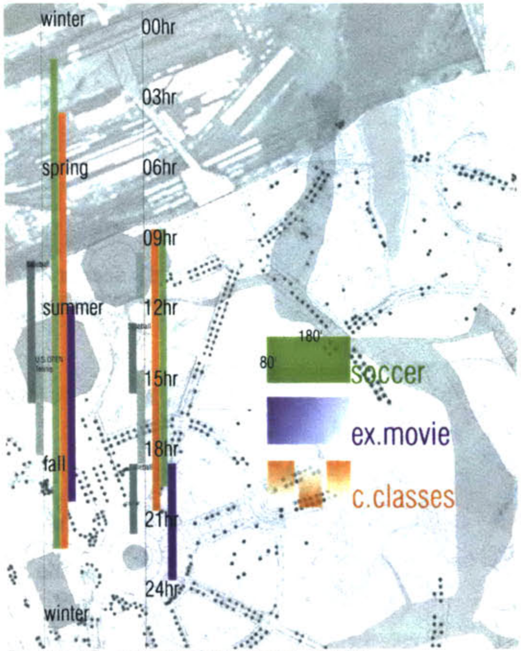
This made sense until I became shocked with the scale of the entire design. Later I decide to focus on two programs as the important design intervention on the site, the soccer field and the outdoor movie theater. After a series of analysis, both programs prove to contain interesting aspects of sound, landscape and architectural design languages.



01.09.26
program analysis

	Dimension	surface elevation	Equipment and Ideal material cond.	Sound directionality
team Soccer	180'x80'		Goal indication Ledge or exterior borders Even surface material	Distributed Inside the limit zone
[illegible] Outdoor Movie Theater	small to large		Screen Stepped or terracing surface for Views [illegible]	Central/focused No limit zone
Community Classes (martial arts)	small to large		Even surface Soft but solid surface texture	Distributed Beyond limit zone
individual Jogging	width of path 6'		Even surface Soft but solid surface texture	Distributed Beyond limit zone
Bicycling/ Rollerblading	minimum width of path 6'		Hard smooth surface	Distributed Beyond limit zone
Performance/ Theater	varies		Center focus platform Sloped surface for view	Central/focused No limit
Picnic	smaller size but varies		Shading Soft surface	Central/focused Collection of smaller clusters No limit zone

[3.2.0 a] programmatic study of various programs



[3.2.0 b] seasonal program study

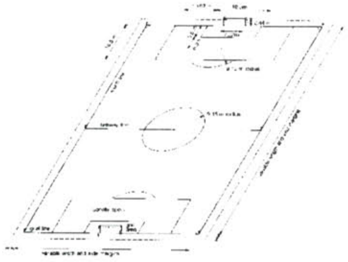
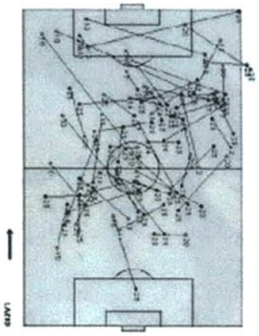


Figure 6.2 Pitch size and layout for football or soccer.

[3.2.0 c]



[3.2.0 d] soccer players movement pattern

[3.2.0 e] soccer players at the existing Flushing Meados Park

Soccer Fields

Dimensions:
330ft x 210ft

Movement:
Players move in a random pattern.
The movement of the players tends to concentrate in the center portion of the soccer field.
The players are restricted inside the exterior boundaries, and rarely go beyond.

Landscape condition of surface:
Flat and even surface, ideal for running.

Necessary equipment:
The soccer field needs indications of goals on both ends of the soccer field.
It also requires marking of ground ledge or exterior borders
The field requires evenly leveled surface material.

Acoustic effect:
The sound originating from the players are minimal.
At the existing soccer field at the Flushing Meadows Park, it is a very social atmosphere where there are music playing, people cheering and having a picnic.
This suggests that acoustically the audience plays large role during the game.

Idea: what if the sound environment of the audience is amplified to give more liveness to the game.
Idea: amplification of the announcements.
Idea: what if the surrounding environmental sound is dampened around the audience so they cannot be disturbed easily, such as the sound of the airplane jet. This will allow the audience to concentrate more on the game.

Performance Space

Dimensions:
Varies

Movement:
The audience sits on the lawn, and in stable position during the performance.
The majority of the people concentrate towards the front central area of the lawn for optimum viewing condition, but people are also distributed throughout the zone as long as the view to the stage is not obstructed.
Boundary does not exist. Audiences are free to move in and out of the boundary continuously throughout the performance.

Condition of surface:
Flat or sloped up ground surface for viewing purpose.
Soft surface is ideal for sitting. Avoid concrete, dirt floor or asphalt.

Necessary equipment:
Indication of the stage
Sound reflective/projection boards
Speaker systems

Interior space for Lockers, showers and field maintenance space

Movie

Dimensions:
Screen size
20'x48'

Movement:
Audiences sit on the lawn, and in stable position while the movie is playing.
The majorities of the audiences tend to concentrate in the middle zone of the lawn for optimum viewing condition, but are distributed throughout the zone where people can tolerate the distortions of projected image.
Boundary does not exist. Audience can be moving in and out of the boundary continuously throughout the screening.

Condition of surface:
Flat or sloped up ground surface for viewing purpose.
Soft surface is ideal for sitting. Avoid concrete, dirt floor or asphalt.

[3.2.0 f] bench structure

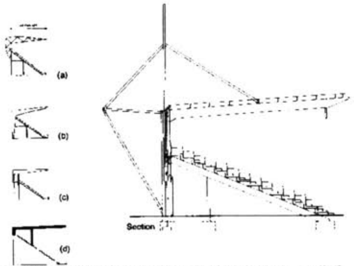
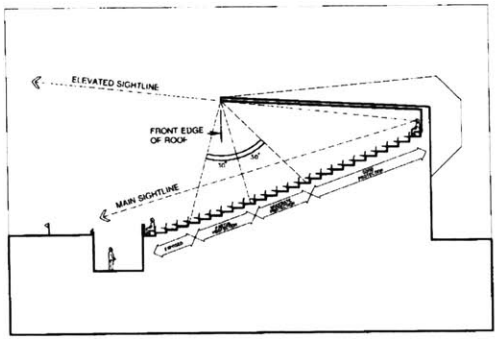


Figure 4.16 Various cantilever configurations; (d) is a 'propped cantilever', which reduces the span but has the disadvantage of obstructing vision



[3.2.0 g] bench structure design

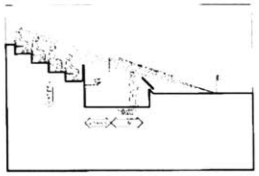


Figure 6.4 A 'half moat' or combination of low fence and shallow moat

[3.2.0 h] design of the saftey zone

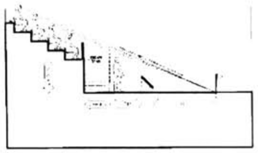


Figure 6.5 The 'building' solution, or level change, is widely used in baseball and American football stadia in the USA.

Necessary equipment:
Movie screen
Speaker system

Acoustic effect
Originally 2 to 3 speakers were placed behind the screen. However, with the growing size of the screen and developing technology, surround sound systems are used for interior movie theaters. For the proposed outdoor movie theater, it will have speaker in both the front of the stage next to the screen as well as behind the audiences.

The sound originating from the viewers are minimal.

Drawn from the following sources:
Campbell, Geraint Johnkit. *Outdoor sports: handbook of sports and recreational building design volume 1*
US Soccer Federation at: *http://www.ussoccer.com/home/default.sps John, Geraint* and Sheard, Rod. At: *STADIA: a design and development guide.*

3.3.0 Acoustic Design guidelines

From the study of sound related Landscape Design, one learned that the following elements in the design demonstrate different acoustic spatial experience parks.

Water sound
Ground texture
Trees, and vertical planters
Initiating other activities
Terracing/elevation change
Pockets of space
Use of artificial ground surface materials
(plastics, rubbers, steel poles, etc.)

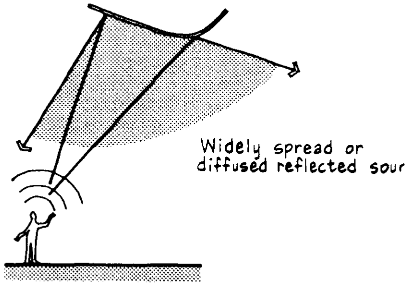
In order to further develop the understanding of outdoor acoustic design, some research from the David Egan's *Architectural Acoustics* will prove helpful.

study on open air theater
pattern of reflected sound
barrier to reduce sound
temperature and wind effects

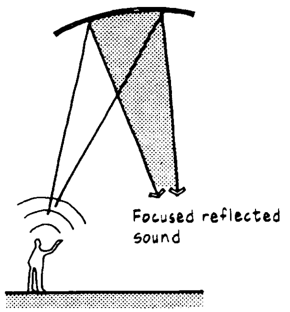
study on open air theater

Open -air Greek and Roman theaters had mostly listening conditions for drama and instrumental performances by small groups. The theaters were usually located on steep hillside within a quiet environment in the rural location. Seating layout often followed a semicircular form in order to be closer to the stage. The tiers were constructed with steep rise for good sight lines. This allowed for reflected sound energy from the orchestra floor, and reduce attenuation caused by the audience.

Design of modern open-air theatre should focus on achieving low noise intrusion and satisfactory distribution of sound.



Convex Reflector



Concave Reflector

[3.3.0 a] sound relecting diagram

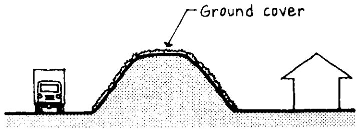
Pattern of reflected sound

Concave reflectors can focus sound, causing hot spots and echoes in the audience seating area. Because of its focusing tendency, it is not a good distributor of sound energy. Therefore it is not ideal to use a concave surface for sound-reflecting surface.

Convex reflectors on the other, if it has hard surface and large enough, can become of sound-distributing element. The sound reflected from a convex surface diverges and enhances diffusion. This is very ideal for reflecting music for listening. Furthermore, the sound is evenly distributed across the wide range of frequencies when using a convex surface.

Barriers to reduce sound

Outdoor barrier can be used to reduce environmental sound, especially the consistent sound of cars and trucks. Tree, elevation changes on earth and berms can be a barrier of sound as long as it is interrupting the direct sound path from source to receiver. Earth berms that are completely covered by grass or other sound absorbing plant material can become isolator and barrier to reduce sound by 5 to 10dB.

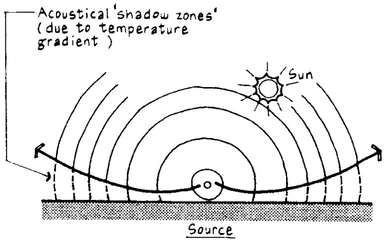


Earth Berm

[3.3.0 b] berm

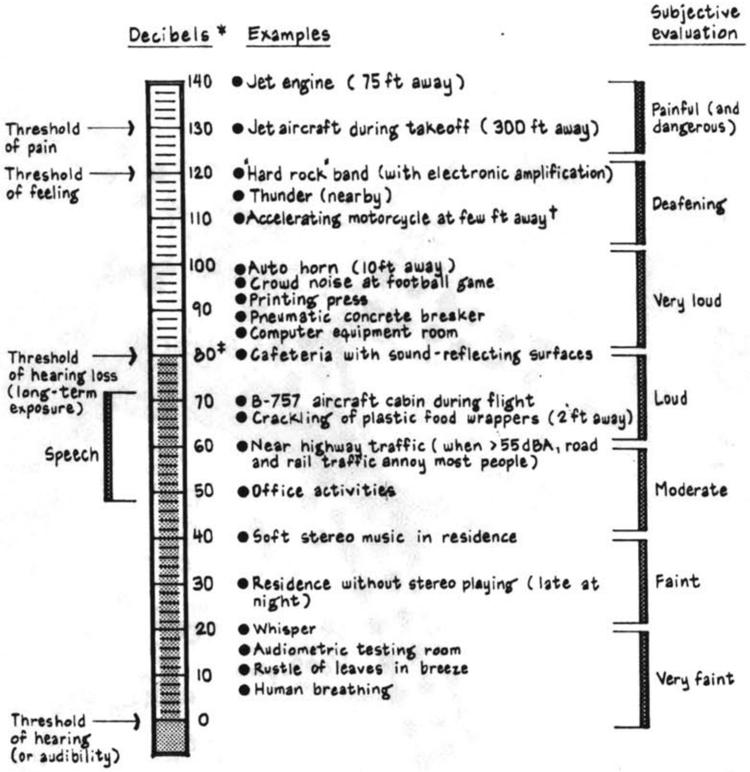
temperature and wind effects

On a clear, calm day the effect of temperature gradients can cause sound to bend upward towards the sky. This is because sound is pushed upward by the warmer air near the ground rising up. Therefore it makes hearing more difficult than a clear, calm night. On a clear, calm night, air temperatures are inverted and sound will tend to focus and bend towards the ground. The difference in sound levels between a clear, calm summer day and night can be about 10dB for sound source at more than 1000 ft away.

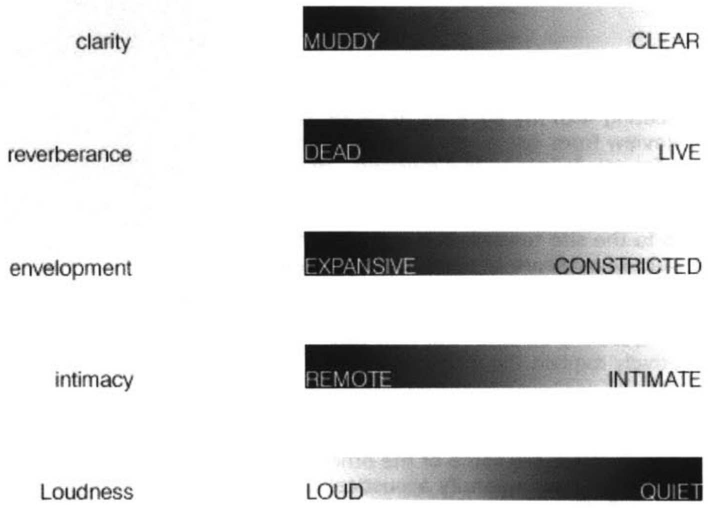


[3.3.0 c] temperature

Drawn from the following source:
Egan, M. David: *Architectural Acoustics.*



[3.3.0 d] commom sounds in decibels (indoor condition).



[3.3.0 e] diagram of sound matrix developed to use to analyze future design.

3.4.0 Site [existing] sound level map

The following is an e-mail message I wrote to Carl Rosenberg, an acoustic consultant to ask for advice on how to measure the acoustics of the site.

01.09.27
Dear Carl,

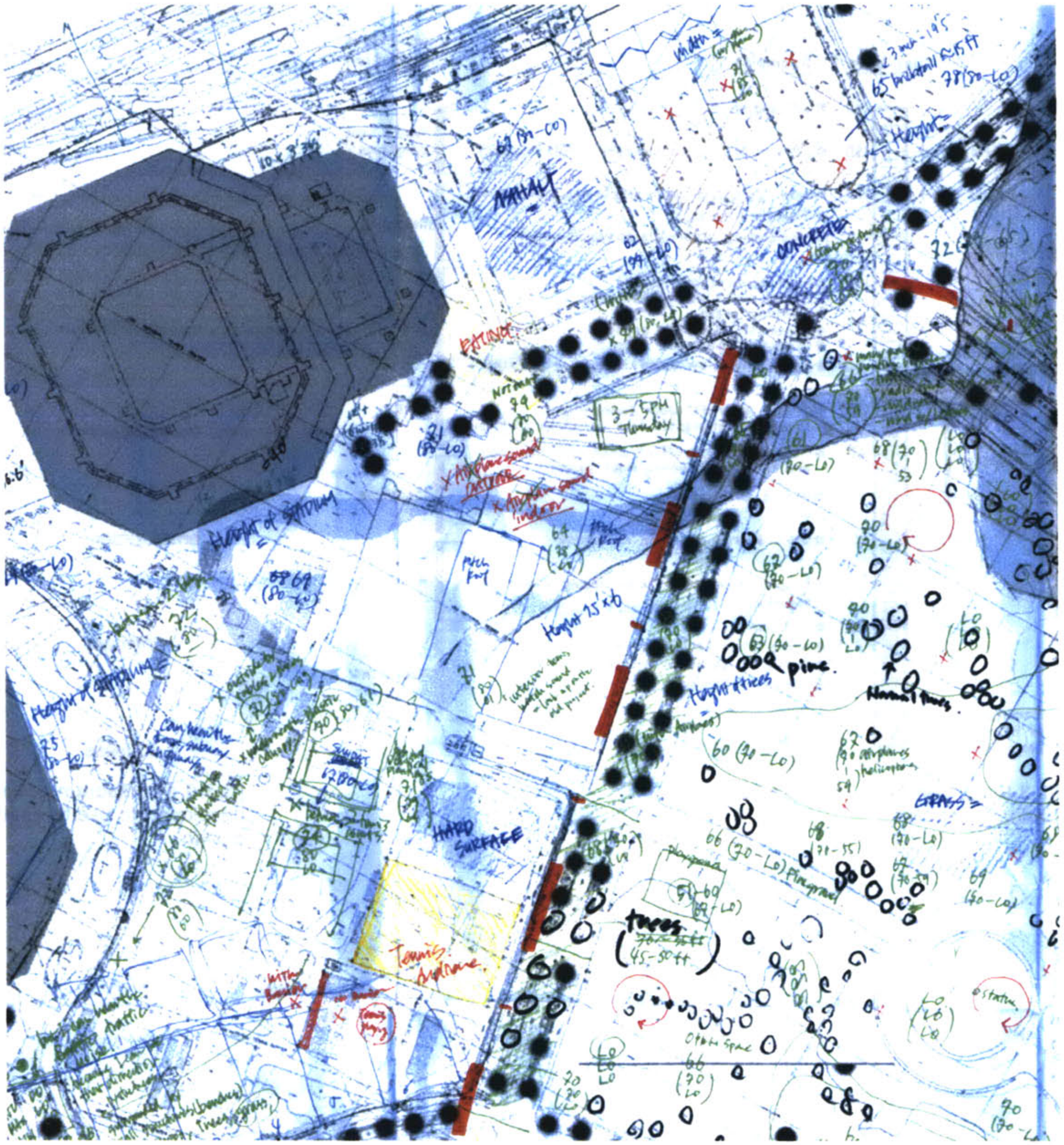
I hope all is well for you.
I had a meeting with my advisors to recap the Content Review from last week. I have some questions for you following this meeting. How do you measuring sound?

When I go to the site towards the end of next week, I want to measure the site both quantitatively, and qualitatively.
I have taken some notes on qualitative impression of few locations on site. But how can I quantitatively explain the acoustical spatial experience?
As an acoustic expert, do you describe sound with numbers (as in Hz and dB) or with reverberation time? What are some of the other methods in which I can quantify acoustical spatial experience? Please give me some suggestions.

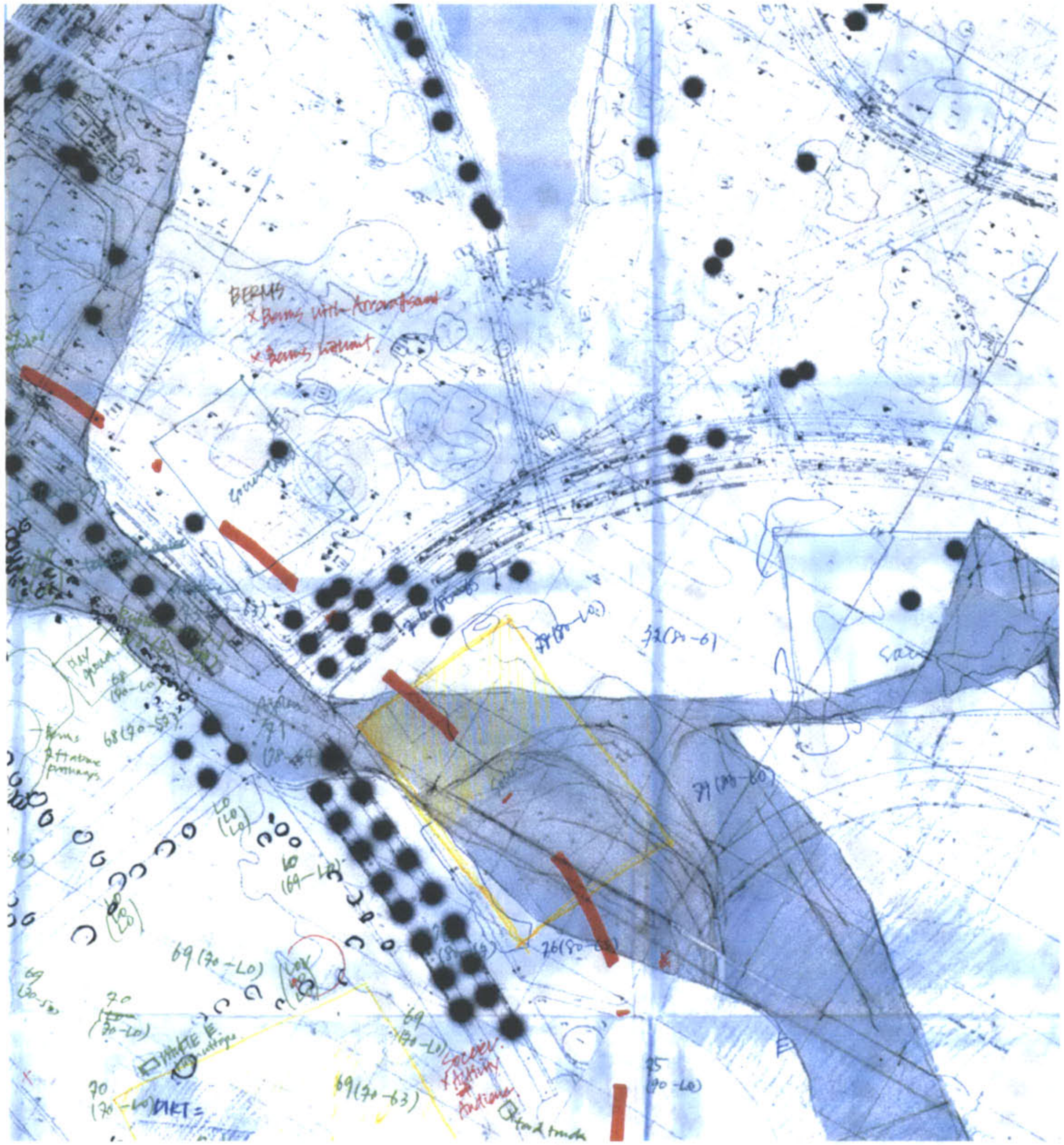
In terms of reverberation time, I remember calculating them in an enclosed space, but how do I measure the volume of an open sky park?
Also, how can I measure Frequency? Is there "frequency meter"?

Perhaps I can speak to you about this and bring some of my progress models. Please let me know when you are available for a meeting.
Thank you.

Sincerely,
Junko



[3.4.0 a] map with sound level information. top left



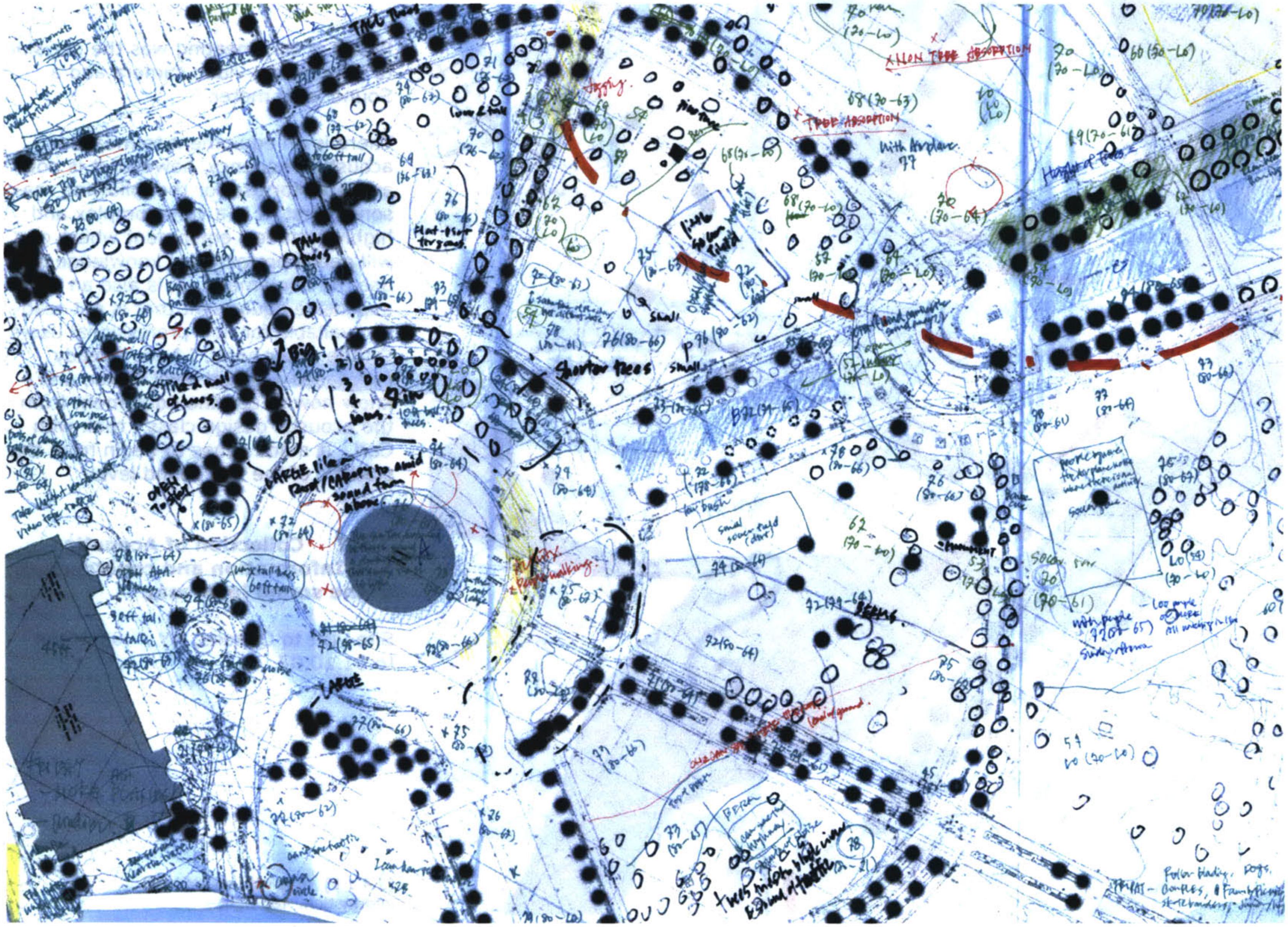
Result of this meeting was the decision to take both a video camera and a Sound level meter.

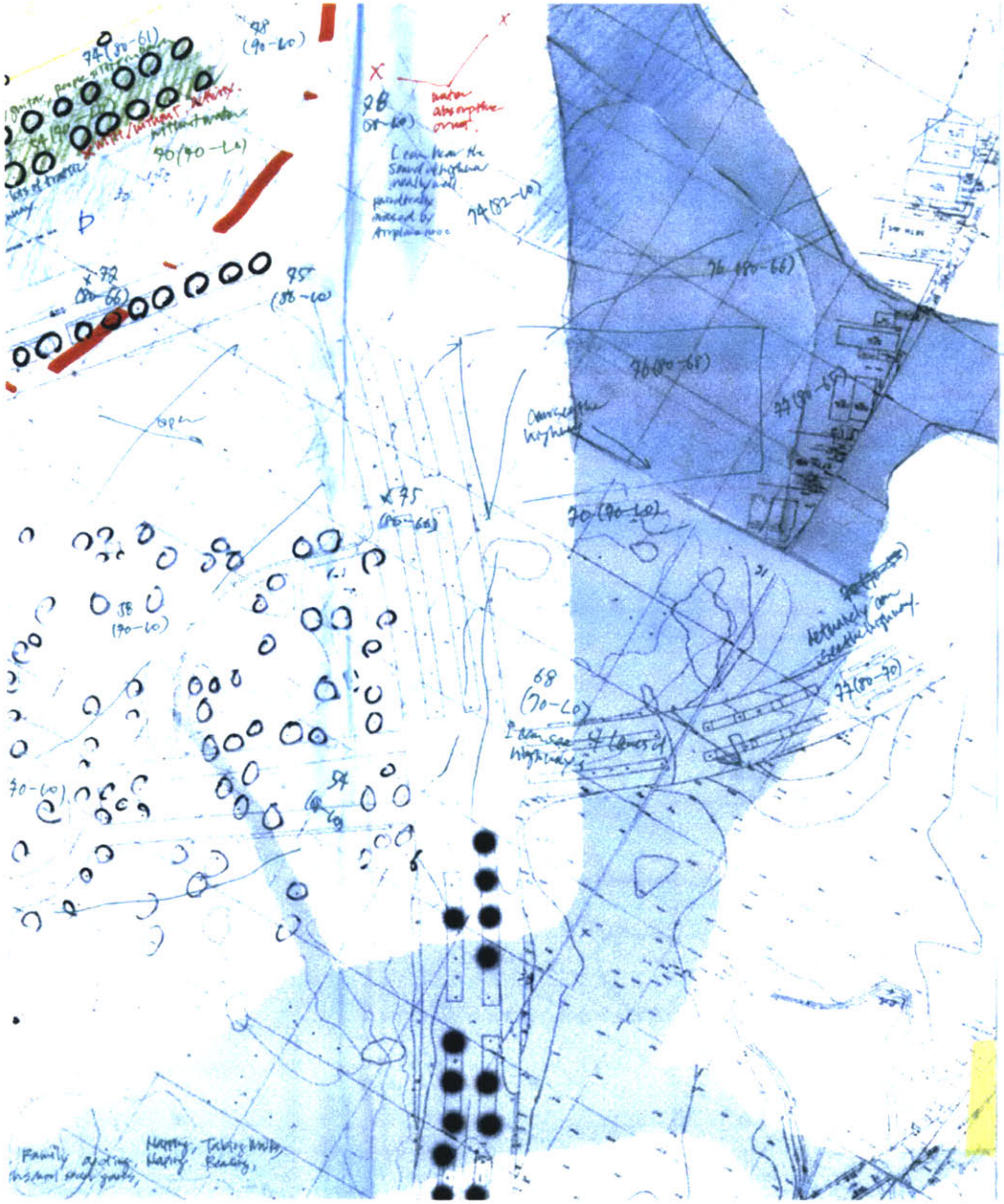
There is an equipment to measure acoustic frequency, however it is not available for use for the following reasons. First, it is a very complex and highly technical equipment where one will needs professional knowledge to use the equipment. It is also an expensive equipment that is not readily available for non-professional users. On the other hand, I have already purchased a sound level meter, and I know how to use the equipment from the acoustic design class I took with Carl. It made sense to begin from the statistic of the site sound level.

3.4.1 Collection of Acoustic Site Information and construction of the sound level map

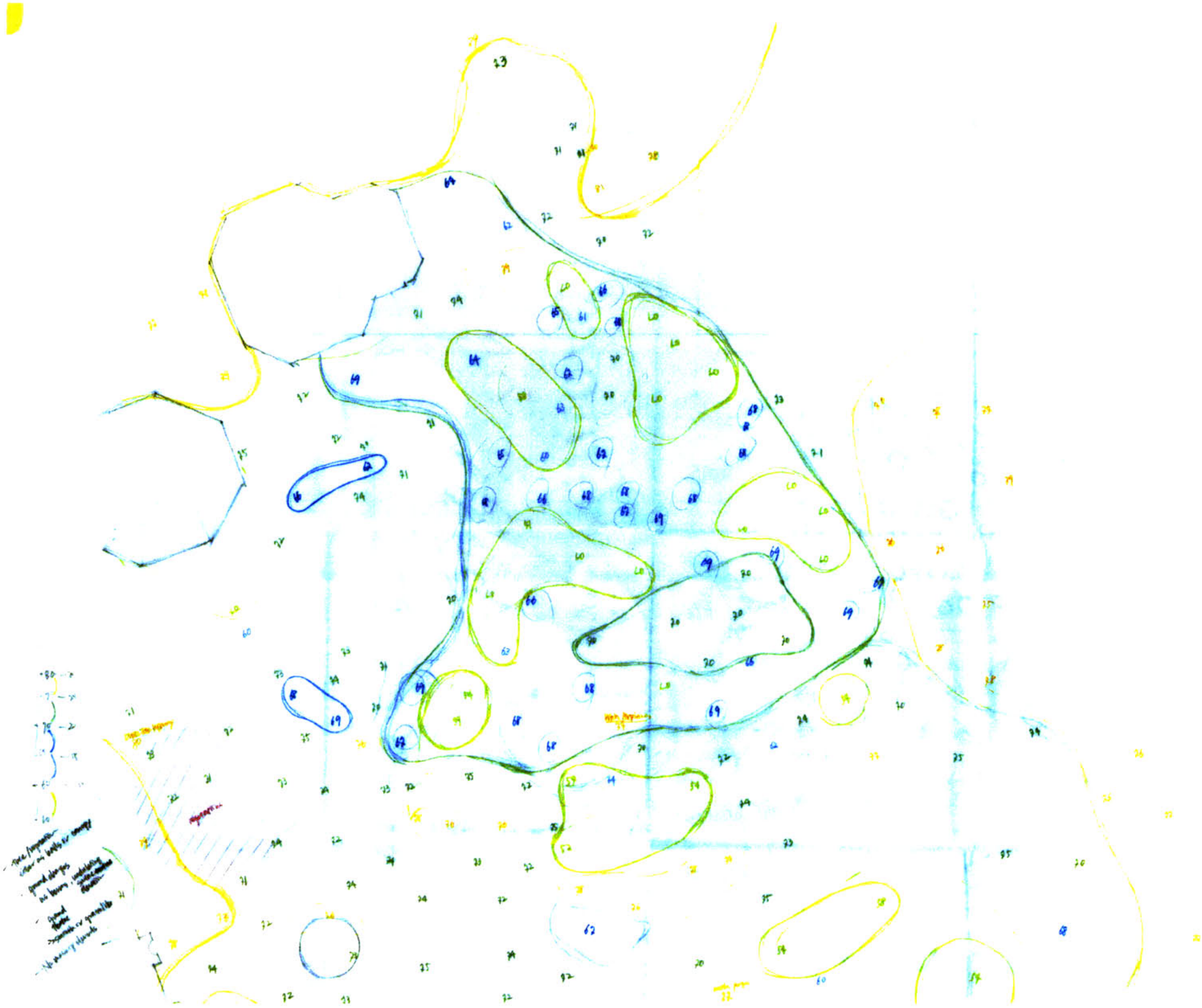
Site visit to Queens, NY 01.10.04 to 01.10.07

[3.4.1 b] map with sound level information. top right

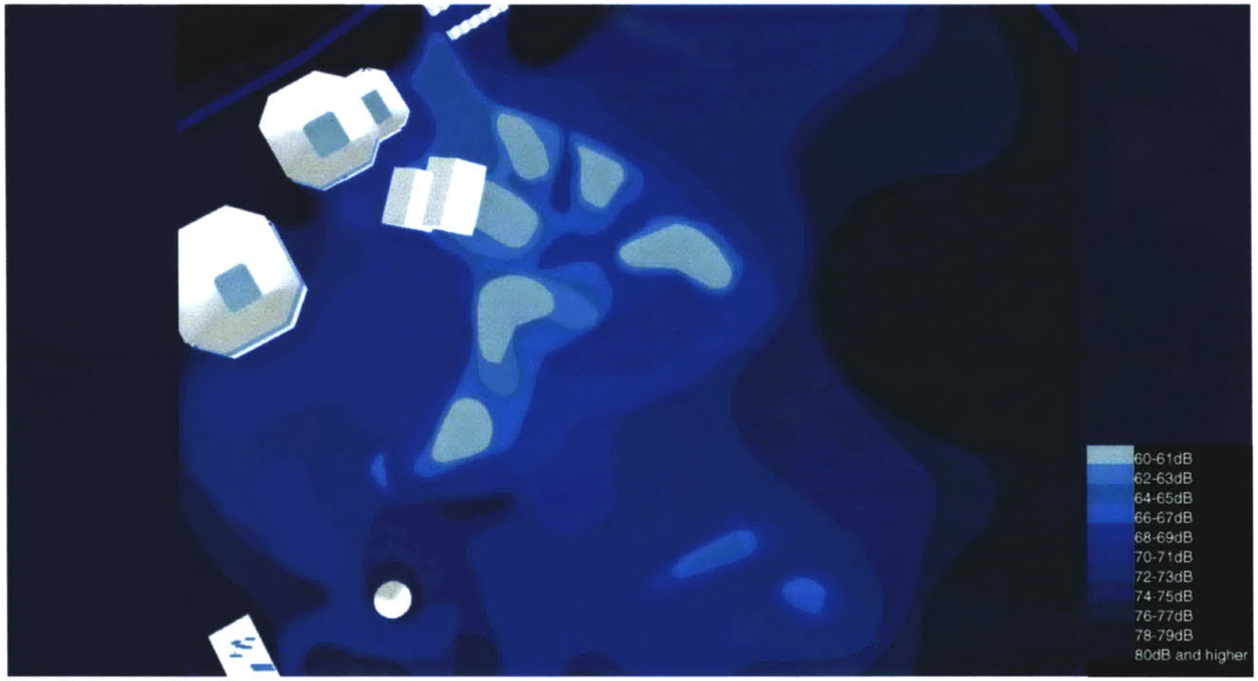

TALL Trees
jogging
ALONG TREE ABSORPTION
TREE ABSORPTION
With Airplane
Height of trees
Flat-floor for games
TALL trees
Big
Shorter trees
small
wall of trees
LARGE lilac Roost/Canopy to avoid sound from above
OPEN to sky
LARGE
social seating
Roller blading, Dogs, couples, & Family Picnic, skateboarders
60 (50-60)
70 (70-60)
68 (70-63)
76 (80-66)
77 (80-66)
72 (80-65)
62 (70-60)



[3.4.1 c & d] map with sound level information. lower half



[3.4.1 e] transition diagram from the site measurement to sound level map.



[3.4.2 a] sound level map

3.4.2 site [existing] sound level analysis

Observation at the park
Interesting behaviors of sound levels:

The height and density of vegetation can act either as barrier walls or canopy to dampen sound (example between the tennis stadium and the Unisphere 80dB > 72dB)

The visibility as oppose to invisibility of highway makes a large difference. (View = ability for sound to travel freely without obstruction)(example by the round reflecting pool:70dB > 80dB)

The distance between the highway (sound source) makes a difference in the sound level. (example: dB above highway to dB along the same bridge towards the front of the Tennis stadium 80dB > 71dB)

The ground materiality whether absorptive or reflective makes a difference in the sound level. (grass-covered earth vs. plaster/concrete/asphalt, textured or smooth)(example: between concrete surface by Unisphere and grass surface by the site zone 74dB > 54dB)

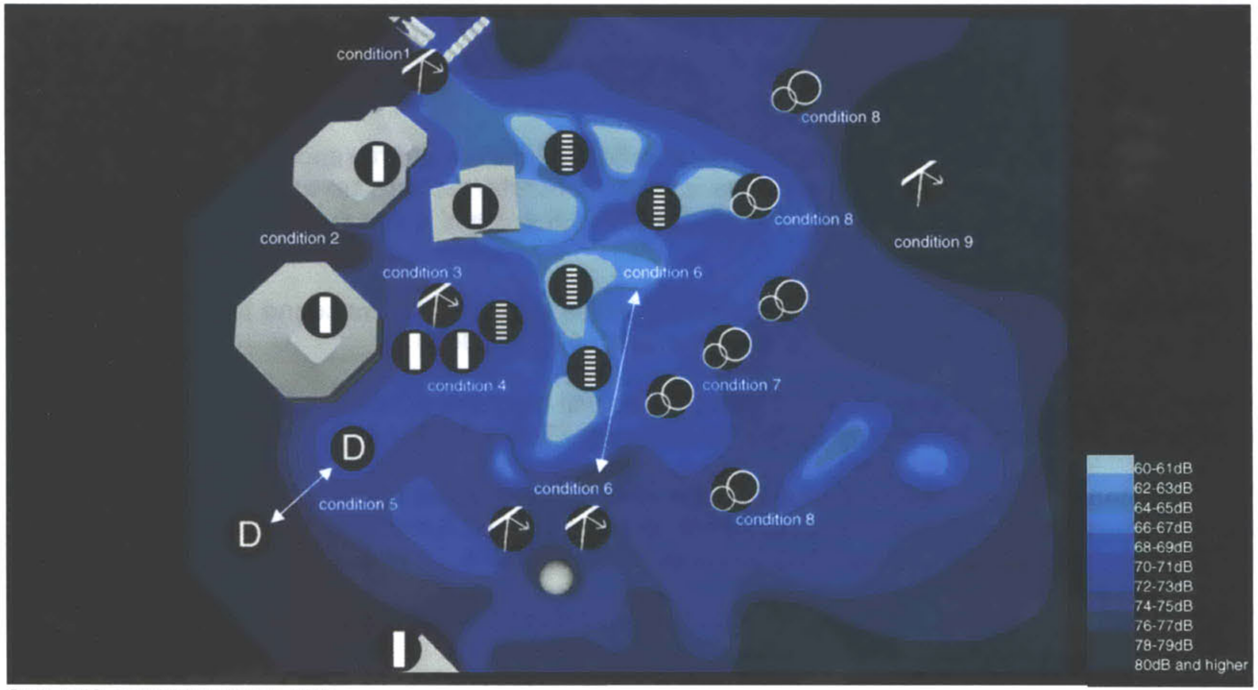
Visible obstacles such as berms or undulating surface elevation allows sound travel differently (example in the site zone near the berm 67B > 60dB)

When measuring under the overhead canopy, one will hear the difference in dampening the sound (example: canopy by the tennis court 75dB > 66dB)

The direction of the overhead canopy has the ability to direct out or bring in sound from the surrounding environment (example by the entrance canopy: in this case, it brings in sound from the surrounding highway and train track 71dB > 76dB)

There is a drastic drop of sound level when one measures behind a solid wall (example: bench structure drops sound level 72dB > 60dB)

There is a drastic rise of sound level when one measures near cheering audiences by the soccer games (example: soccer field south of the water fountains 70dB > up to 90dB)



[3.4.2 b] sound level map with sound behavior icons

The open and flat space with concrete (smooth) ground surface becomes very quite due to the wind blowing the sound away, resulting to a very low sound level (example by the water fountain: 55dB when the surrounding environment is in the 70's dB)

The existing site has no intentional sound masking element (adding sound resulting in masking other sound), but the various nodes of activities acts as such by catching the audience's attention by the action and sound. To the point the audience can ignore the airplane jet noise.

Construction of 3D sound level step model

The step model is constructed according to the actual sound level measurement taken from the site using the Decibel Meter.
Each step is constructed every 2dB ranging from 60dB to 80dB and higher. Colors are added to each steps to indicate the lowest sound level in the light blue, and as the sound level rises the color turns into darker blue.

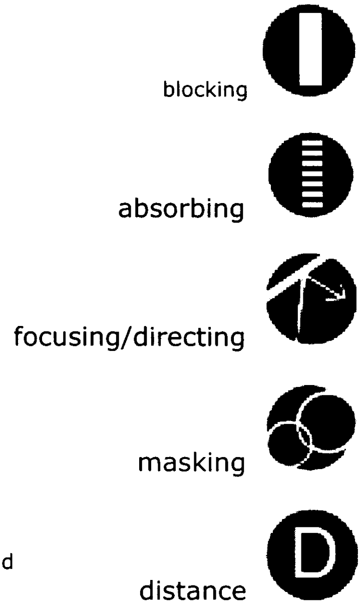
Note: test site = the central triangular site I have designated as the test site.

Step model observation:
The elevation of the step model is the highest along the highway and lowest in the area of the test site. There are several small patches of lower sound level zones indicating the ideal zone for proposing program to this location.
Between the highest sound level around the highway and the lowest sound level in the test site area, there are interesting behaviors of the sound topography that can indicate clues into how to manipulate sound.

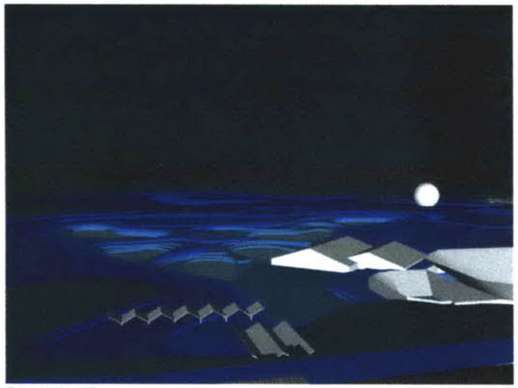
Observation 1: major sound source

The sound travels most intensively in line along the highway roads. However, significant levels of sound are also emitted to the surrounding areas according to the measurement.

Data: 80dB measurement on the bridge above the highway
71dB measurement in the parking lot next to the highway. (The highway is visible from the location of measurement.)
As one can see in the 3D model, the second highest elevation of the step model loops around the highway making a 78dB to 79dB ring around the exterior boundaries



[3.4.2 c] sound behavior icons



[3.4.2 d]

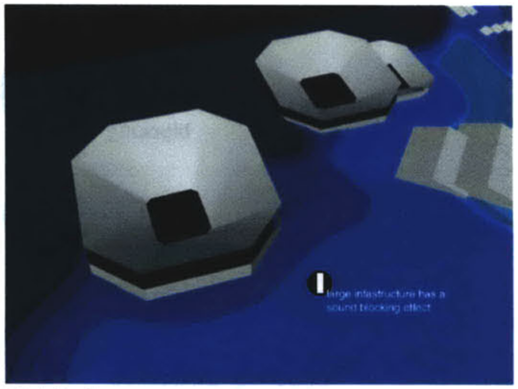
of the park.
This result indicates that the major source of sound affecting the sound level in the entire park ground is the highway surrounding the park. It is the most consistent and dominating sound source.

Observation 2: objects of obstruction
The topography is obstructed by the infrastructures such as the two US Tennis Stadium and the Queens Museum of art. They act as visible barriers as well as sound barrier to obstruct the path of travel.

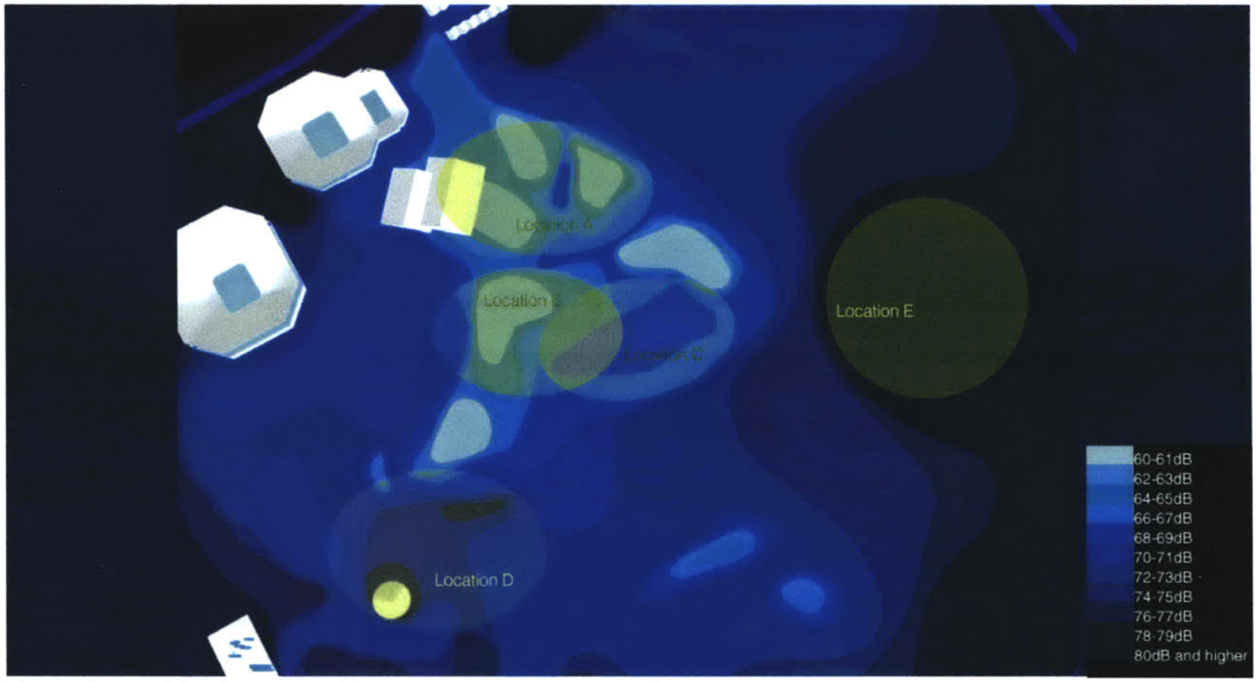
Observation 3: elevation changes
Note that the highway rise and fall around the park, so when the highway is leveled with the ground of the park, sound travel most easily.

Observation 4: ground surface material

The concepts one can learn from the Highway sound source analysis:
1, The visibility of the sound source from the location of measurement,
2, The ground surface materiality (reflective/absorptive quality) of the measuring location.
3, The distance from the sound source to the measuring location



[3.4.2 e]



[3.5.1 a] sound level map identifying zones of interest

3.5.0 Site Locational Analysis

Based on the site understanding from the existing sound level model, series of design analysis are made followed by a design proposal using the sound level model.

3.5.1 Identifying zones of Interest

Location A: several small areas of ranging sound condition
DB ranging from 60dB to 71dB
Clarity = relatively clear but varies
Reverberation level = varies

Conclusion:
sound condition is controllable but it requires
Strategic planning to overcome the inconsistency of sound level in the area

Location B: a large area of Moderate sound condition
60dB to 65dB
Clarity level = clear
Reverberation level = closer to dead

Conclusion:
This zone has sound controllable condition. With strategic planning, it has the potential to develop into an ideal site for inserting new programs.

Location C: a large area of Loud sound condition
70dB to 72dB
Clarity level = closer to Muddy
Reverberation level = closer to Live

Conclusion:
This zone has less controllable sound condition
Careful selection of the program necessary

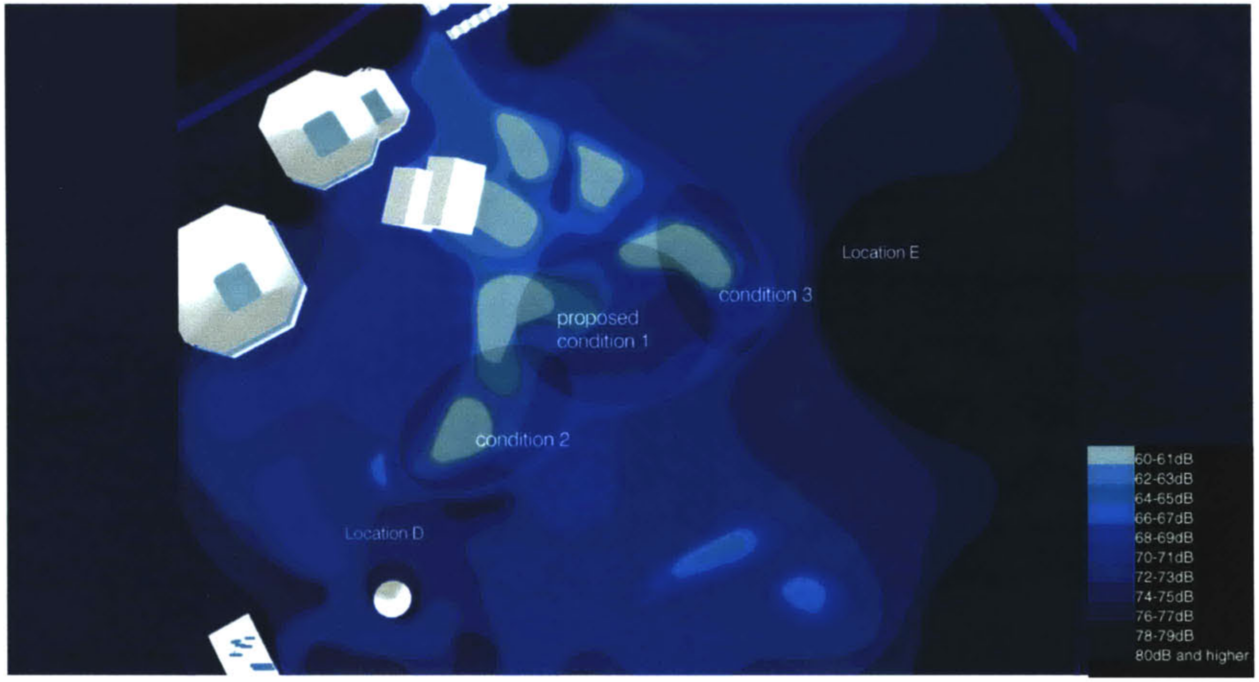
Location D: a large area of Very Loud sound condition
78dB and higher
Clarity level = Muddy due to the high background noise reflected by the large

reflecting pool
Reverberation level = Live

Conclusion:
Very difficult to concentrate. This zone is inappropriate for programs requiring listening

Location E: an area of Very Loud sound condition
76dB and higher
Clarity level = Muddy due to the high background noise reflected by the concrete ground surface material
Reverberation level = Live

Conclusion:
This zone is inappropriate for programs requiring listening



[3.5.2 a] sound level map with design proposal

3.5.2 Design Proposal

condition 1 = SOUND SOURCE
Programmed Zone
soccer field
outdoor movie theater or concert (evening)

Method using Sound control Language:

- Absorbing
- Blocking
- Focusing/directing
- Canceling
- Masking

condition 2 x 3 = BUFFER ZONES

Non-Programmed Zone
Zone designated to adjust obstructing sound filtering into the programmed area. This zone requires a consistent sound condition.

Method using Sound control Language:

- Absorbing
- Blocking
- Masking

3.5.3 Sound level model studies with an initial design

Condition 1

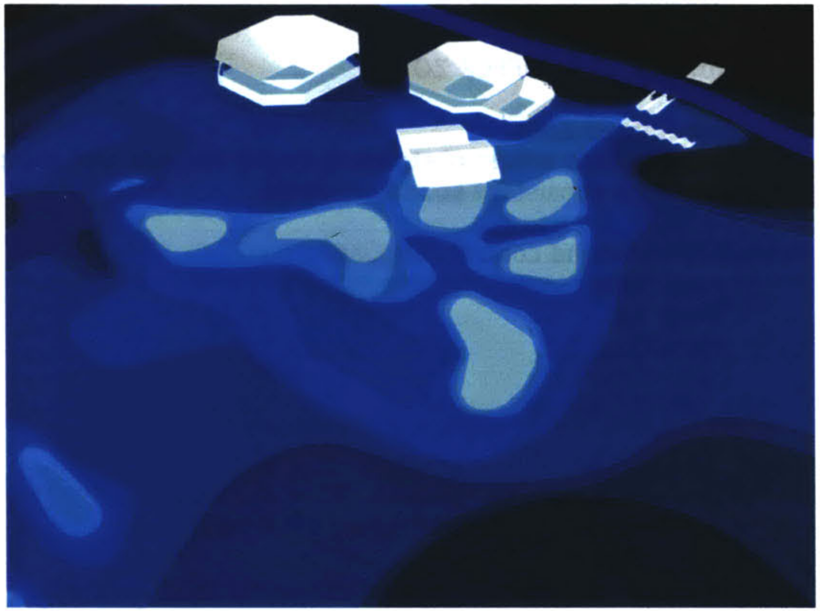
Zone where the sound condition of the space has the most potential to fluctuate during the course of the day. Layers of various sound thresholds surround it, which effectively affects the sound conditions in and around spaces.

Condition 2

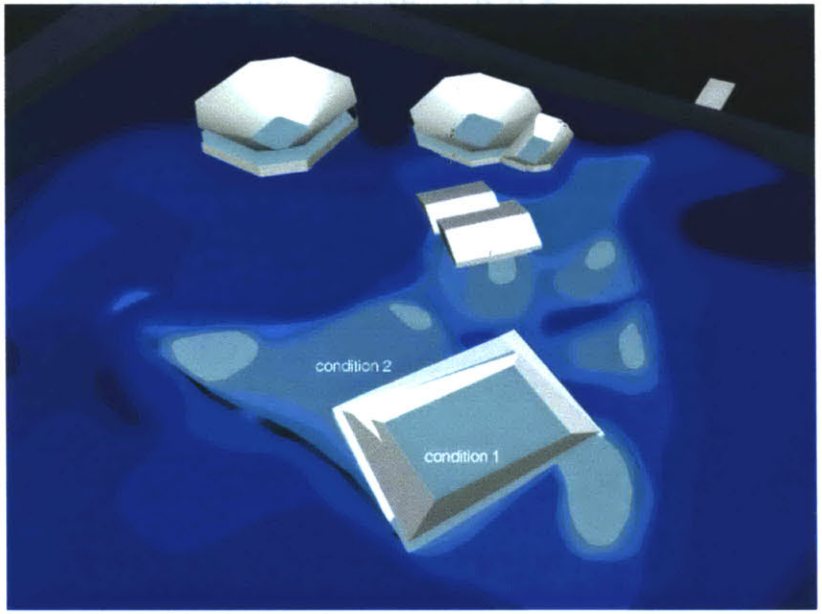
Zone where a passive sound control language is utilized in order to create a Buffer zone between the Condition 1 and Location D (Very Loud sound condition) In order for Condition 1 to obtain a consistent sound controllable condition.

Condition 3

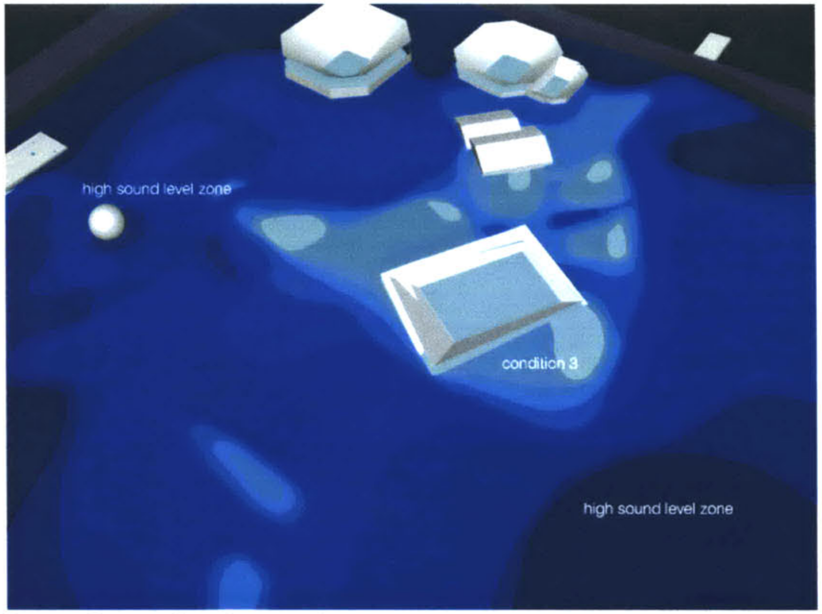
Zone between High sound level of Location E and Condition 1. This zone will perform similarly to Condition 2 utilizing the passive sound control method. The purpose of this zone is to maintain a consistent sound level condition for Condition 1 area from the affect of highway sound reflected by the reflecting pool in Location E.



[3.5.3 a] sound level map



[3.5.3 a] sound level map with initial design



[3.5.3 a] sound level map with initial design

4.0.0 design development

[4.0.0 a] designing from section studies

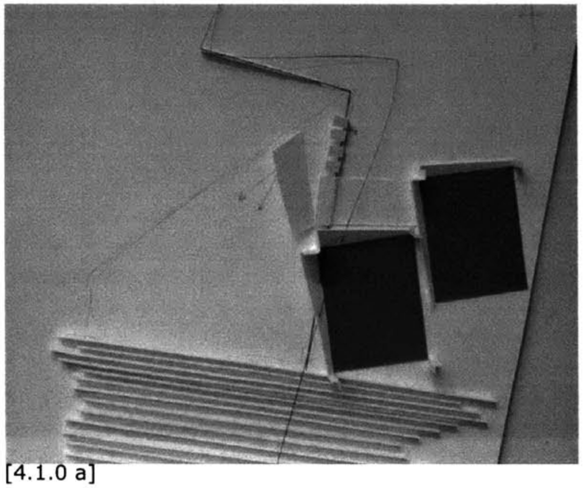
4.1.0 iteration 1

01.10.17 no scale

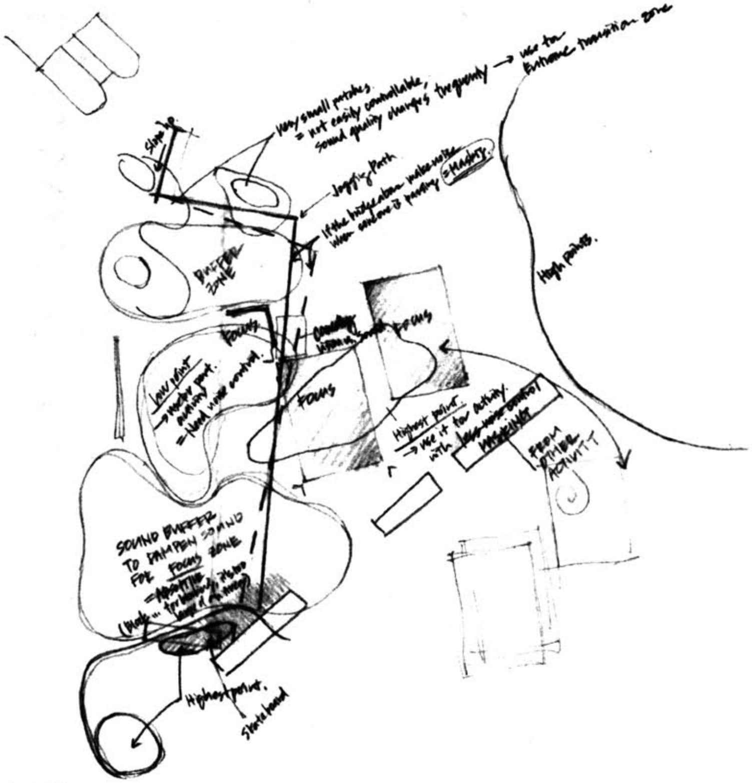
Chipboard model locating multiple programs according to the sound sequence I imagined one to experience when walking through the site.mmThe model consisted of 2 soccer fields and a performance space where one will pierce through each "sound volume experience" through one linear path. The path is choreographed acoustically through one's various relationships to each event (soccer game and performance concert).

Comments:

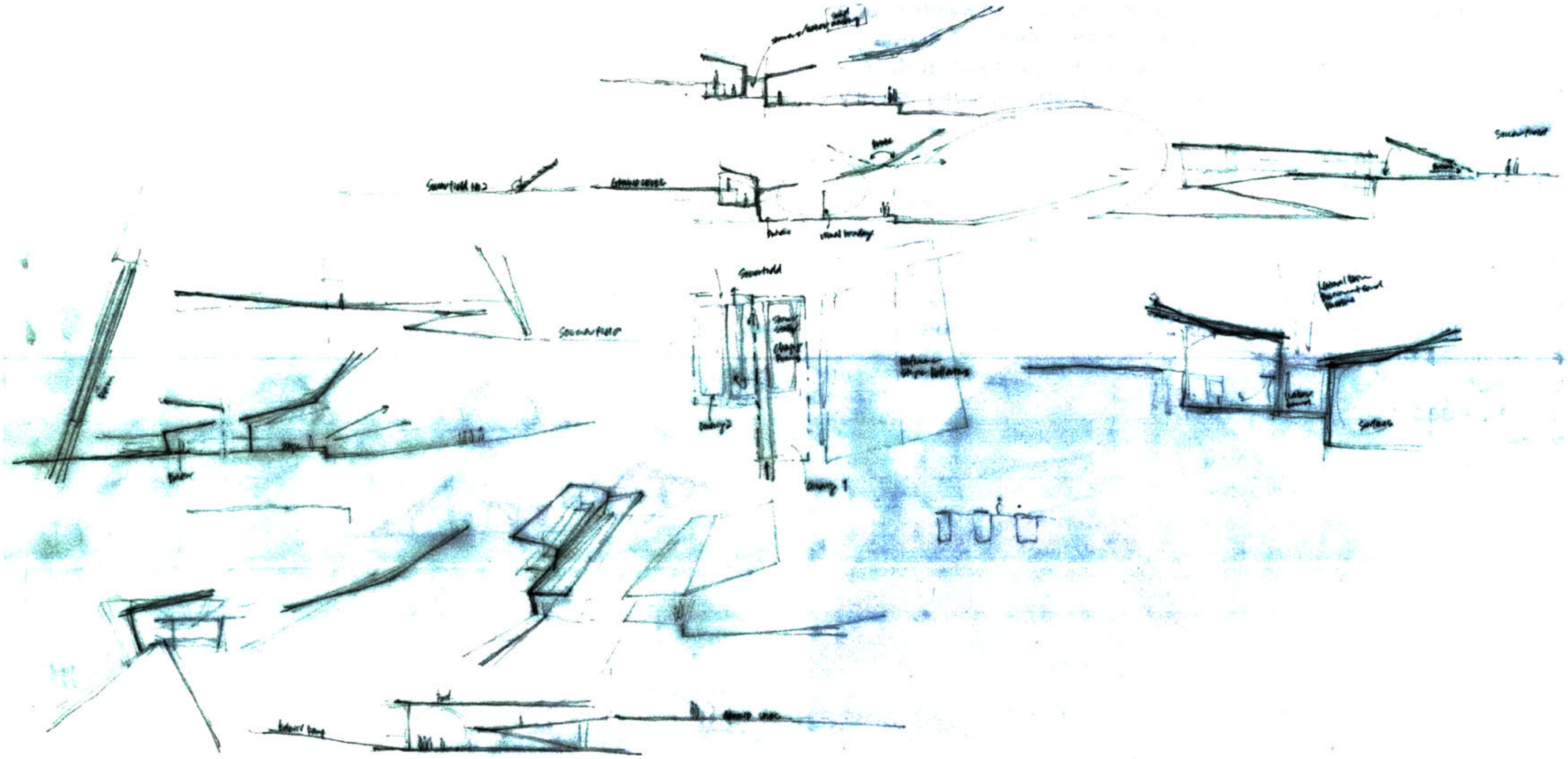
Some of the conditions created through the single jogging path piercing through each event is interesting. However, it also creates strange conditions where the programs don't function ideally. Examples are having only one entrance the soccer field and entering the performance space through the back stage. Also, the major source of trouble is the scale of the project growing too large. I realized through the sound research that sound can be controlled best locally especially in an outdoor environment where there are many background ambient sound. The larger area each program occupies, the more difficult one will experience the variation in sound manipulation outdoor.



[4.1.0 a]



[4.1.0 b]



[4.1.0 c] sectional studies of the acoustic spatial experience

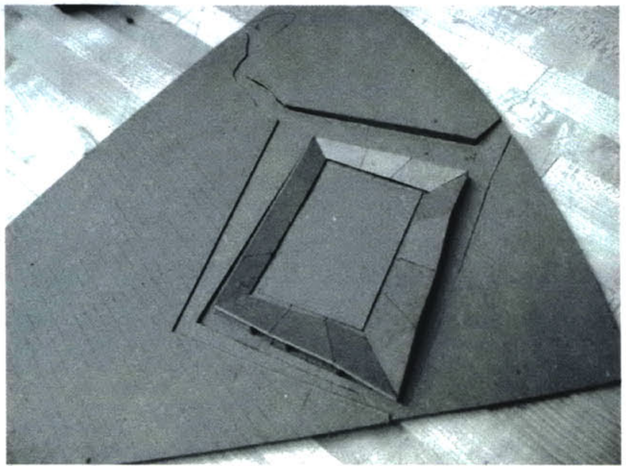
4.2.0 iteration 2

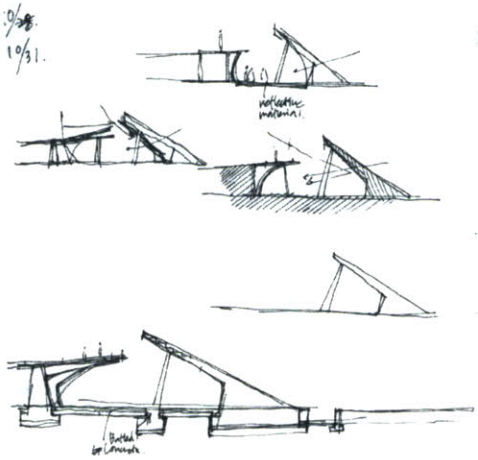
01.11.02 1"=100'

Chipboard model demonstrating a single program with spaces between the program and the landscape. The design focuses on a soccer field located according to the sound landscape constructed through sound level measurement taken from the site. This is the first model to be site specific (according the sound landscape data) and showing a functioning program. I discovered the possibility of designing the in between space or the non-program space to have a rich quality of acoustic experience. The separation also between the built architectural element and the earth form (landscape design) is very clear and ideal.

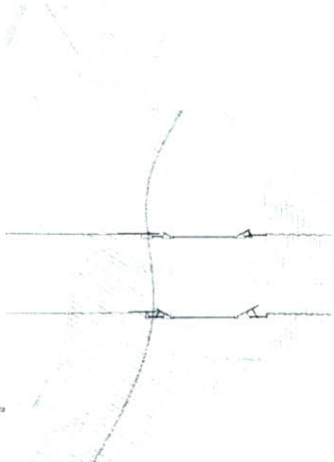
Comments:

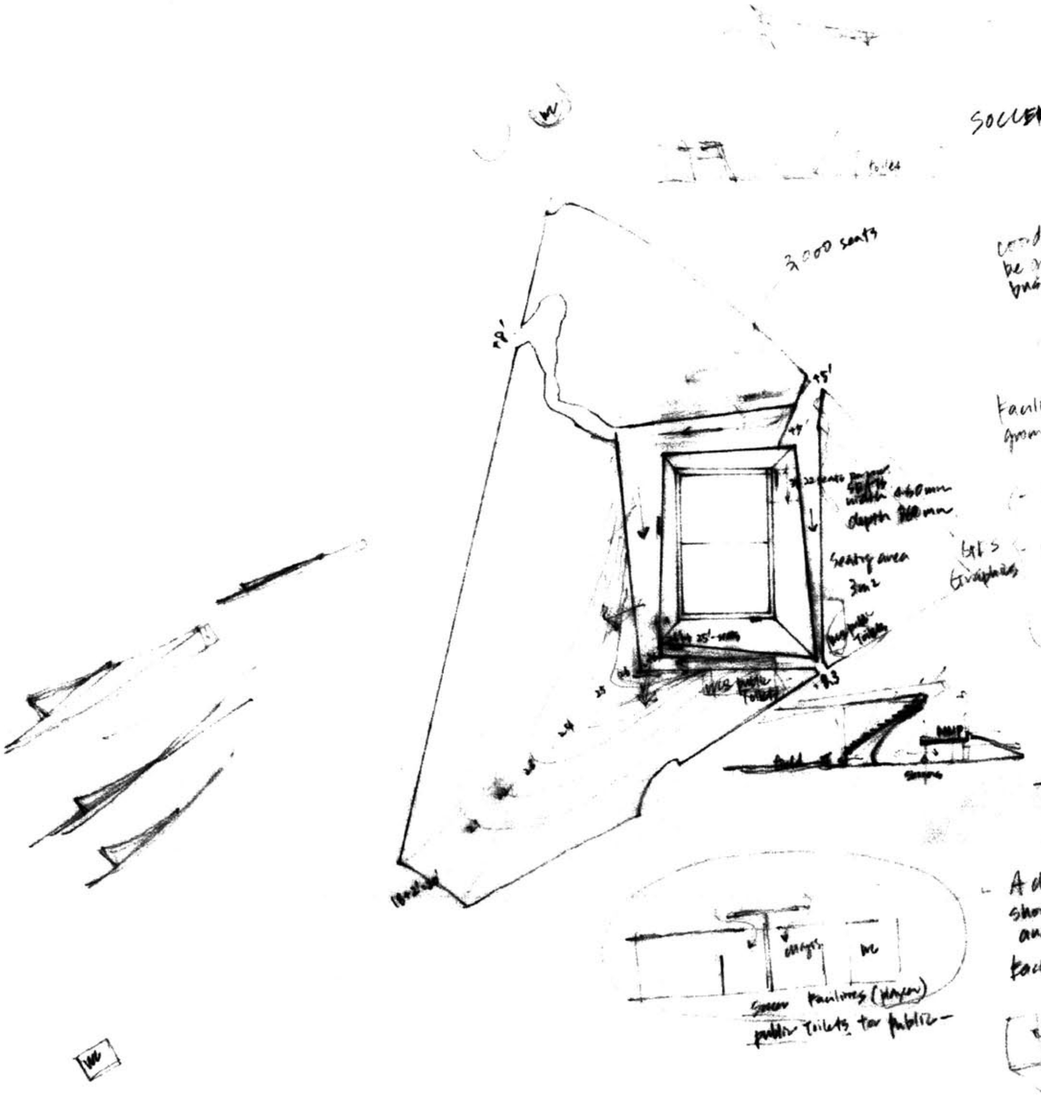
It is probably the clearest model demonstrating a possible design product, but it lost the flexibility and possibility of programmatic relationship study model 4 demonstrated. It also became an object inserted on a site, so the multi-possibilities of previous models need to be reconsidered.


[4.2.0 a]



[4.2.0 b] design section dwg


[4.2.0 c] site section dwg



Felationship – to the landscape.
Sound Control. → language.
– Factor – Ourotspace – why
~~Quiet~~ on the field.

Quiet.

Zaha – 15yrs ago.
Sharp [illegible] ~~corners~~
Amorphous: conversation
Raphael.
– Viñoly.
– [illegible].

SOCCER FIELD

Corridors & door width should be generous, because these are busy areas on a matchday.
1.2m is a minimum width, 1.5 preferable

Facilities ~~these~~ must be at the ground level, ~~should~~

– Floors should be of impervious material,

GFS Graphics – walls should be of materials resistant to moisture and should be surfaces that are easily cleaned.

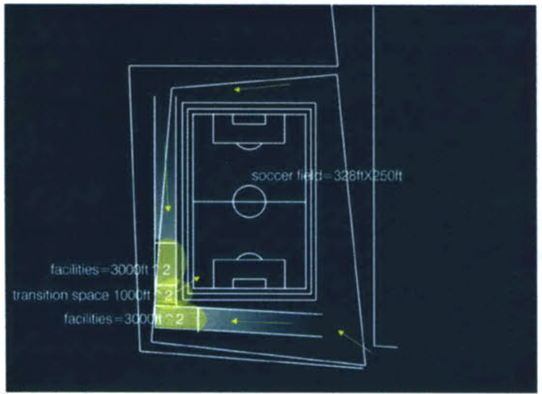
~~Good ventilation is essential to prevent condensation, as well as a heating and/or cooling system~~

– A changing room or locker room should be provided ~~by~~ for each home team, and at least one visiting team

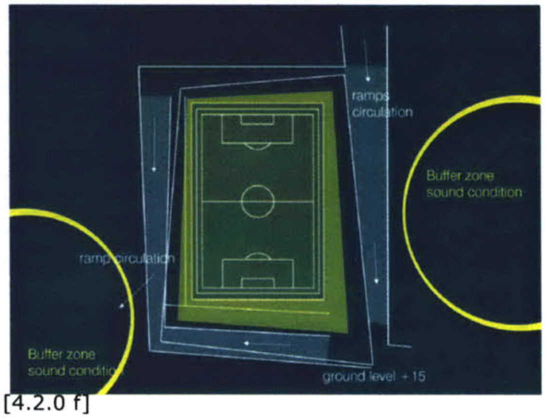
Each

different material ?

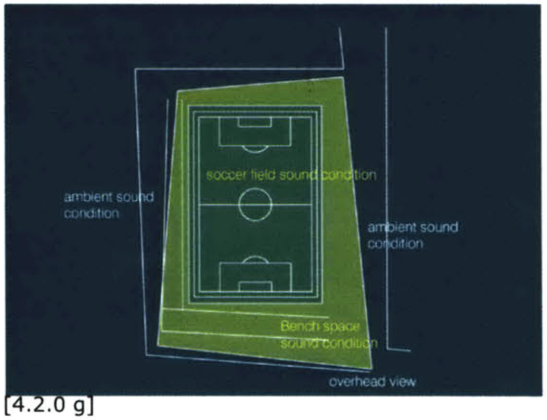
[4.2.0 d]



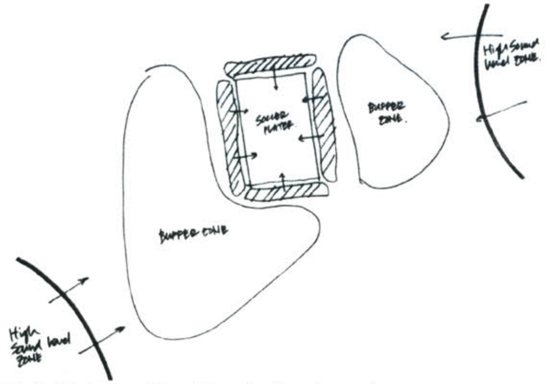
[4.2.0 e]



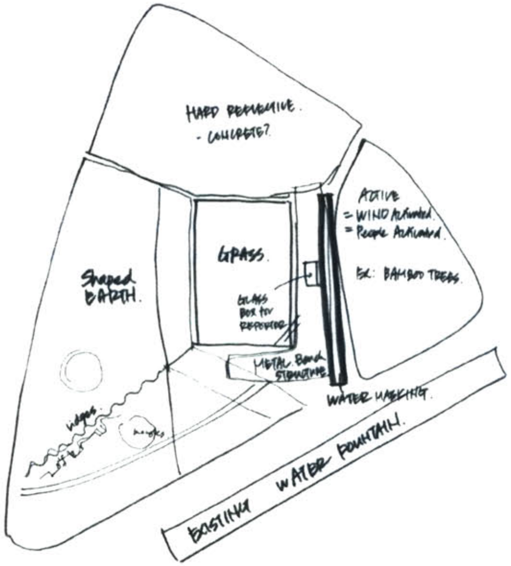
[4.2.0 f]



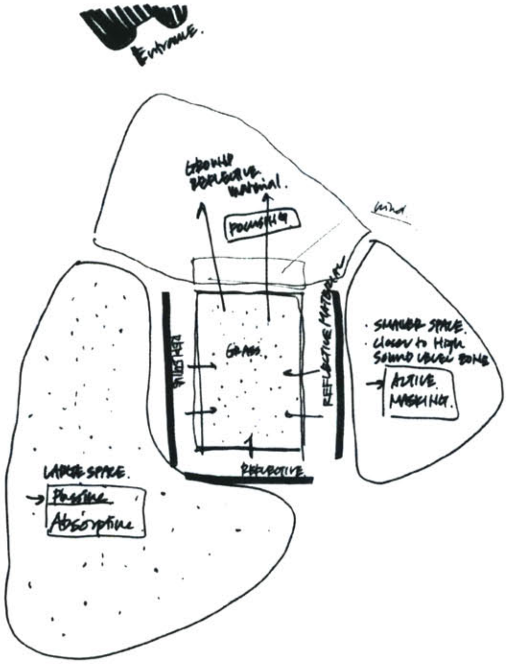
[4.2.0 g]



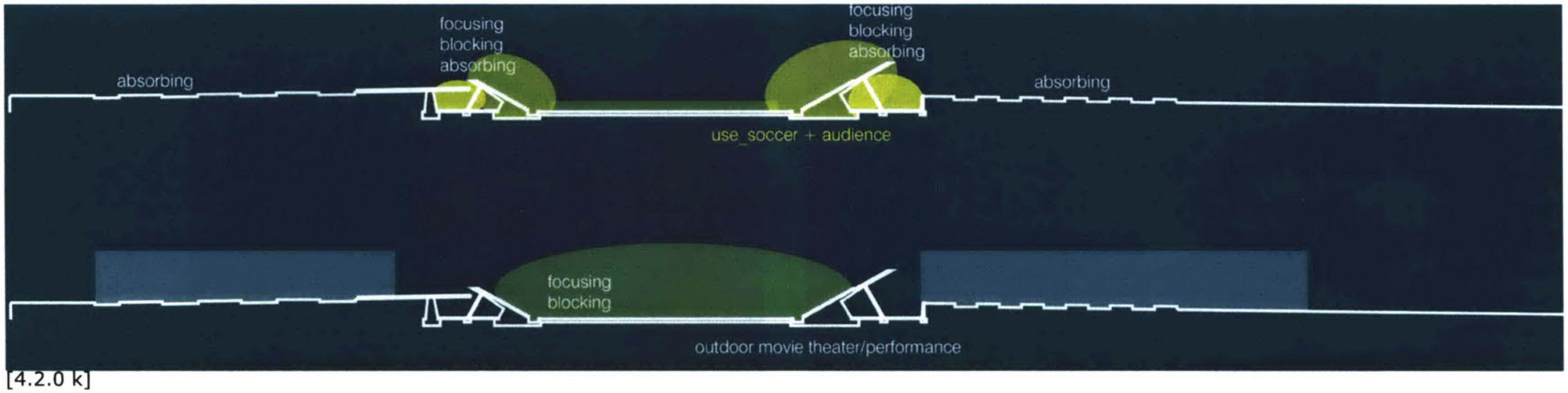
[4.2.0 h] locating the design based on the surrounding acoustic environment



[4.2.0 i] material selection based on acoustic quality of material



[4.2.0 j]
acoustic condition of the design



[4.2.0 k]

4.3.0 iteration 3

11.11.02 1"=100'

This model is design following the comments on the previous design iteration during the Design review on November 1.

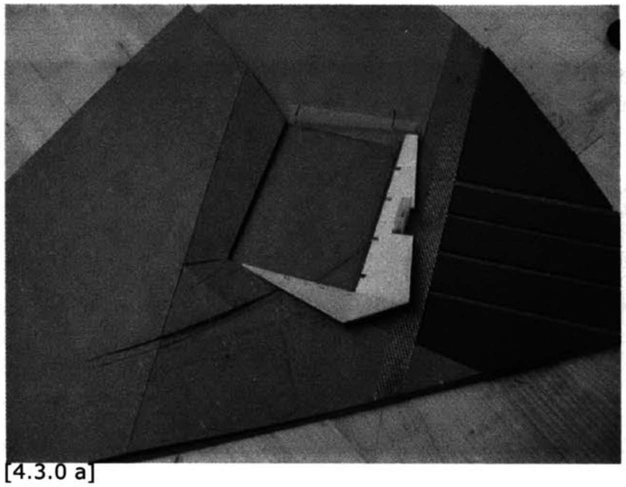
Comments:

At the end, the design should not look like a conventional soccer field.

The subtlety of programs and landscape movement expressed on the previous model is lost, but it should inform the next model. The current model looks like an object.

Flipping the model around, and use the landscape in a more subtle way. Ground indentation and slope can be used as part of the design language.

The Blocking effect from the sound control language is used too much in the current design. It is an additive design. Other sound control language needs to be utilized to create a soundscape for soccer. Perhaps a more subtractive method of design can be used as opposed to an additive method.

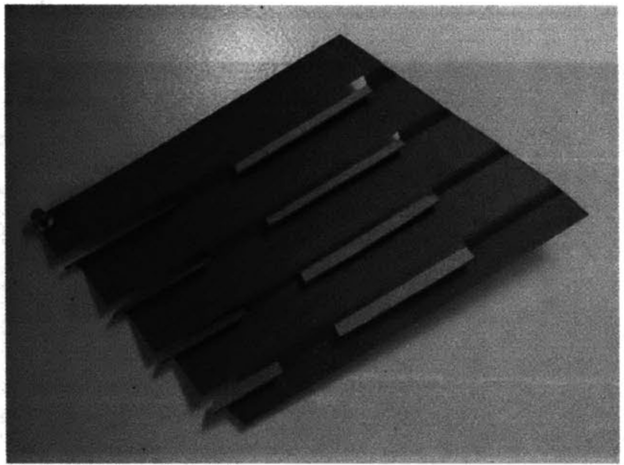


[4.3.0 a]

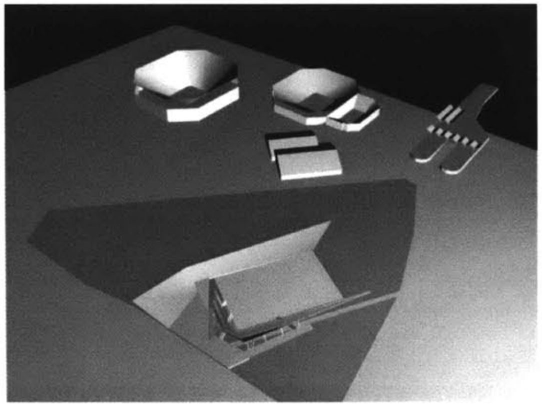
A Material Palette should be made along with sound control, landscape and architecture language.

The space between the soccer field and the landscape can work (axel). There are examples of this such as the Harvard Stadium.

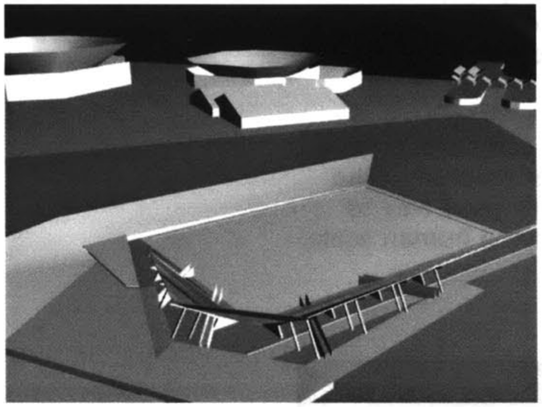
One need to be careful that the design insertion does not become too big as the tennis court stadium. Of this happens, there will be other issues to be dealt with, such as parking.



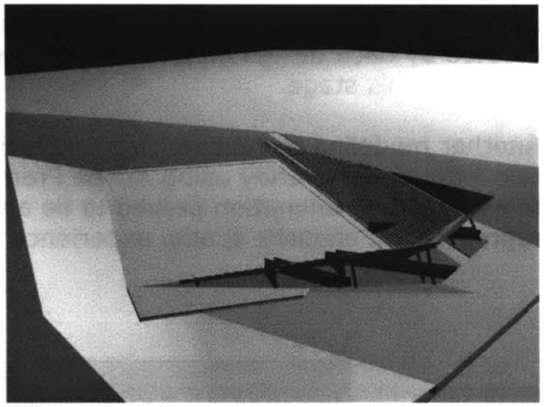
[4.3.0 b] bench detail



[4.3.0 c]



[4.3.0 d]



[4.3.0 e]

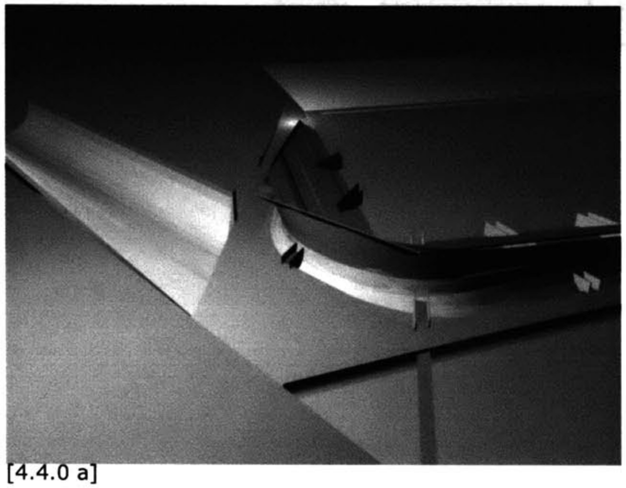
4.4.0 iteration 4

19.11.02

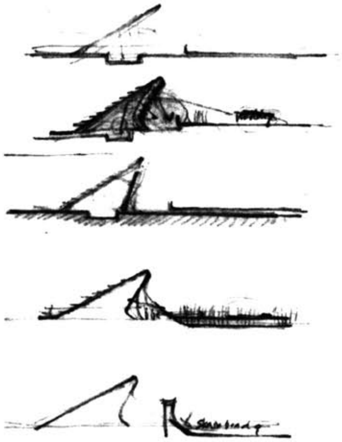
This stage of the project is mostly designed through the sectional relationship of the design to the landscape. The angles and curves are derived from the kind of acoustically manipulated spatial experience.

Through the process of redesign, the design tries to refine each shape and the relationship to other design intervention in the site. The choreography of various acoustic effects created by each design intervention is the key focus of the design at this stage.

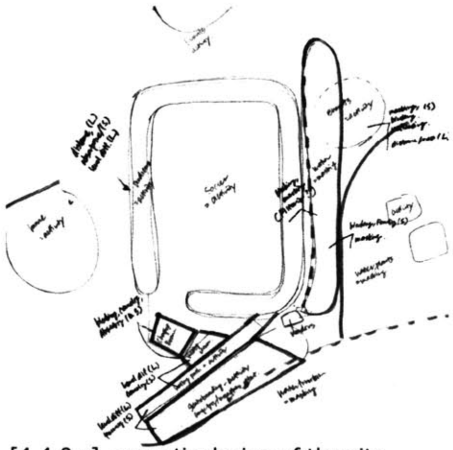
Another modeling technique I learned is 3d computer animation with sound overlay using Adobe Premier program. The five test sound animation proved to be a very good way to represent the acoustic spatial experience from a human scale.



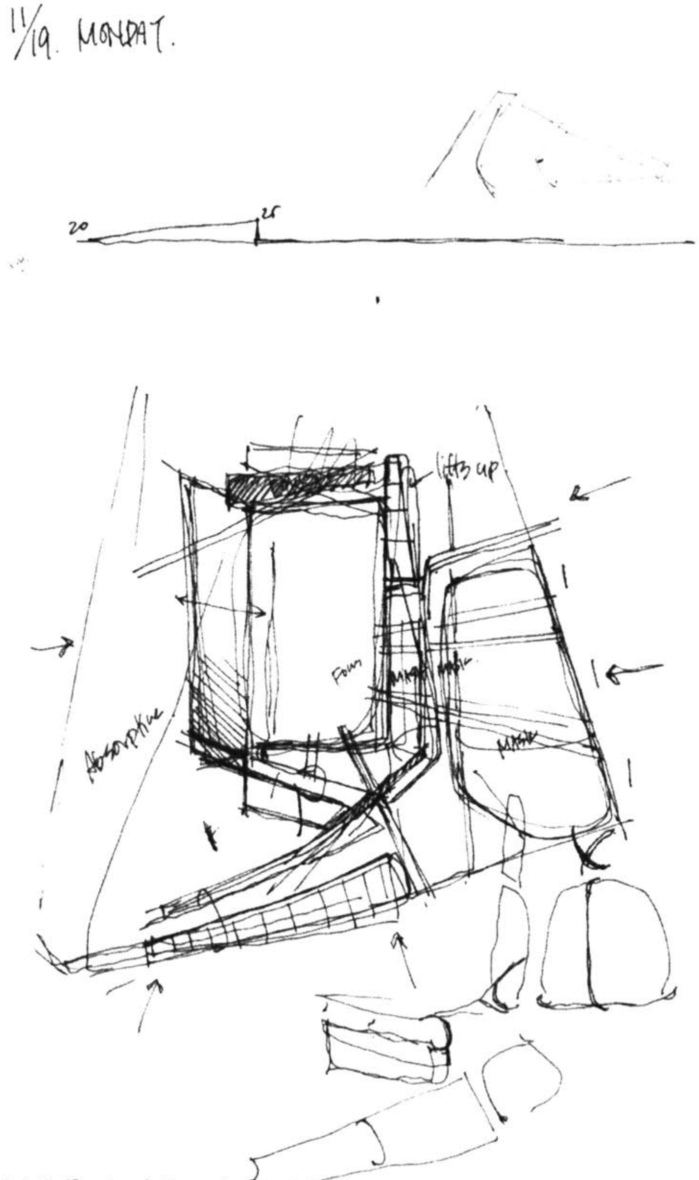
[4.4.0 a]



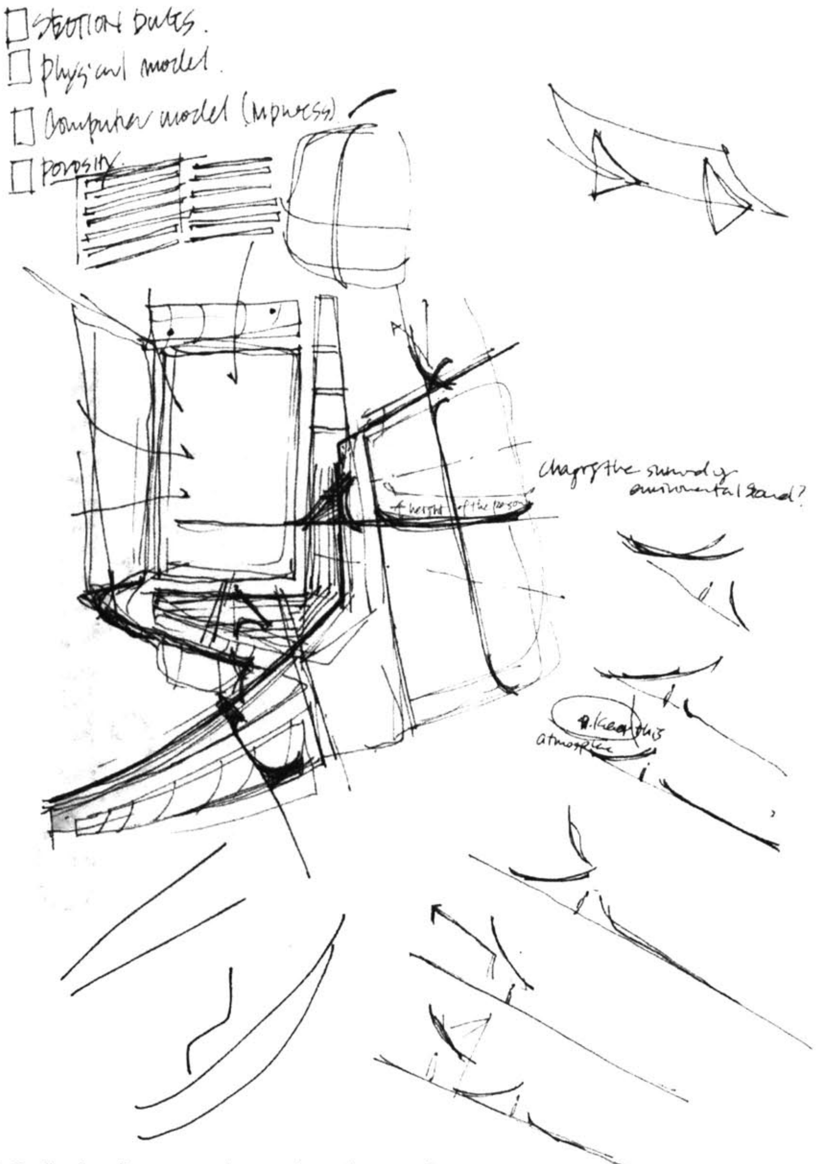
[4.4.0 b] section study sketch



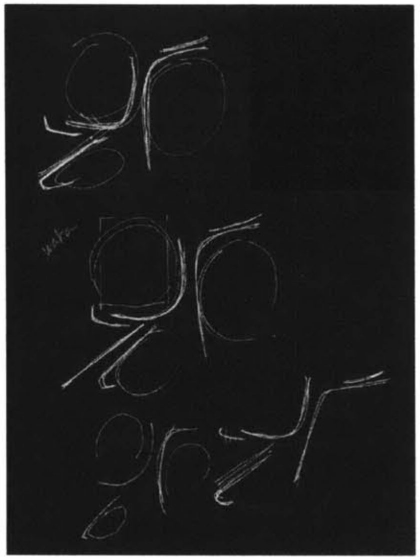
[4.4.0 c] acoustic design of the site



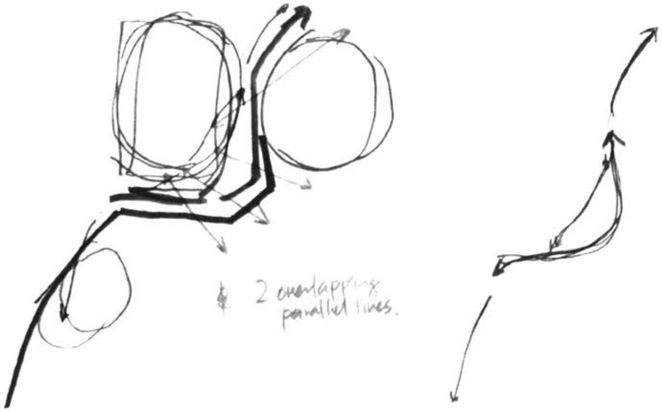
[4.4.0 d] circulation study



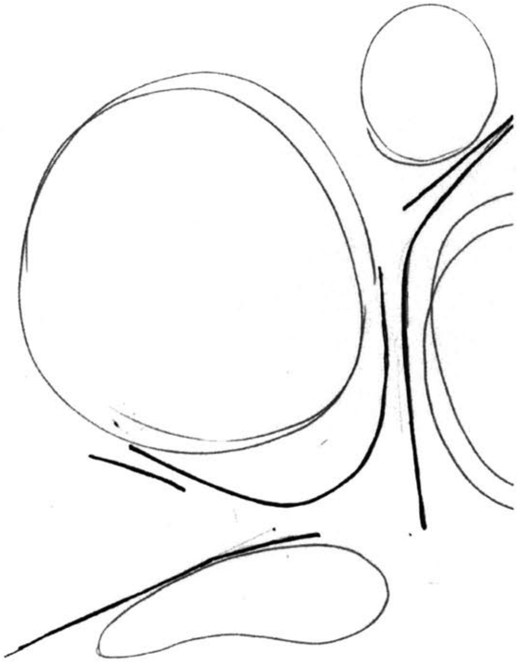
[4.4.0 e] simultaneous plan and section study



[4.4.0 f] placing thresholdsaround the circle of events.

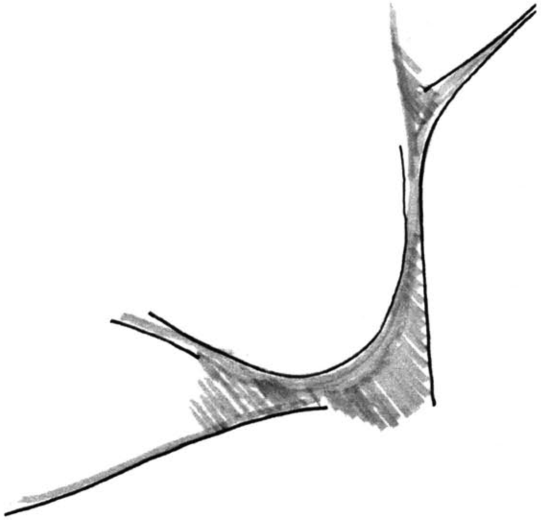


[4.4.0 g] study of thresholds and their relationship to each other through linking them.

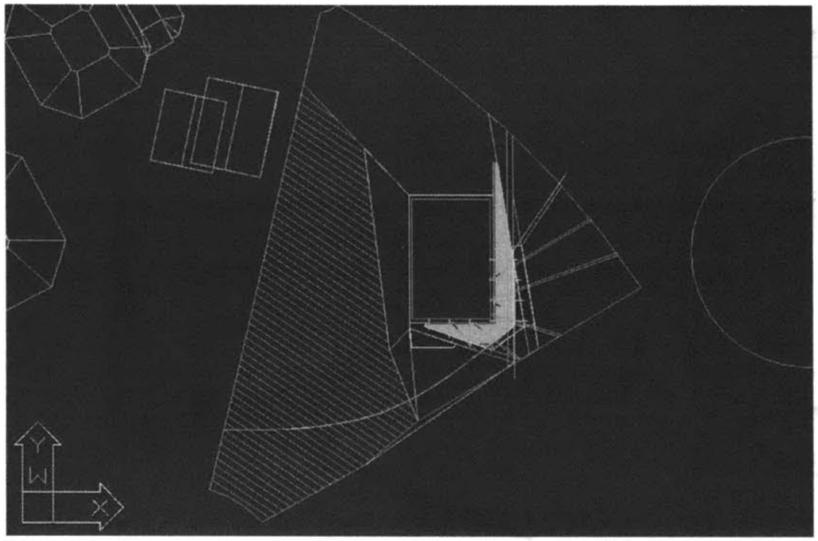


[4.4.0 h] study of thresholds around series of sound initiative events.

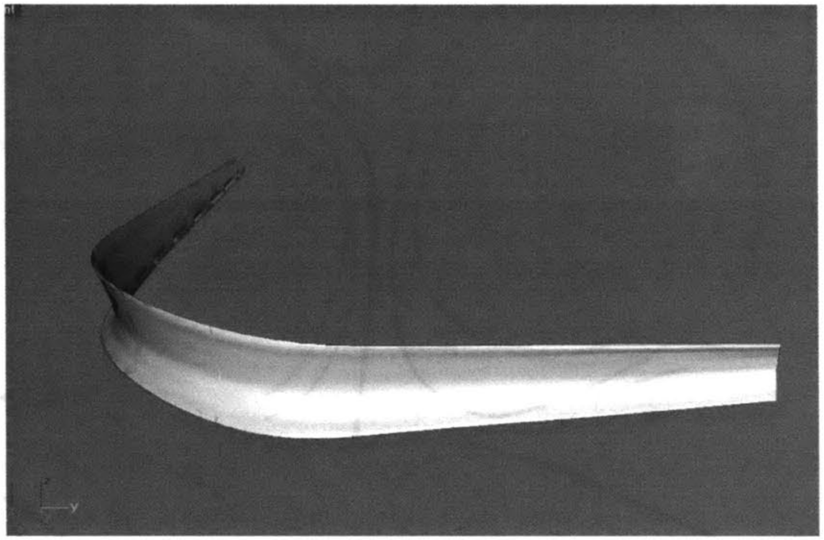
[4.4.0 i] study of thresholds and it's effect to acoustic spatial experience based on sound behavior.



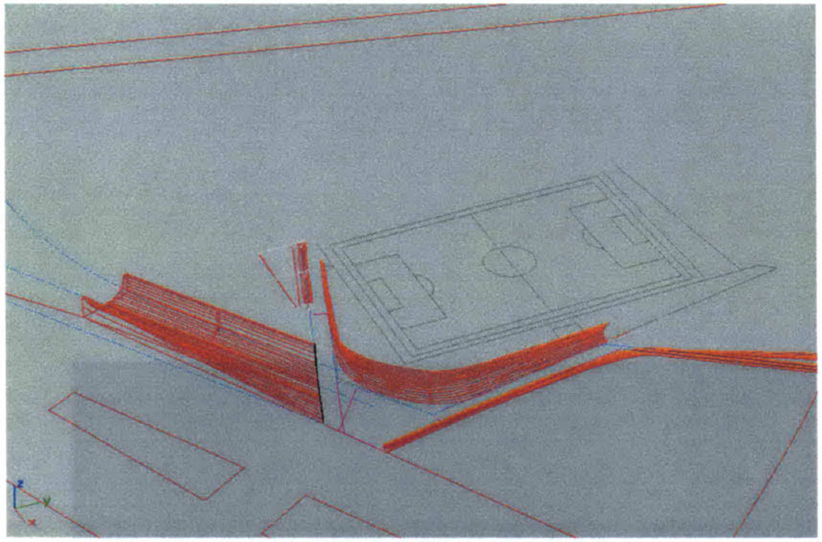
[4.4.0 j] study of zones with iintense acoustic experience.



[4.4.0 k]



[4.4.0 l]



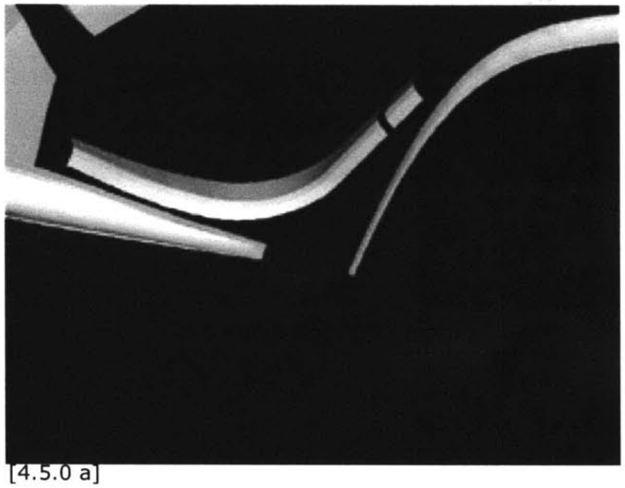
[4.4.0 m]

[4.4.0 n]

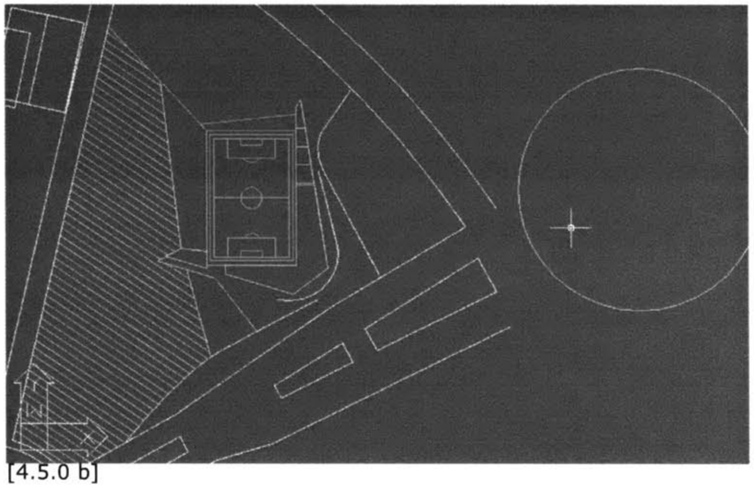
4.5.0 iteration 5

08.12.02

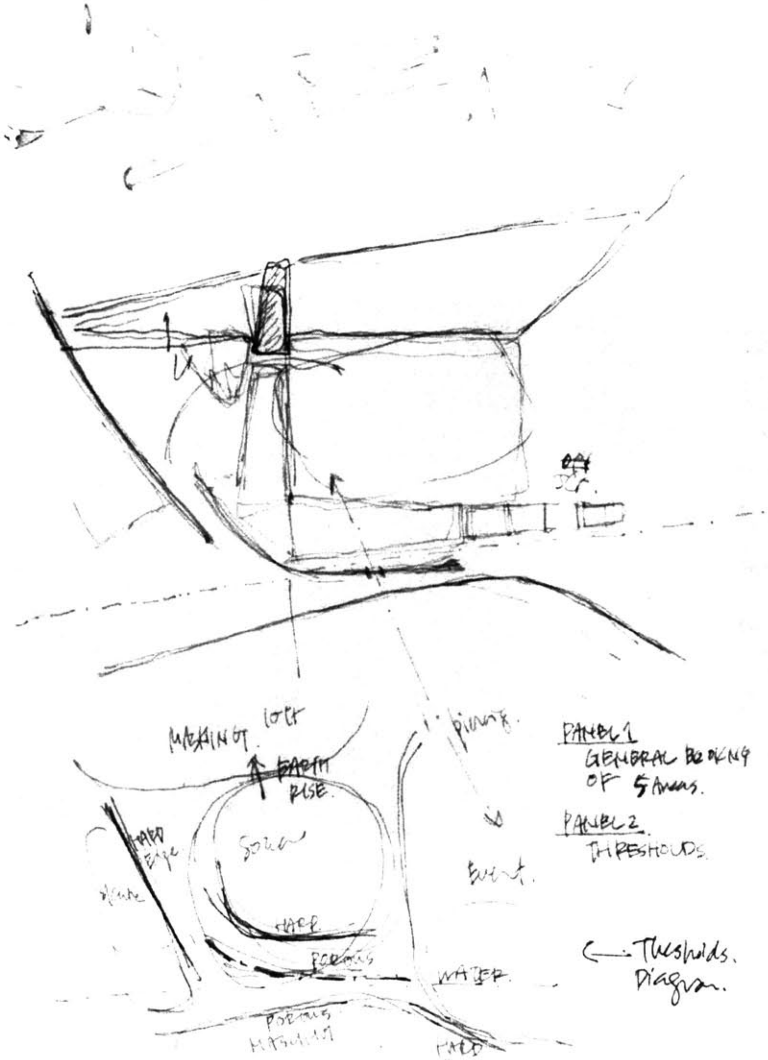
This stage of the project is about looking at each design intervention closely. Choreography of fluent acoustic spatial experience initiated by each event became the key design concept. I also try to further develop the structural aspect of one of the design intervention.



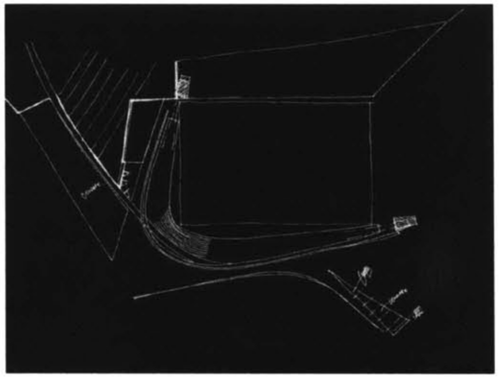
[4.5.0 a]



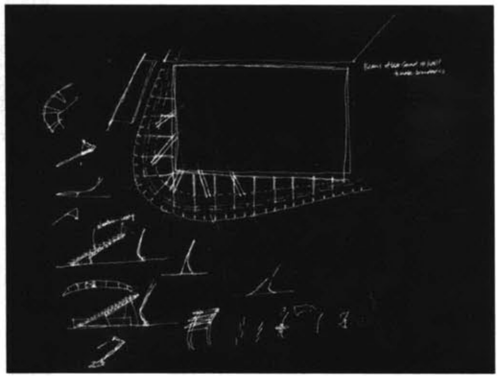
[4.5.0 b]



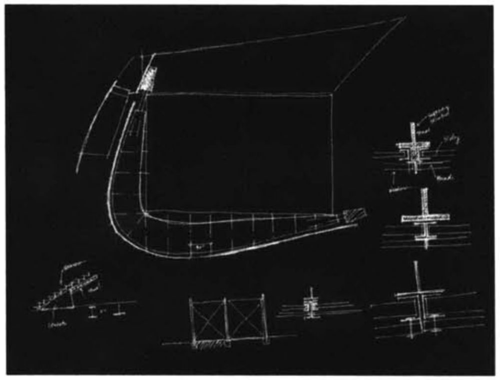
[4.5.0 c] acoustic studesi of design



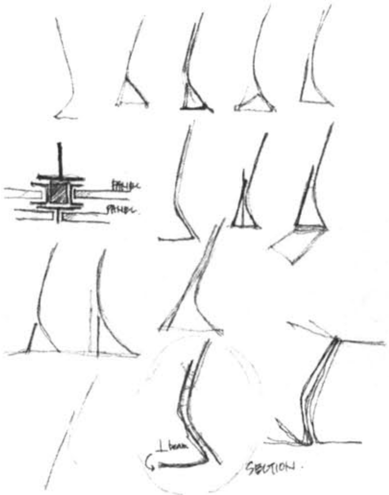
[4.5.0 d] idea of the bench structure supported by cables



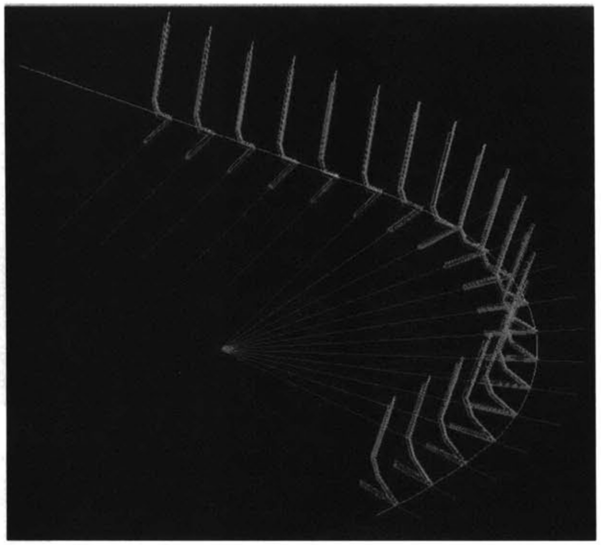
[4.5.0 e] idea of the bench structure supported by concrete ribs and steel beams



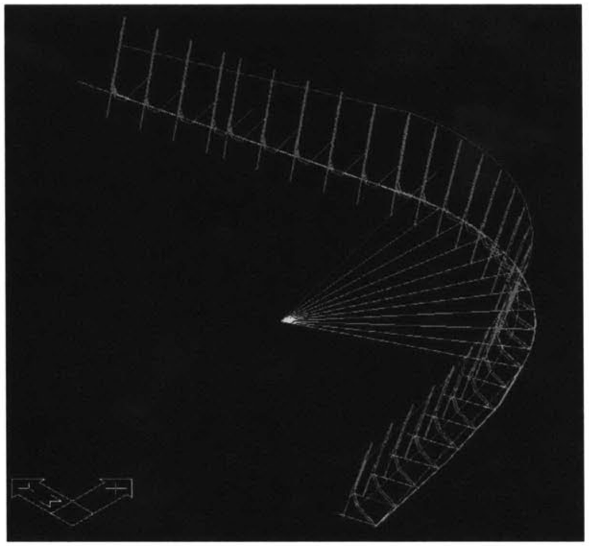
[4.5.0 f] details of the sliding panels in the screen structure to change its sound porosity



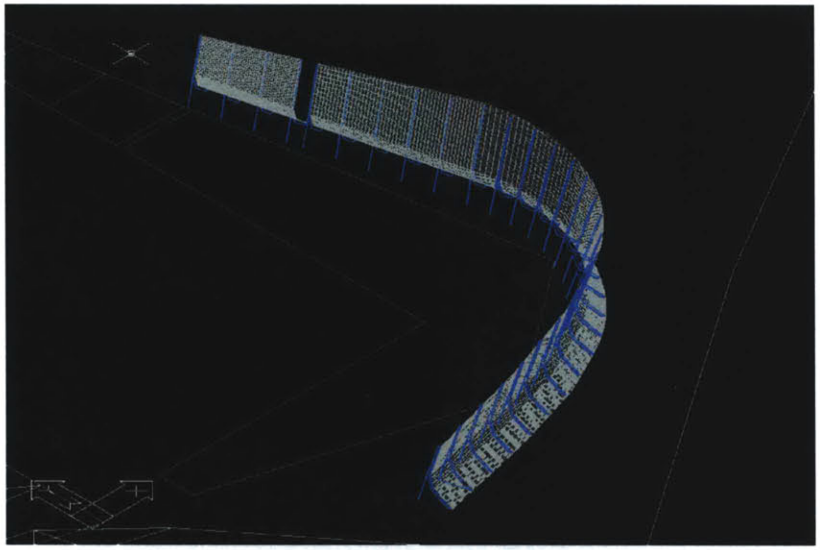
[4.4.0 g] sketch study of screen supporting structure



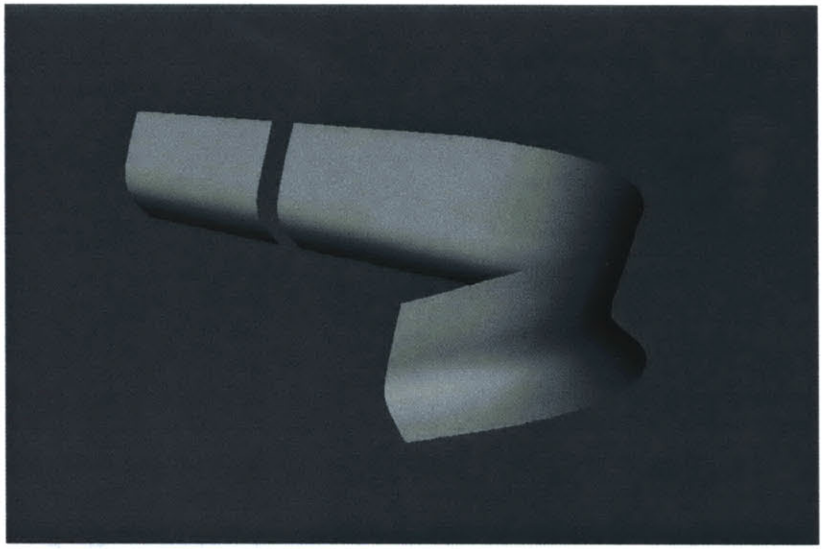
[4.4.0 h] initial screen structure design



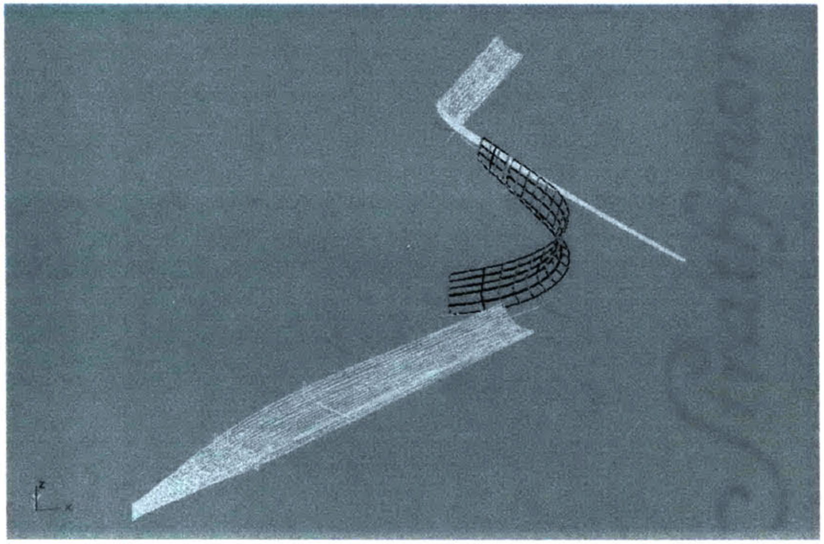
[4.4.0 i] final screen structure design



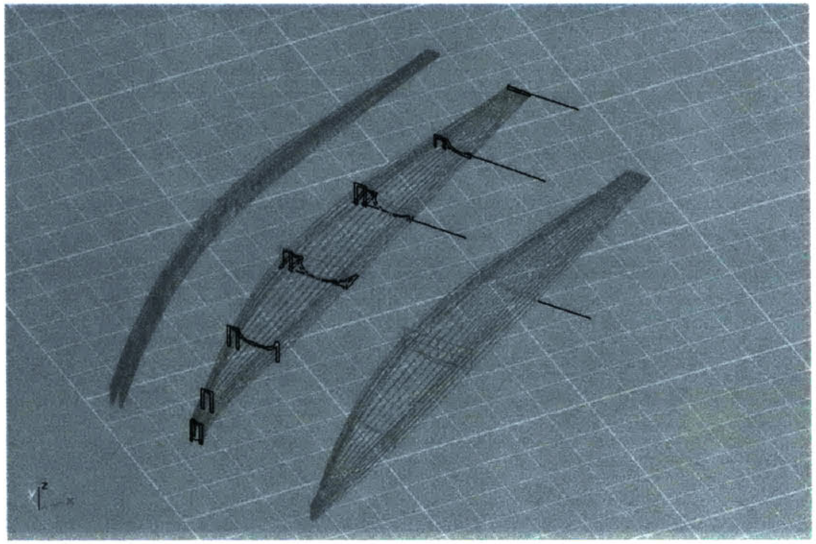
[4.4.0 j] final screen structure design in context



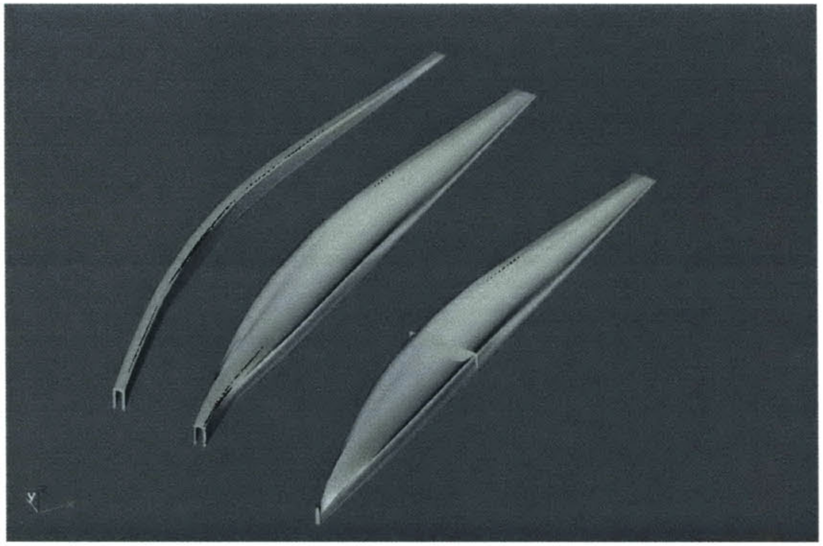
[4.4.0 k] final screen structure design in 3d modeling program prepared for the 3d printer.



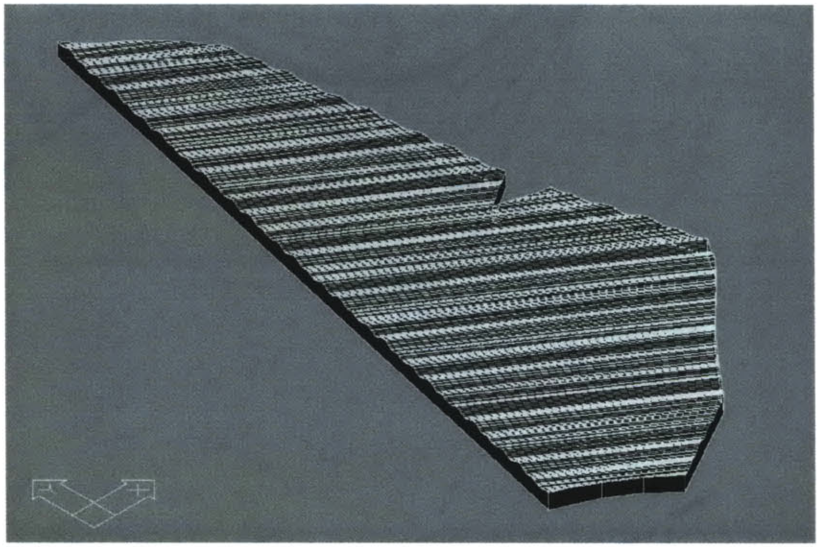
[4.4.0 l] final screen structure design with the skateboard halfpipe and the edge of pampas grass field.



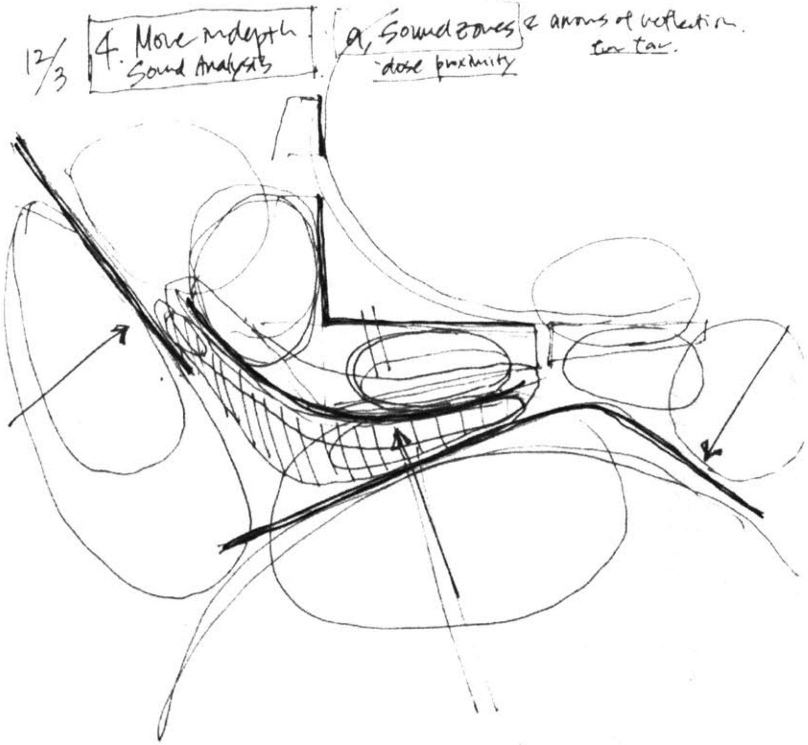
[4.4.0 m] sectional study of skateboarding halfpipe.



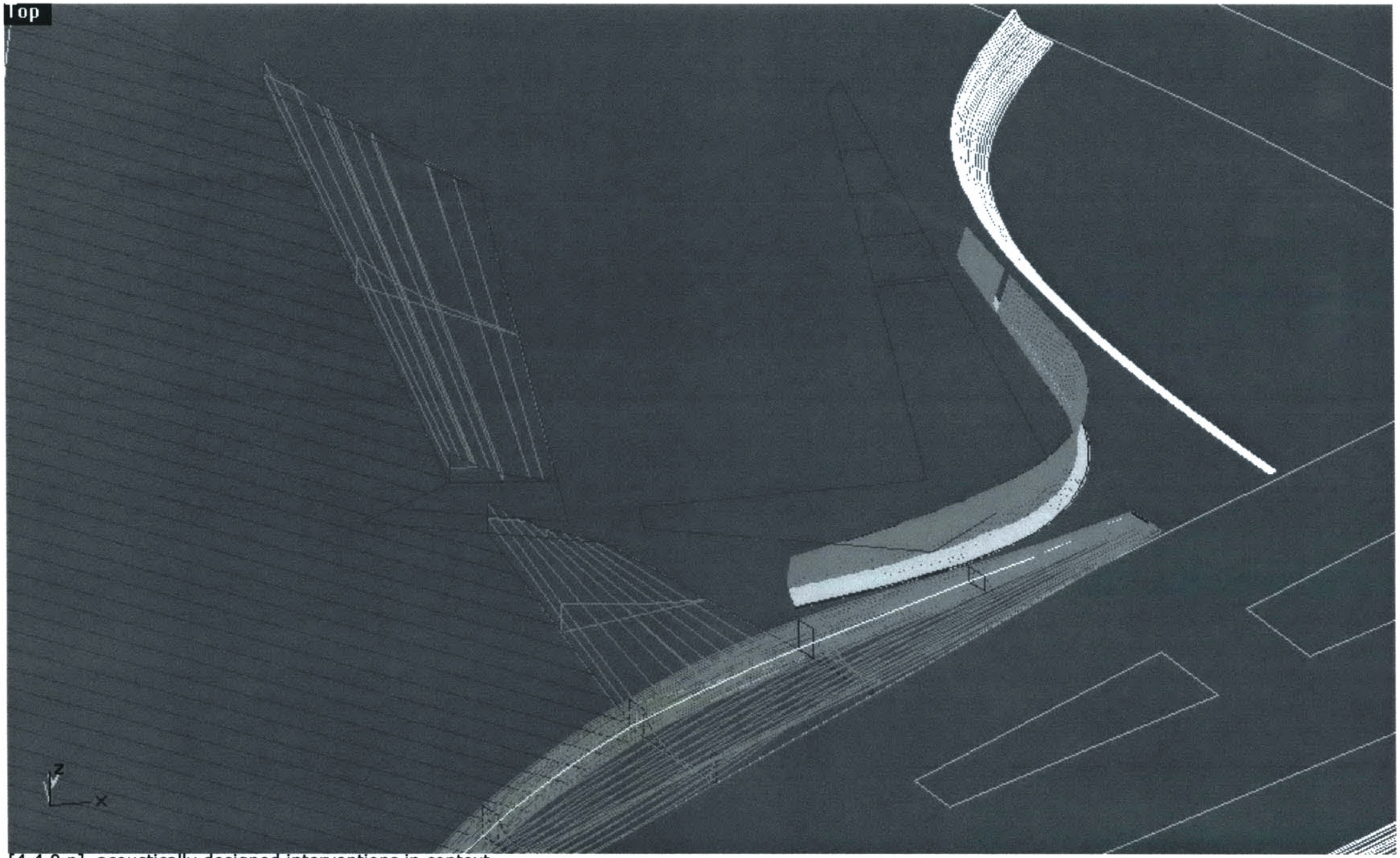
[4.4.0 n] 3d model of the skateboarding halfpipe.



[4.4.0 o] undulated grass field designed to absorb environmental sound.



[4.4.0 q] acoustically designing architectural intervention



[4.4.0 p] acoustically designed interventions in context

5.0.0 final proposal

[5.0.0 a] final design presentation

5.1.0 Overview

date:
Thursday, December 13, 2001
time:
12 00 hrs
location:
Advanced Visual Theatre (AVT) 7-431

participants:
Peter Testa
Associate Professor of Architecture, MIT

John Fernandez
Assistant Professor of Architecture and Building Technology, MIT

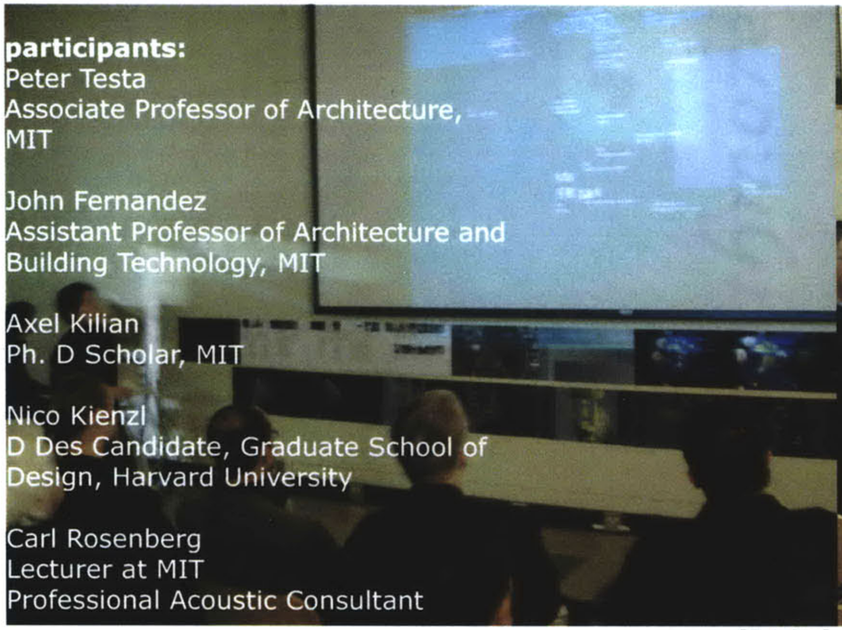
Axel Kilian
Ph. D Scholar, MIT

Nico Kienzl
D Des Candidate, Graduate School of Design, Harvard University

Carl Rosenberg
Lecturer at MIT
Professional Acoustic Consultant

Cynthia Weese
Dean, School of Architecture
Washington University, St. Louis MO

Shane Williamson
Faculty of Architecture
University of Toronto, Toronto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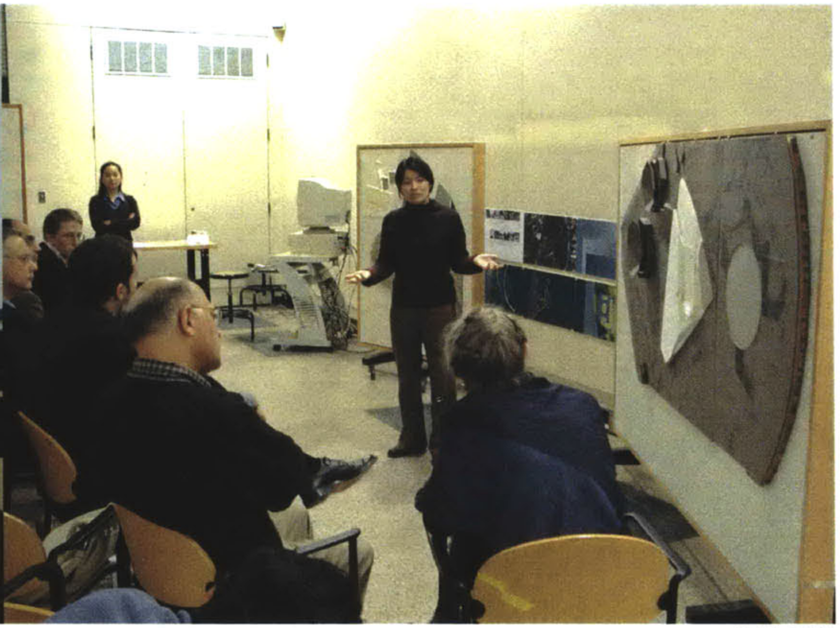

[5.1.0 b]


[5.1.0 c]


[5.1.0 d]

5.2.0 materials

website presentation

presentation panels [01 - 22]

study models:
site model 1 scale: 1'-0" = 200'
site model 2 scale: 1'-0" = 200'
sound model scale: 1'-0" = 400'
program/landscape model
programmatic adjacency model

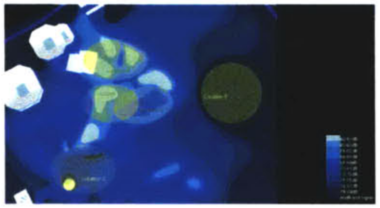
presentation model
scale: 1'-0" = 50'

computer animation 1 [movie]
computer animation 2 [movie]
computer animation 3 [movie]

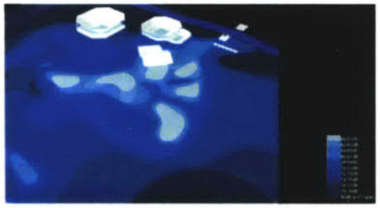


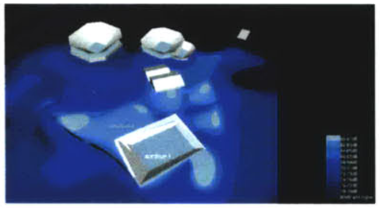


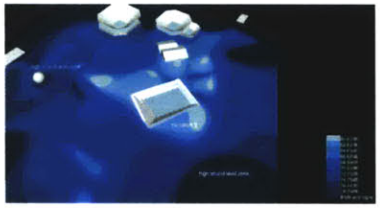


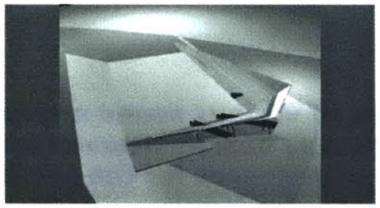



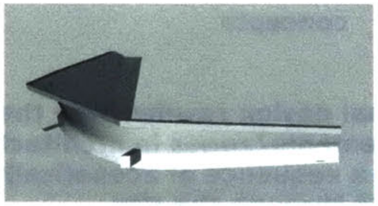
[5.2.0 a] to [5.2.0 t]

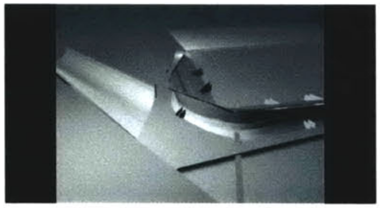


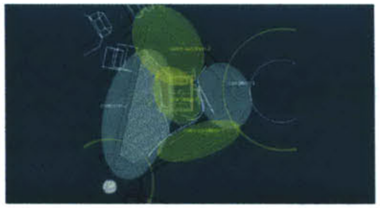


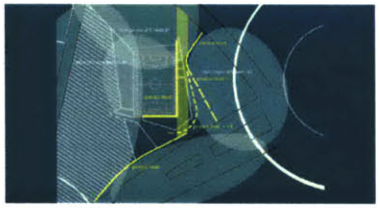


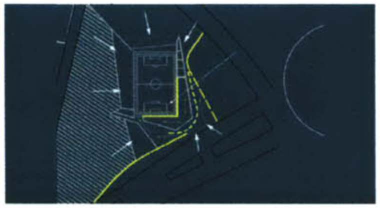


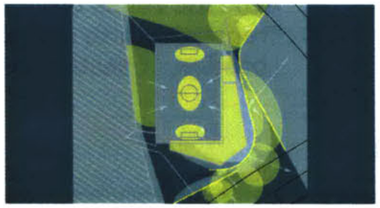


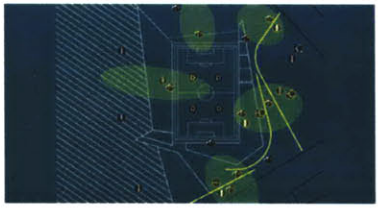












5.3.0 concepts

The final design results from the choreography of various sound manipulative elements/zones in architectural and landscape design interventions to create a sequence of acoustically rich spatial experiences for the person walking through the site.

5.3.1 L_scale site proposal
    Aerial sound level mapping diagram
    Refine sound zones based on spatial design intention
    Surface material for projected acoustic condition

5.3.2 M_scale area proposal
    Placing thresholds
    Circulation pattern formed from thresholds

5.3.3 S_scale spatial proposal
    Acoustic zones created by design intention
    Translation into sound control icons
    Location of section cuts

5.3.1 [L _scale site proposal]

Large scale site proposal begins from revisiting the aerial sound level-mapping diagram. This diagram indicates the location of each zone relative to each other and the sound level variation. Based on the sound level variation, the acoustic character of each zone is analyzed (sound source zone or buffer zone). Then, the result of the acoustic character leads to the selection of program and function of the zone relative to the surrounding environment. Recommended type of sound control language is listed based on the scale of the zone and it's proximity to the high sound source zone of location E and D. The driving reason for the design decision is to choreography a series of acoustically rich experience for the person walking in the park, but simultaneously allowing each program to acoustically function and further stimulate each space.

Aerial sound level mapping diagram

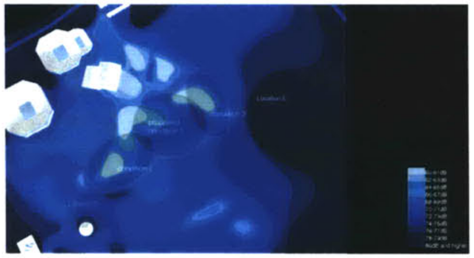
condition 1 = SOUND SOURCE ZONE

- Programmed Zone
  - soccer field
  - outdoor movie theater or concert (evening)
- Method using Sound control Language:
  - Absorbing
  - Blocking
  - Focusing/directing
  - Canceling
  - Masking

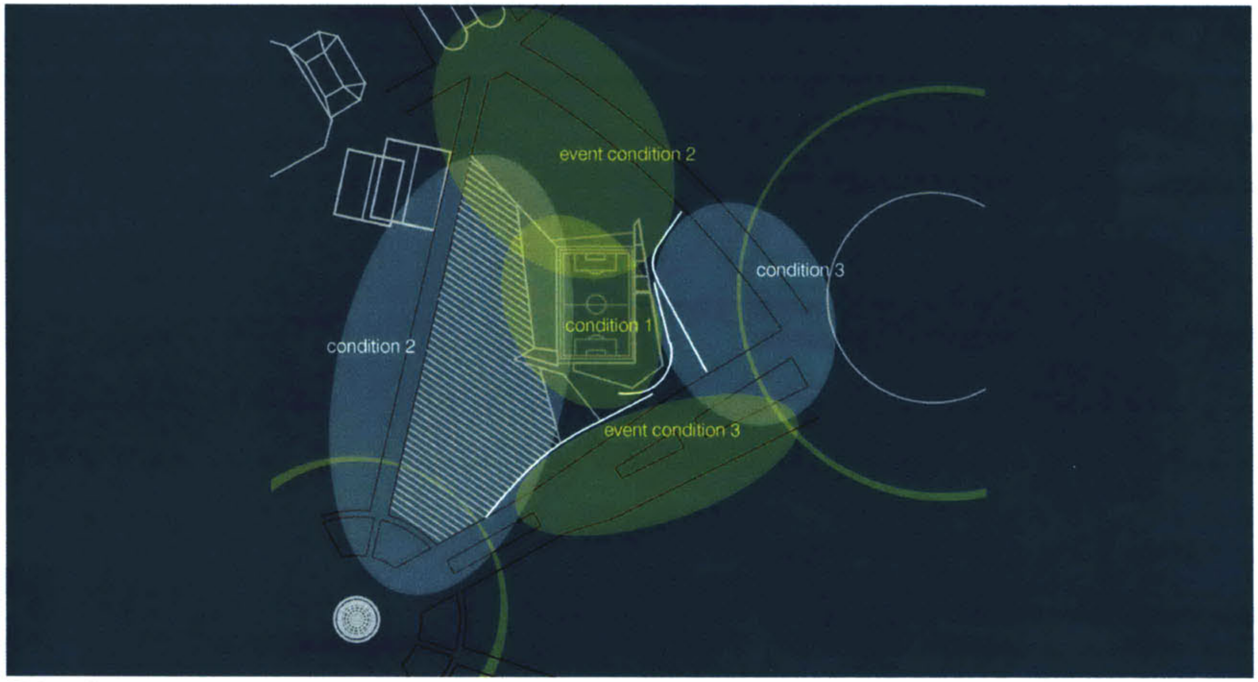
condition 2 x 3 = BUFFERING ZONE

Non-Programmed Zone
Zone designated to adjust obstructing sound filtering into the programmed area.
This zone requires a consistent sound condition.

- Method using Sound control Language:
  - Absorbing
  - Blocking
  - Masking



[5.3.1 a] sound level map from 3.5.2



[5.3.1 a] Diagram showing the refined sound zones

Refine sound zones based on spatial design intention

The final proposal contains additional zones of events (condition 2 and 3) from the initial proposal, which are both sound initiating zones, that suggests an increase in the intensity of sound, tension in program adjacency and complexity in the spatial experience in the designed site. With these changes, in order to understand it's acoustic effect on the site, the following text refines the program and the type of sound control language proposed for each zone.

condition 1 = SOUND SOURCE

Programmed Zone
    soccer field
    outdoor movie theater or concert (evening)
Sound control Language:
    Absorbing
    Blocking
    Focusing/directing
    Canceling
    Masking

event condition 2 = SOUND SOURCE

non-Programmed zone
space to host outdoor events such as small circus,
Sound control Language:
    Absorbing
    Focusing/directing

event condition 3 = SOUND SOURCE Programmed zone

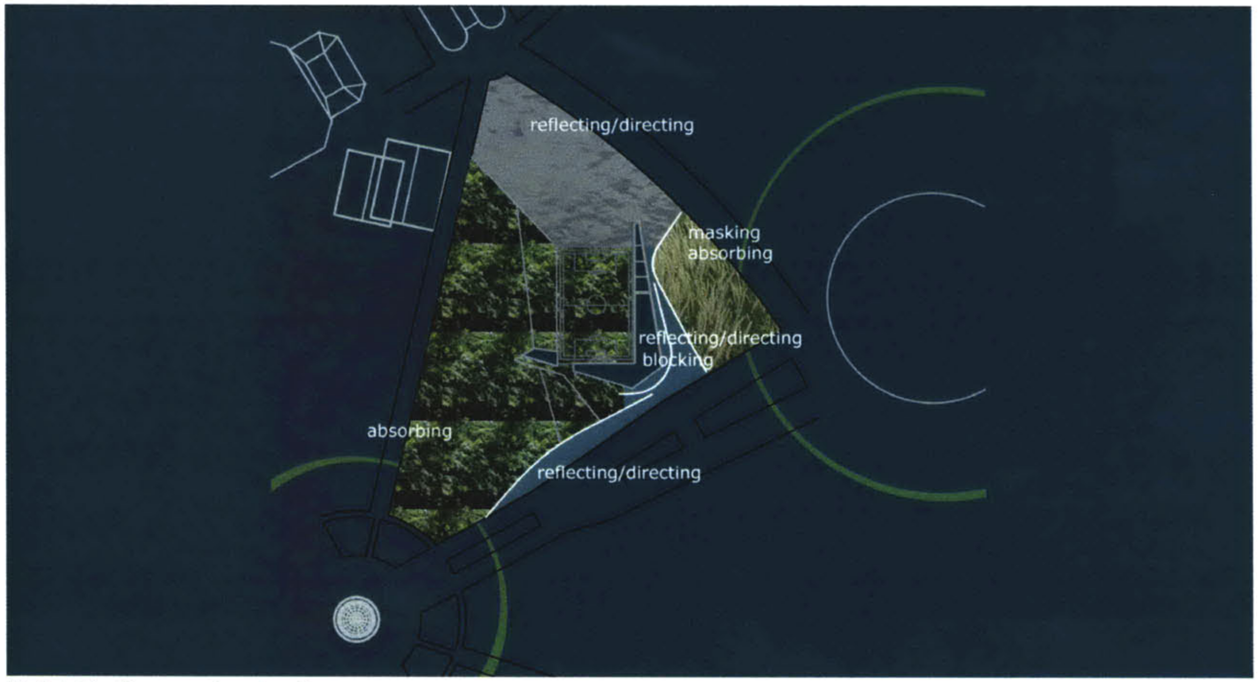
    skateboarding park
Sound control Language:
    Blocking
    Focusing/directing
    Masking

condition 2 = Buffer Zone

Non-Programmed Zone
Zone designated to adjust obstructing sound filtering into the programmed area.
This zone requires a consistent sound condition.
Sound control Language:
    Absorbing

condition 3 = Buffer Zone

Non-Programmed Zone
Sound control Language:
    Masking



[5.3.1 b] diagram showing the surface material selection based on acoustic quality of the material

Surface material for projected acoustic condition

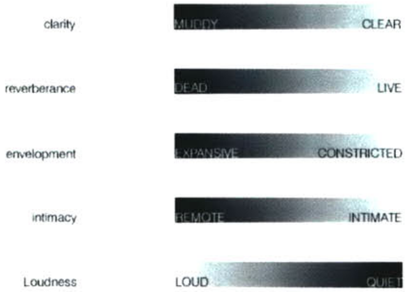
Designing in a large scale outdoor park, learning from the sound research/park (0.02 design foundation/sound study) surface material plays an important role in effecting the acoustic spatial experience. In the diagram, the surface/ground material is selected based on the previous diagram showing acoustic and program study, and simultaneously considering the size and the sound control language options. An acoustic condition analysis further explains the acoustic matrix (clarity, reverberance, envelopment, intimacy and loudness) the spatial experience one will have based on the surface material and the size of the zone.

[5.3.1 c] park acoustic study from section 2.3.2

SOUND SOURCE
condition 1

soccer field = TRIMMED GRASS

Sound Control Language
    absorbing
Acoustic Condition
    clarity = muddy
    reverberance = dead
    envelopment = constricted
    intimacy = remote
    loudness = quiet



[5.3.1 d] acoustic matrix introduced in section 3.3.3

design intention:
Between artificial grass and natural trimmed grass, the natural grass is chosen for it's better performance as a soccer field. From the player's point of view, natural grass is ideal because it decreases the injuries from sliding. From the acoustic point of view, natural grass has a higher absorptive level. Grass has a high absorptive acoustic property because of its high porosity of the material as well as it large mass with earth.

bench structure = STEEL STRUCTURE

Sound Control Language
    reflecting/directing
    blocking

Acoustic Condition
    clarity = clear
    reverberance = live
    envelopment = expansive
    intimacy = remote
    loudness = loud

design intention:
People will be more aware of the spatial acoustic experience if there are higher sound contrast in the space. In order to increase the excitement during the soccer game for example, the sound level needs to be increased when there are loud sound source and decrease sound level when there are low sound source. The loudest sound source during soccer games is not on the field from the players, but in the bench area from the audience. Steel is ideal for the bench structure because of its sound reflective/blocking character of the material. In addition, it is possible to give steel structure porous sound properties by adding kinetic parts in the bench design. I imagine the kinetic details on a smaller scale of the seating itself, but also on a larger scale where the entire bench structure can be rotated. It the entire bench is rotated, the structure can act as a reflective/blocking element for another event taking place next to the soccer field. Concrete is also a sound reflective/blocking material, but in this case where sound contrast is also a necessary condition, steel seems to be a better material.

event condition 2
outdoor events space = POROUS AND RELECTIVE ASPHALT

Sound Control Language
    absorbing
    focusing/directing
Acoustic Condition
    clarity = clear
    reverberance = live
    envelopment = expansive
    intimacy = remote
    loudness = loud

design intention:
If one can hear the sound of the main event on the soccer field from the entrance area, it will increase the spatial acoustic richness of the park as well as the

excitement of the people as they enter the park. In order to achieve this acoustic effect, a reflective material needs to be selected. In addition, if one considers this zone having various temporary events such as a traveling circus or a small scale amusement park with its large machines, I would recommend a very durable material. There is asphalt of varying porosities available on the market. Varying porosity also indicates varying acoustic conditions according to the material analysis. Selecting asphalt as a surface material for the event zones seems to be an ideal material from a functional and acoustical perspective.

event condition 3
_skateboarding parks = CONCRETE

Sound Control Language
    focusing/directing
    blocking
Acoustic Condition
    clarity = clear
    reverberance = live
    envelopment = expansive
    intimacy = remote
    loudness = loud

design intention:
The two most common materials used for skateboard parks are plywood and concrete. Concrete is selected for the following reasons - the large size, the complexity of the proposed shape, and the permanence and durability required for the skateboard park. Another important quality of this material is it's high sound property in blocking. This quality is necessary when there is another acoustically demanding event (it is ideal not to hear the sound of the skateboard from the soccer field during games) adjacent to the skateboard park. High reflective quality will also help direct the consistent and loud skateboarding sound toward the masking buffer zone (condition3).

Buffer Zone
condition 2

Non-programmed area = GRASS in undulated waveform

Sound Control Language

    absorbing
Acoustic Condition
    clarity= muddy
    reverberance= dead
    envelopment= constricted
    intimacy= intimate
    loudness= quiet

design intention:
Large size of this zone requires a passive absorptive measure. The most common material in the park, and a material also indicating a high absorptive rate according to the sound level-mapping diagram is grass. Furthermore, if a grass field needs to perform as an over-scaled acoustic panel, the square area of the field needs to be increased. The design of the undulating waveform is instigated from the purpose of increasing the absorptive grass surface area in order to multiply the level of absorption of the buffer zone.

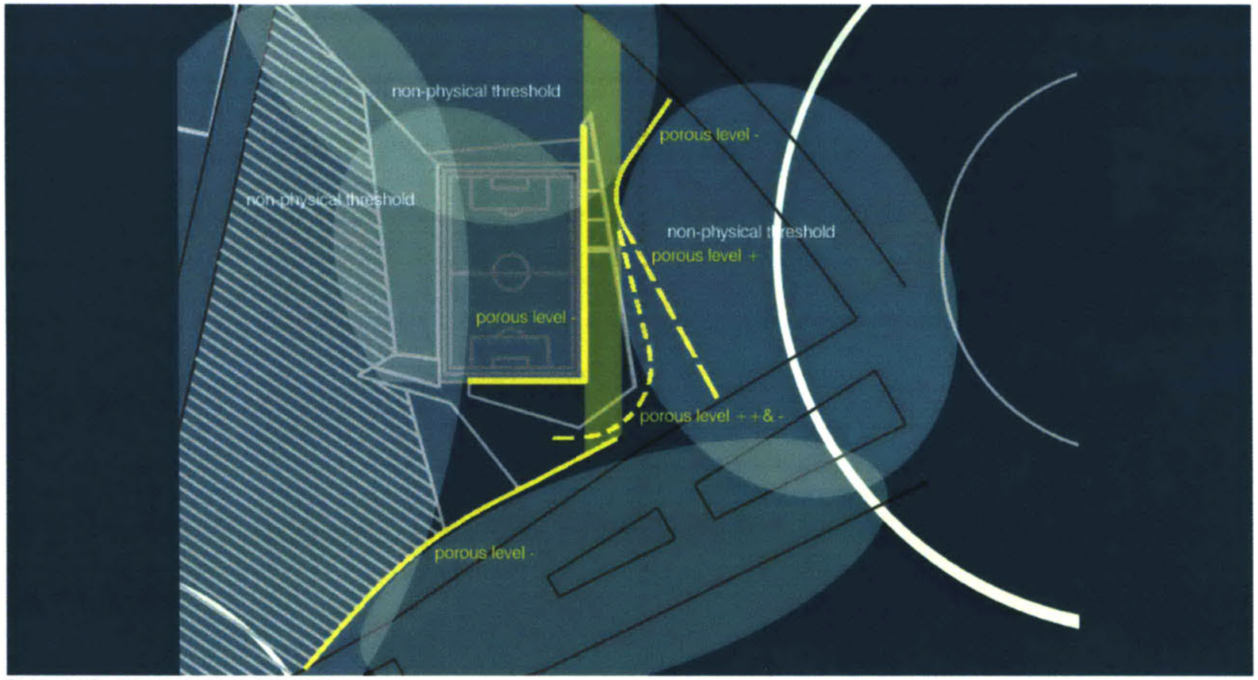
condition 3
Buffer Zone

Non-Programmed Zone = pampas grass (type of grass growing in the lower half of the Flushing Meadows Park near the two ponds)
(Cortaderia selloana) grass with showy white panicles borne on tall stems

Sound control Language
    masking
Acoustic condition
    clarity= muddy
    reverberance= dead
    envelopment= constricted
    intimacy= intimate
    loudness= quiet

design intention:
Small size of this zone compared to condition 2 buffer zone, and the soccer field's close proximity to the high environmental sound source (location E) requires a more active sound absorptive measure. Masking is a more active sound separation method by adding another sound to cancel original sound condition. In order to have an effective masking condition, one will need to introduce a new sound source in the

close proximity and the height of a person. The pampas grass growing wildly in the lower half of the Flushing Meadows Park has the potential to satisfy those requirements by taking advantage of the height of it's stems and it's movement in the wind causing a rustling sound. Furthermore, numerous walkways and platforms placed between the fields of pampas grass will allow for circulation and areas for smaller events requiring some intimacy (and not in an open field, such as reading, family picnic or a small wedding ceremony).



[5.3.2 a] diagram showing the threshold design

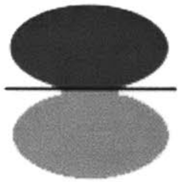
5.3.2 [M_scale Area Proposal]

Medium-scale plan looks closely, to the spatial acoustic experience of the area where programs are most concentrated. Compared to the previous proposal (0.04 exploration models), addition of sound sources (event condition zone 2 and 3) results in an increasing sound level of the area and complexity of spatial experience in the park.

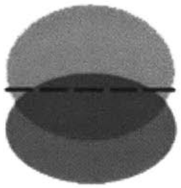
Placing thresholds

Each zone has different acoustic spatial experience because they each have varying sound source, surface material and different landscape and architectural interventions that manipulate sound. In the case of the soccer audience on the bench, if the audiences are loud (high sound level), and there is low sound absorptive ground surface material (non-porous asphalt) and there are also architectural interventions that direct the sound (steel soccer benches), this sound source can travel a great distance. There is a possibility that the sound reflected from those soccer benches can travel to the northern tip of the site by the entrance area. On the other hand, if there are high sound levels produced by the skateboarders, the sound can be stopped from traveling to the soccer field by placing two architectural interventions between the two sound sources to block the sound from traveling. As in these examples, the spatial acoustic experience in the design can be intensified further with architectural and landscape design interventions. In order to explain the acoustic effects each intervention is performing, the diagram explains each intervention in terms of thresholds. Thresholds are the place or point of entering or beginning another zone. They are placed between two sound zones and drawn as a solid or dotted line. The line quality shows the porosity of the threshold. The porosity of the threshold is determined by the character of the two sound zones it resides between. Depending on the programmatic requirement for each program to function properly the threshold character changes. When the end boundary condition is less defined and sound is overlapping from one zone to another, the threshold is drawn in a dotted line expressing the porous quality of the threshold. One the other hand, where a clear sound separation of the two zones is necessary, the threshold is drawn in a solid line expressing the less porous quality of the threshold. In addition, in the case of the east and south sides of the soccer field, the lines of the thresholds are increased by 3, as oppose to the minimum of 1 line. This is a case where multiple layers of thresholds or filtering layers were necessary in order to have the sound from one zone travel to the other. In the design intention, it is also intended to create

multiple spaces in between the 3 thresholds to differentiate the sound quality of one zone from the others. Keeping in mind that each threshold plays a large role in manipulating sound, a person walking through this part of the park will walk through multiple thresholds and experience varying acoustical spatial experience.
The choreography of various sound manipulative elements/zones through the thresholds intends to create a sequence of acoustically rich spatial experience to the person walking through the site.



[5.3.2 b]
diagram showing the condition of low threshold porosity



[5.3.2 c]
diagram showing the condition of high threshold porosity

Porosity definition

1 a: possessing or full of pores
b: containing vessels <hardwood is porous>

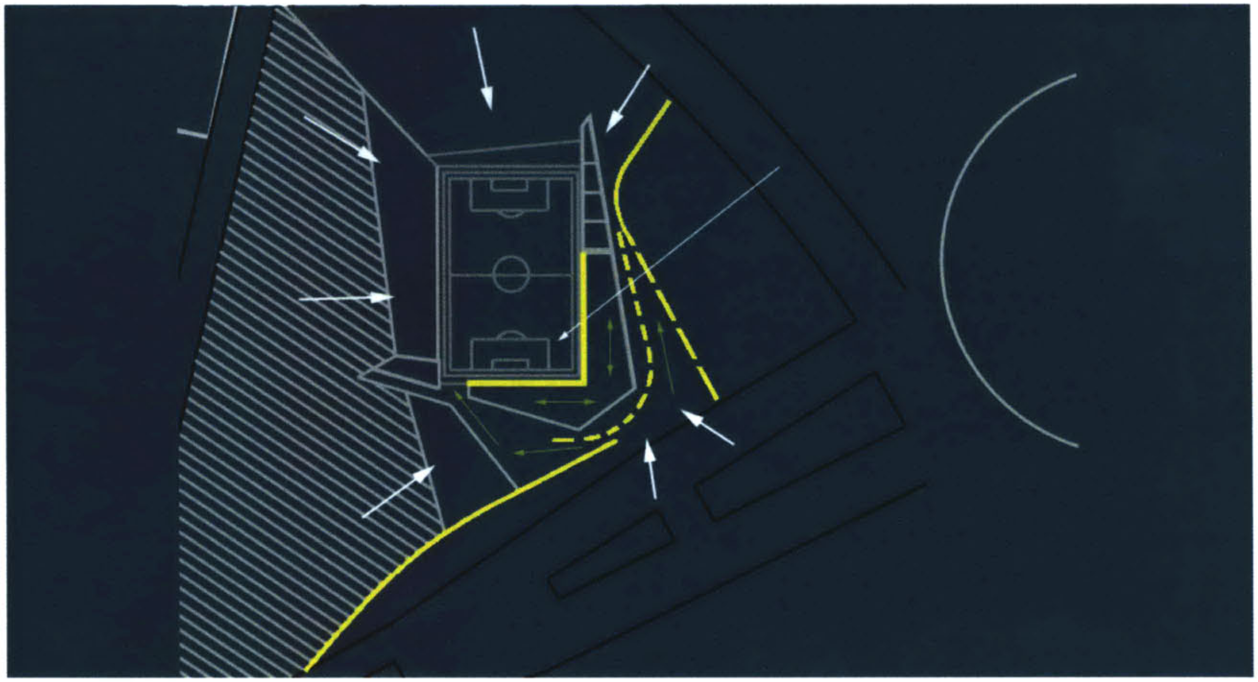
2 a: permeable to fluids
b: permeable to outside influences

3 : capable of being penetrated

In Acoustic terms:

Porous level +
Higher porosity in material enable sound to penetrate through material. In some cases, this result in the material to absorb the projected sound there by it dampens sound.

Porous level -
Lower porosity in material does not enable sound to penetrate through the material. Therefore resulting in a blocking or reflecting/directing sound effect.



[5.3.2 d] diagram showing circulation pattern

Circulation pattern formed from thresholds

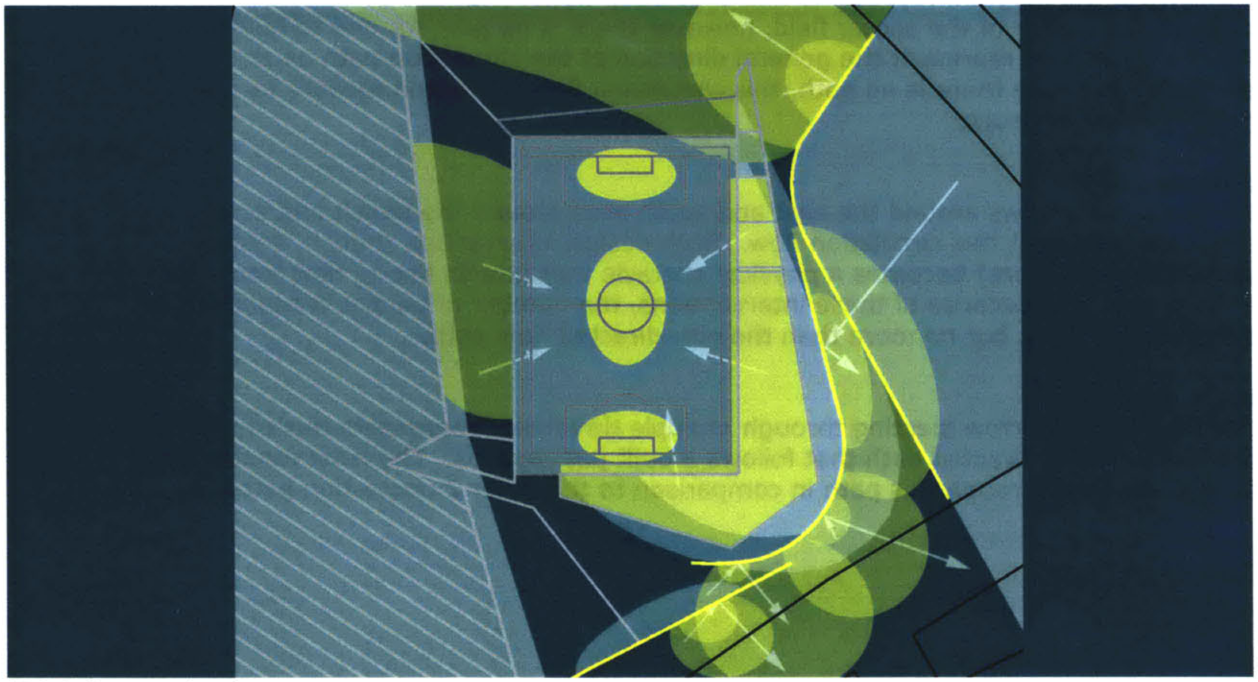
As a result of creating several thresholds, it made sense for the circulation patterns to follow those threshold patterns. Three types of circulation patterns generated from the threshold patterns can create a sequence of acoustically rich spatial experience to the person walking through the site.

3+ circulation patterns

non-directed flow
7 arrows in the diagram represents this circulation flow. They are all directed towards the center of the soccer field, however there is no path for one to follow. The 7 arrows only represent the general direction of the circulation path as an example. Because there is no path, this circulation flow can accommodate for the most number of people.

directed flow
The 3 narrow arrows around the east and south area around the bench and screen structure represent this circulation flow. Each design intervention (bench, screen, skateboard structure) becomes a physical obstacle that directs one to flow from one area to another. Because of these interventions, the number of people in transition of this path can vary, but no more than the non-directed flow path.

piercing path
The long narrow arrow piercing through multiple thresholds represents this circulation flow. It is a directed path that follows a built passageway. The least number of people can flow through this path in comparison to the other 2 circulation patterns.



[5.3.3 a] zoomed in diagram showing acoustic zones created by design intention

[S_scale Spatial Design]

Smaller scale plan further articulates the acoustic experience from the person's scale where the site contains the most complex spatial acoustic experience.

From the human scale, the changes in sound intensity and reflective behavior of sound predominantly constructs the acoustic spatial experience. Therefore, it's important to understand the effect on the site with multiple direction and intensity of sound sources.

The following diagram demonstrates the concept of scale and how sound can be transported from distant location and create a spatial experience foreign from the immediate surrounding.

Acoustic zones created by design intention

Smaller scale plan further articulates the acoustic experience from the person's scale where the site contains the most complex spatial acoustic experience.

From the human scale, the changes in sound intensity and reflective behavior of sound predominantly construct the acoustic spatial experience. Therefore, it's important to understand the effect on the site with multiple directions and varying intensity of sound sources.

The following diagram demonstrates the concept of scale and how sound can be transported from distant location and create a spatial experience foreign to the immediate surrounding.

yellow zone = area of sound intensification

location of sound source

location where sound from another location is reflected or transported, and resulting for one to experience a sound intensification or foreign sound experience to the immediate surrounding.

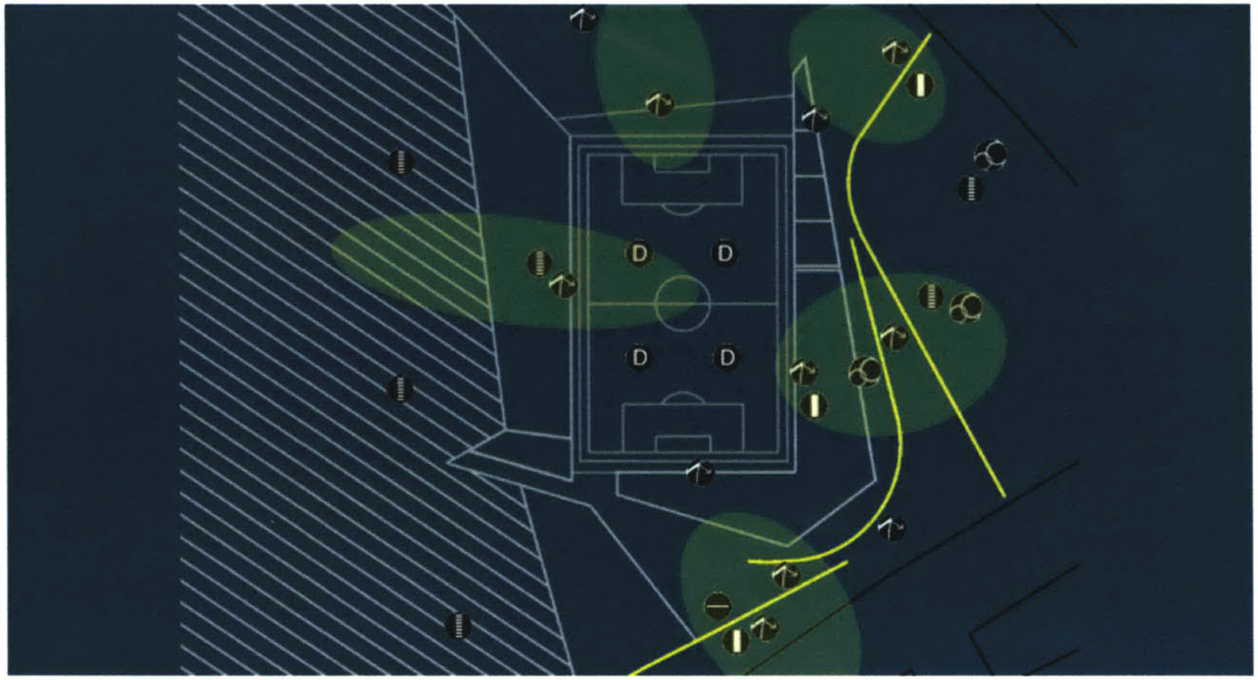
light green zone = area of sound moderation

location where sound is dampened by the surface material absorbing the surrounding sound.

location where one will experience sound being dampened by creating another sound to mask the original sound.

area where sound is decreased from traveling a long distance

overlapping zone = area where sound level is decreased by either the absorbing or masking effect of the design intervention.

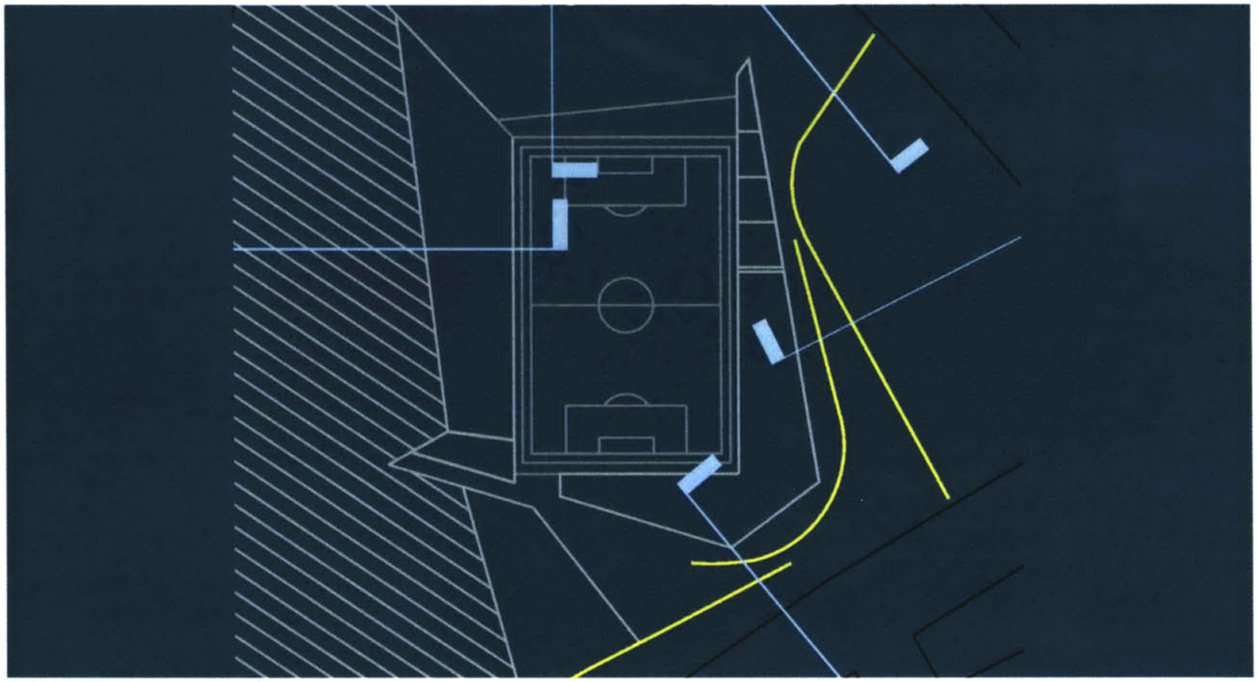


[5.3.3 b] diagram showing the acoustic condition from the previous diagram translated into sound icons

Translation into sound control icons

As one way to further analyze the condition of the previous diagram, I placed a sound control language icon to indicate the sound behavior of each zone. This diagram adds another layer to the depth of understanding the acoustic spatial experience at each location.

Light green zone = This is an area where there is a concentration of different sound control icons. It indicates the zone where it is the most complex, rich and interesting conditions of acoustic space created by the various sound manipulative methods applied to the site.



[5.3.3 c] diagram showing the location of section cuts

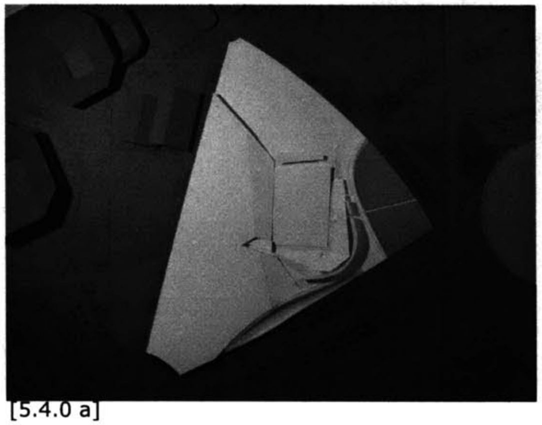
Location of section cuts

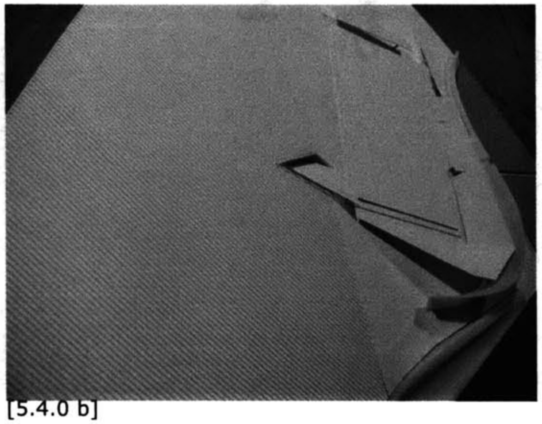
To further understand the acoustic condition, the light green zones highlighted in the previous diagram are studied in sections.

[5.3.3 d] section showing sound behaviors in the design

5.4.0 Final model

material: stereolithography model, strathmore boards, gray color paper, base board.


[5.4.0 a]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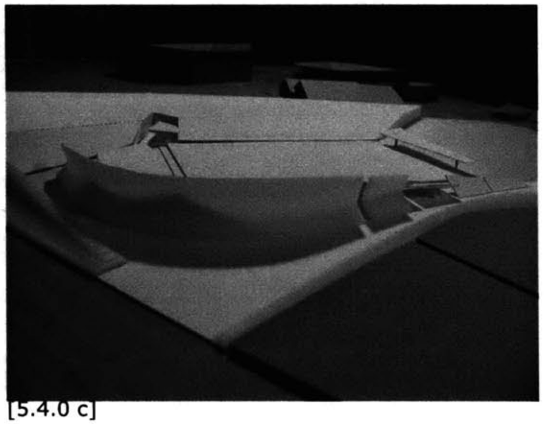
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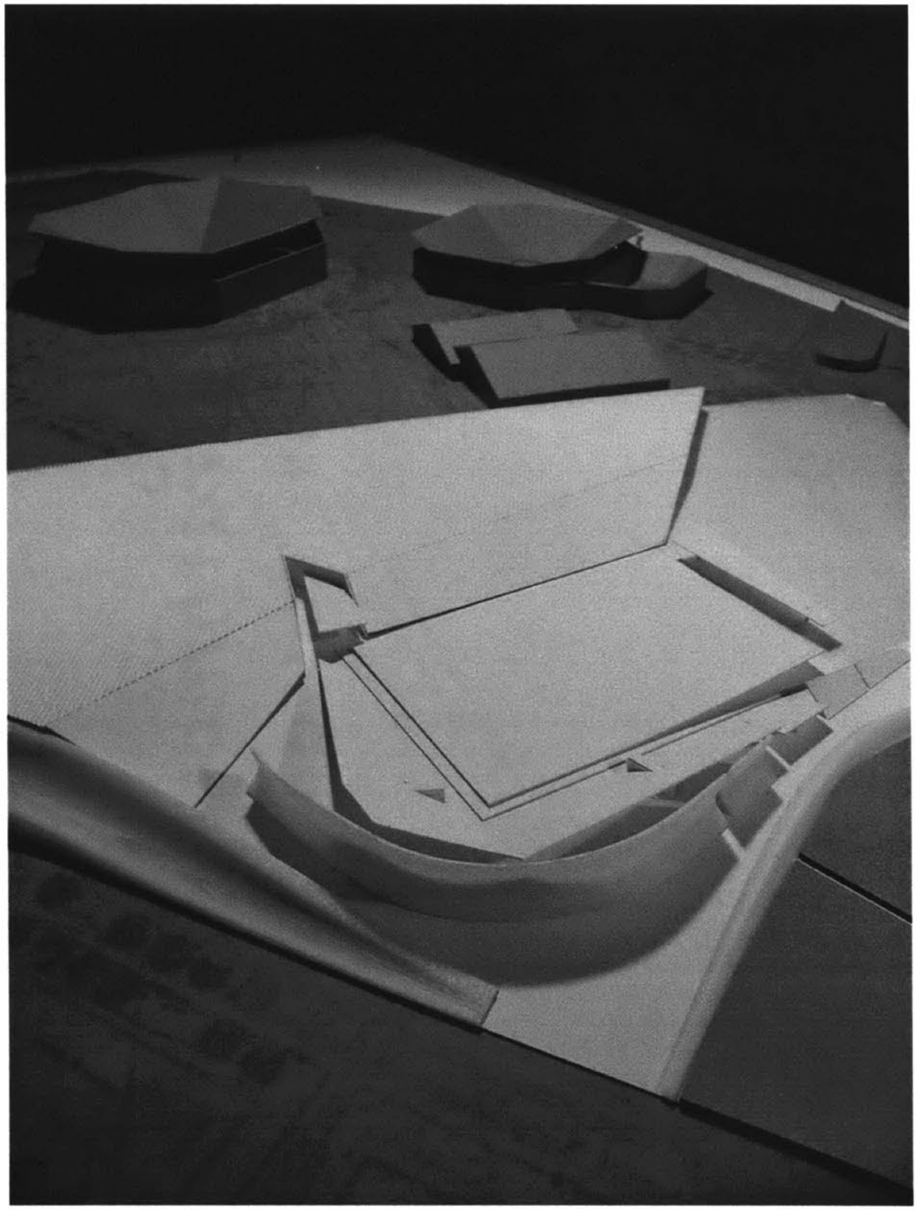
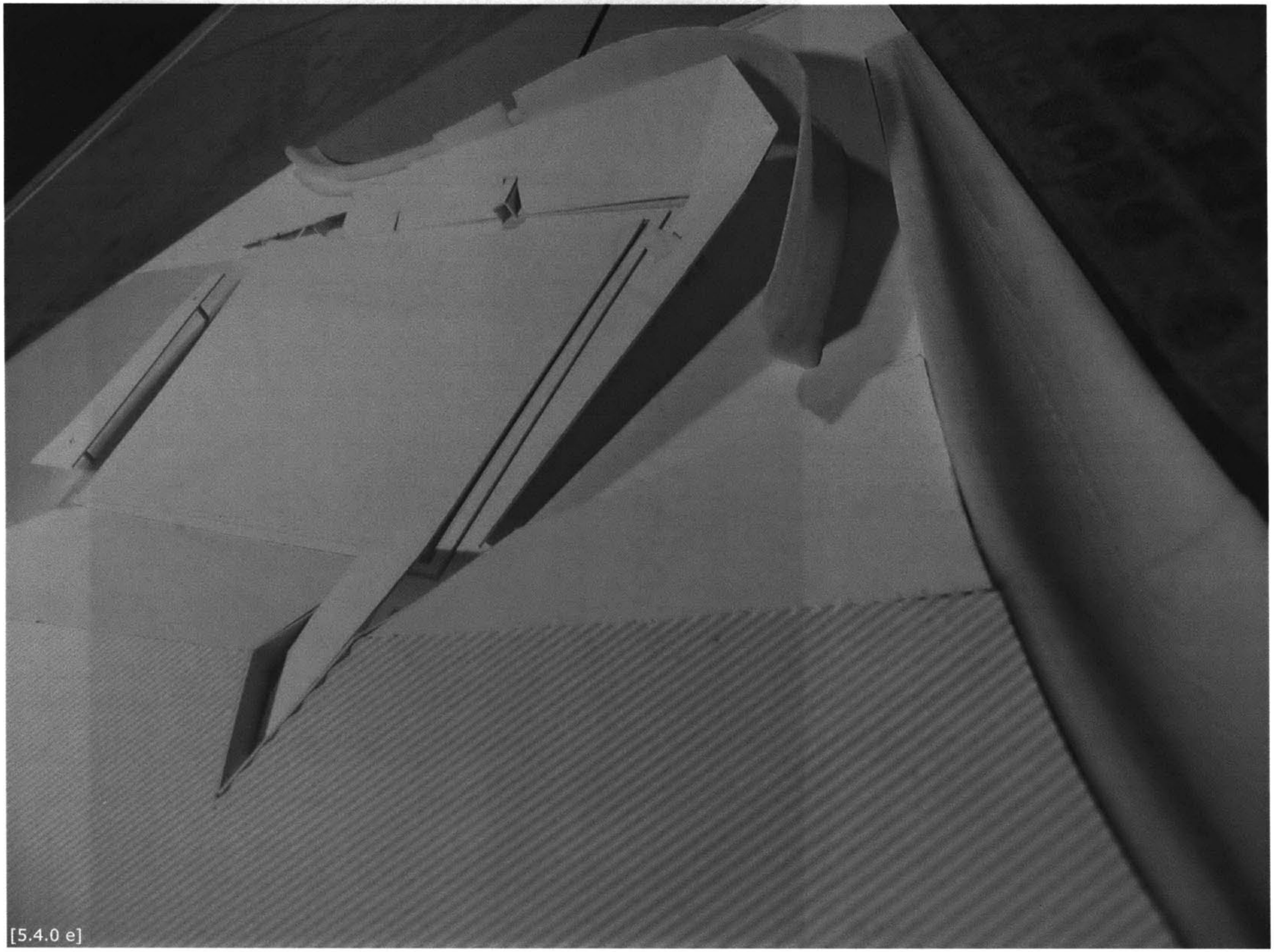
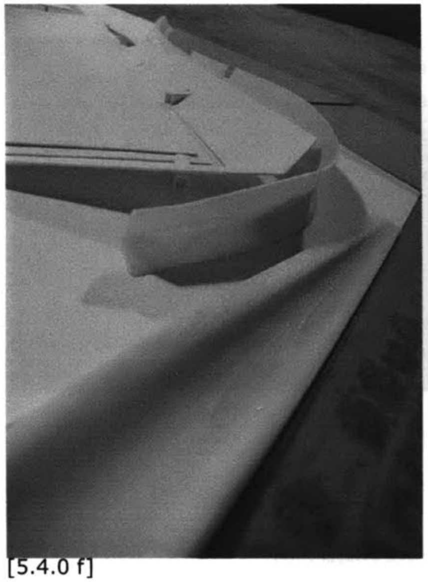


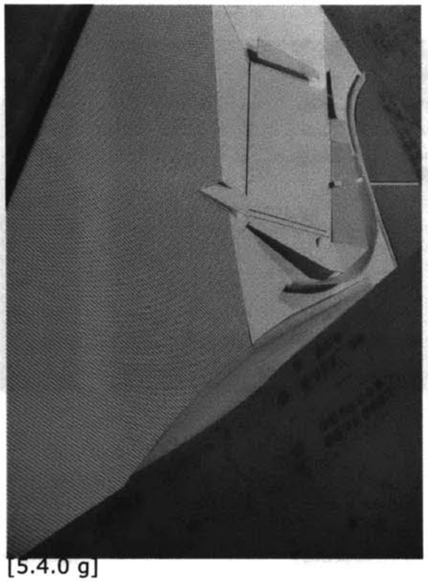
[5.4.0 d]



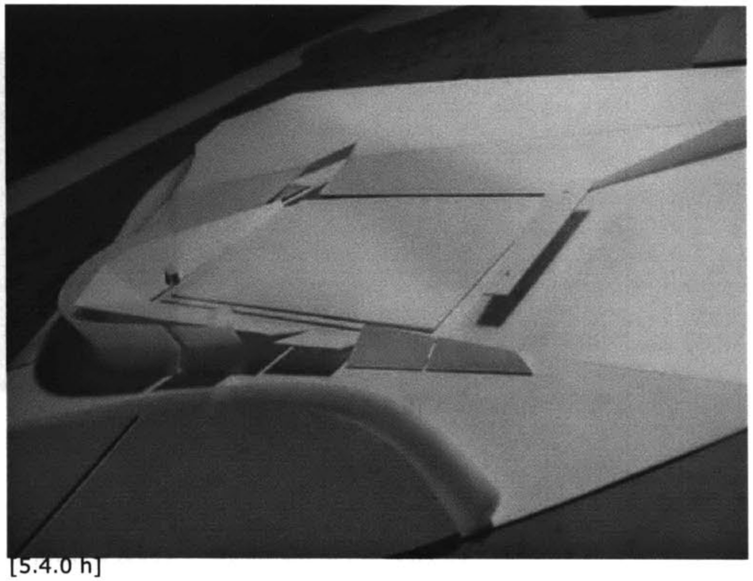
[5.4.0 e]



[5.4.0 f]



[5.4.0 g]



[5.4.0 h]

5.5.0 Final sound animation

The final presentation of the design was presented as a movie. Computer animation combined with samples of sound recording from the Flushing meadows Park tries to demonstrate the sequence of acoustic thresholds one will experience.

sound movie 1
sound movie 2
sound movie 3

sound movie 1

[5.5.1 a] to [5.5.1 o]

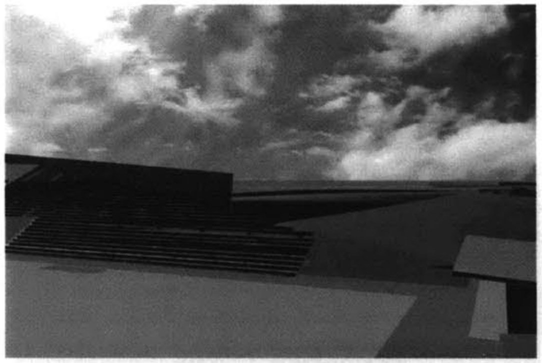
sound effect in the movie sound = pampas grass [masking]

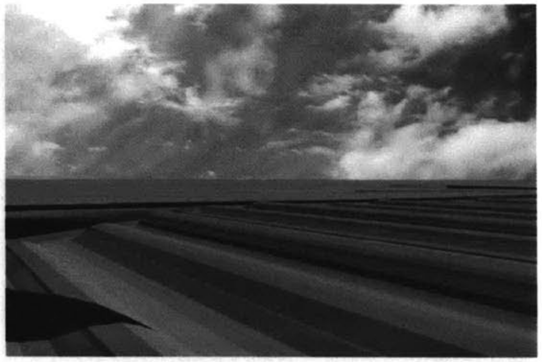
sound = gravel [masking]

sound = water [masking]

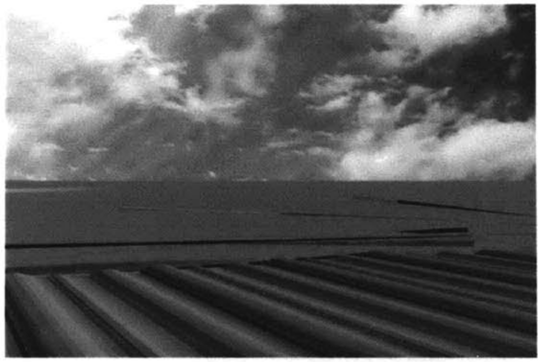
sound = soccer audience (event)

sound = soccer players (event)



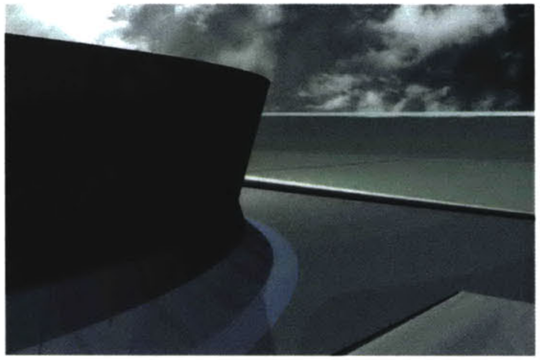


sound = grass [absorbing]

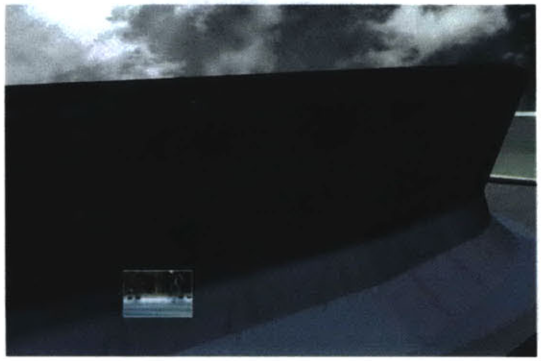


sound movie 2

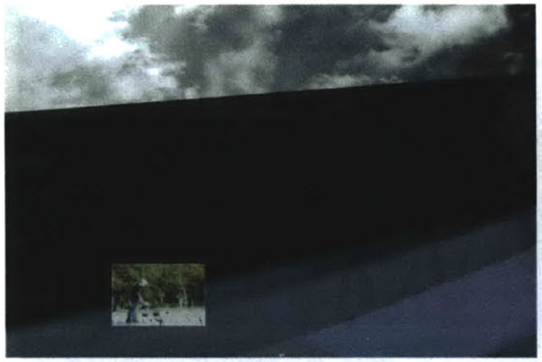
[5.5.2 a] to [5.5.2 n]

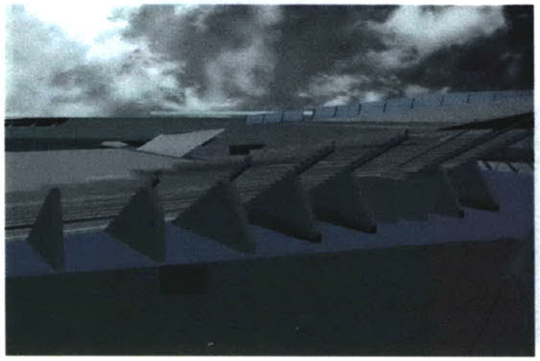


sound effect in the movie



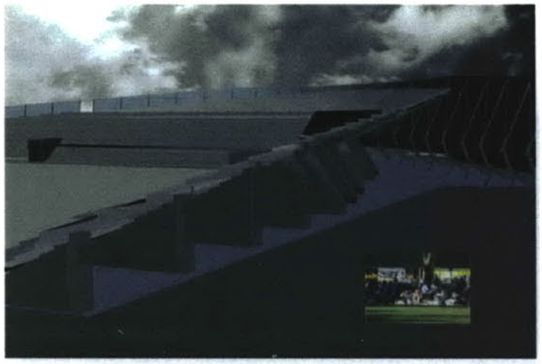
sound = skate board (event)





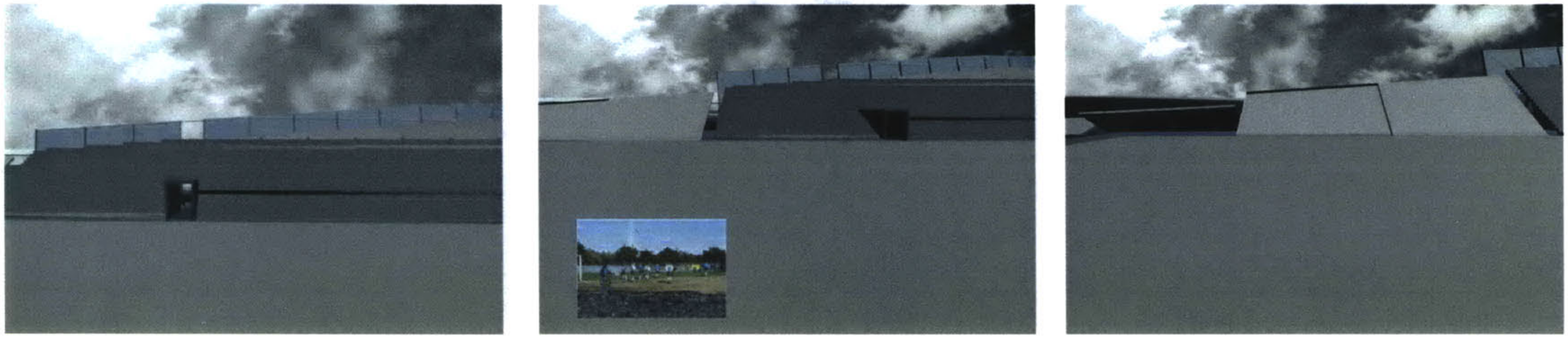
sound = vendors (event)

sound = picnics (event)



sound = vendors (event)

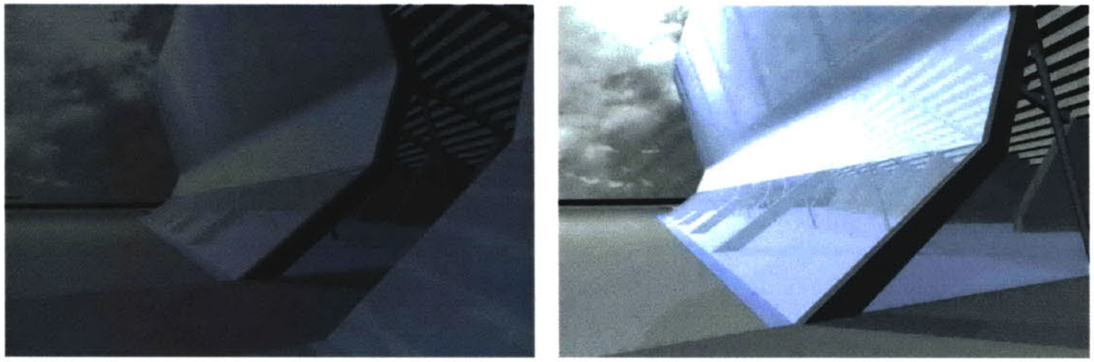
sound =soccer audience (event)



sound = soccer players (event)

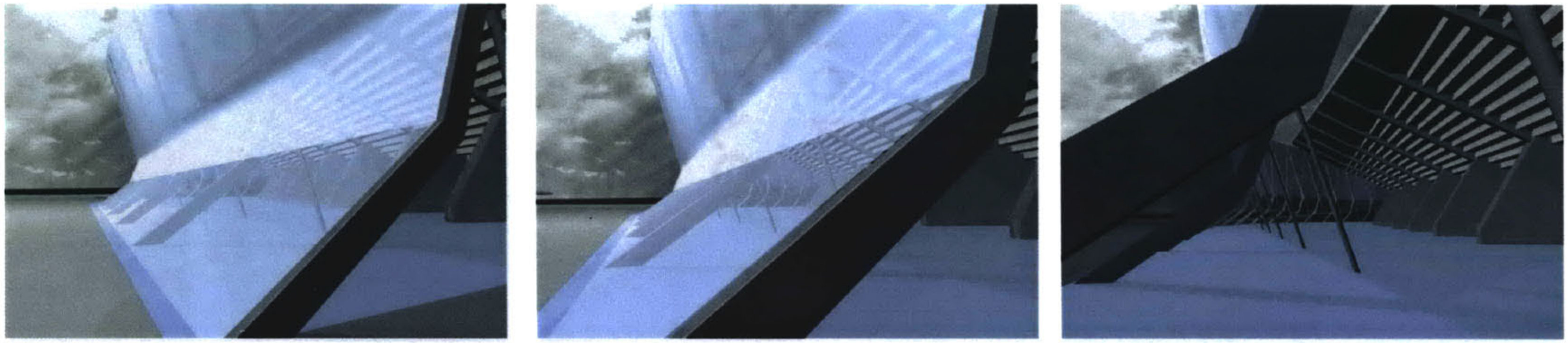
sound movie 3

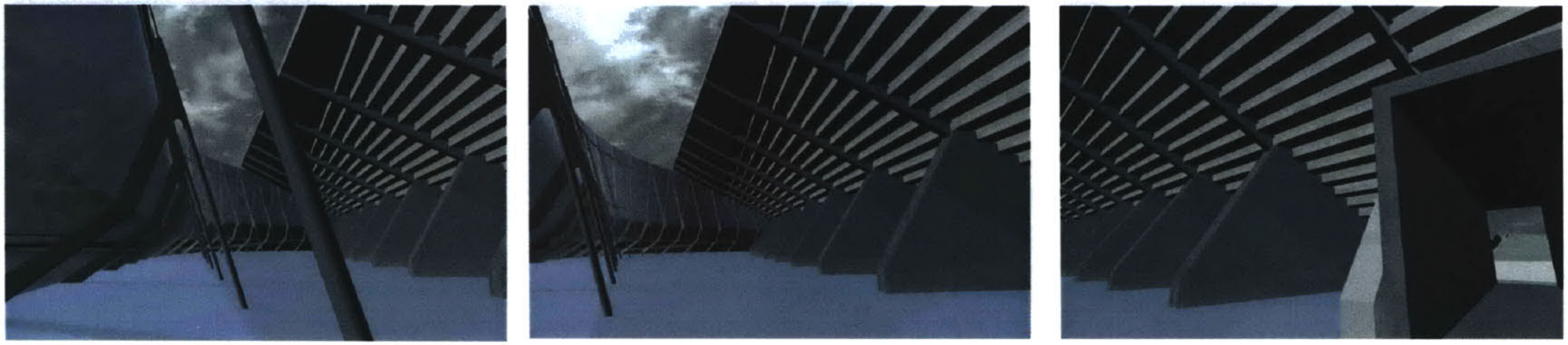
sound = water [masking]



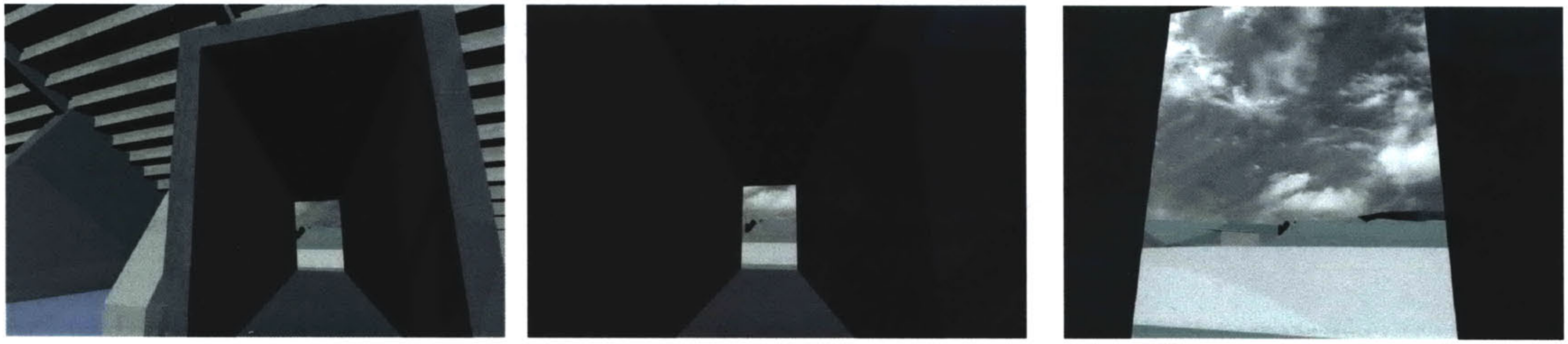
[5.5.3 a] to [5.5.3 k]

sound effect in the movie





sound = soccer players (event)



5.6.0 Participant's comments

Fri, 11 Jan 2002

comments on thesis:

The exploration of sound as a parameter driving the design process is a challenge. Sound in architectural design rarely plays an important role outside concert halls and auditoriums. It is being considered but is much less prominent then conditions that directly shape the visual appearance of architectural space like light. If this is true for architecture it is even more so at the scale of landscape design. The thesis makes a proposal for a design spanning the architectural and landscape scale guided by the study of sound conditions as a basis for its design.

It is very successful at demonstrating an alternative design approach based on sound analysis and at developing building blocks for shaping the acoustic environment both at the architectural and the landscape scale. The thesis leaves many questions unanswered and does not fully resolve the treatment of the created spaces at the scale of architectural details and the specific design of border conditions of the chosen plot of land. But its rigorous and consistant development taking into account a variety of information sources both collected on site and drawn from previous work makes it a valuable addition to the study of architecture related to the acoustic environment.

Axel Kilian
Ph D Scholar, MIT

Wed, 9 Jan 2002

Dear Junko,

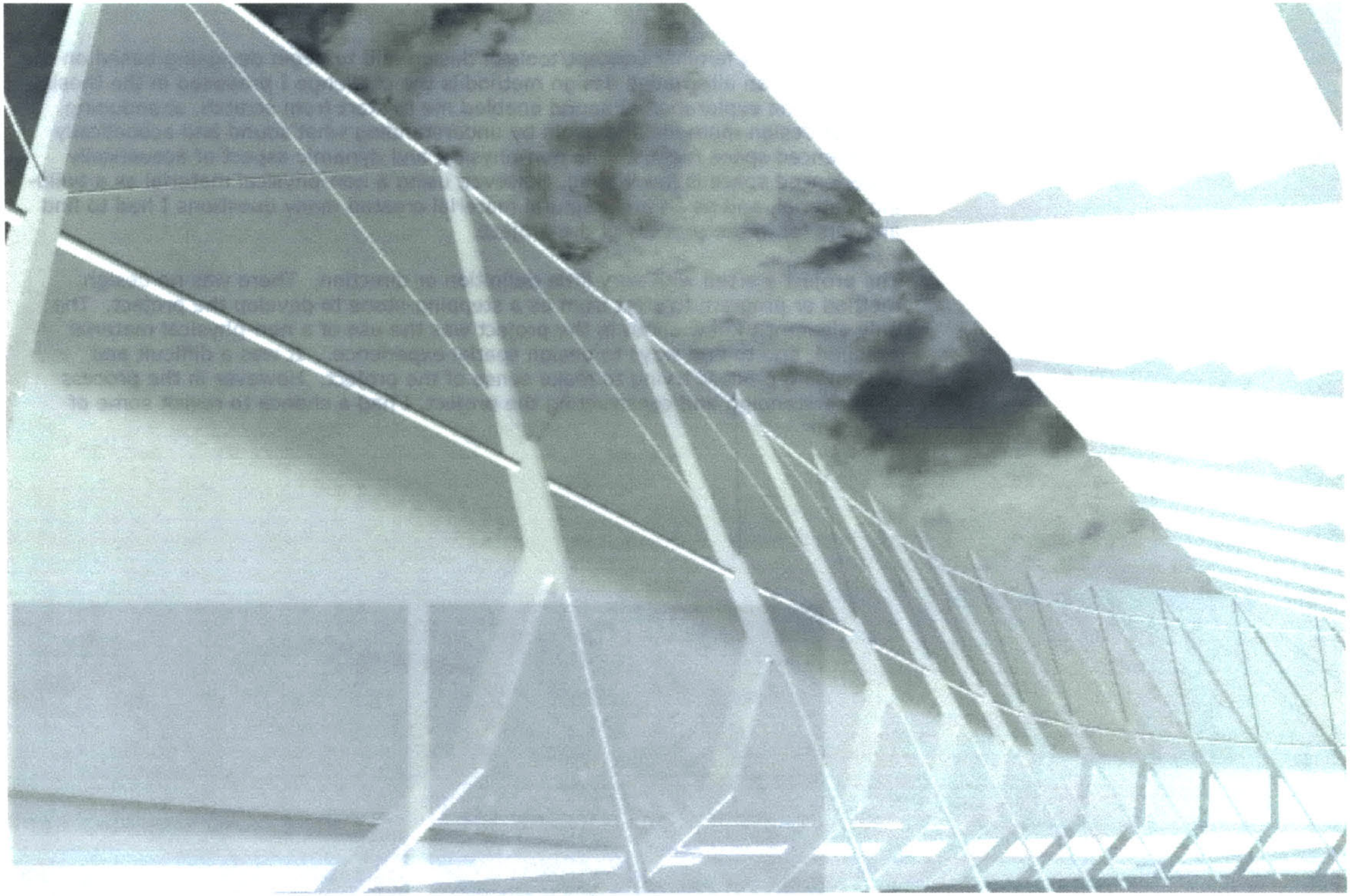
I think it is noteworthy that you started the project by physically and acoustically mapping the site, using a sound level meter. By measuring sound levels at various locations (a lot of measurements over a long time), you gained first hand knowledge and calibration of the range of levels and the role of the topography.

I also found you created your own visual vocabulary for representations of sound levels and acoustic qualities. This is a challenge for those of us like myself who wrestle with how to communicate aural parameters by visual means. The results were clever and captivating, and certainly show an effective learning mechanism for design.

In the development of the thesis, you researched and developed acoustical performance of materials (absorption, reflection, transmission) into large scale physical tools. The actual final design integrates the acoustical goals of your design to shape the aural landscape with an engaging visual and formal sequence.

Carl Rosenberg
Lecturer at MIT, acoustic consultant

6.0.0 conclusion

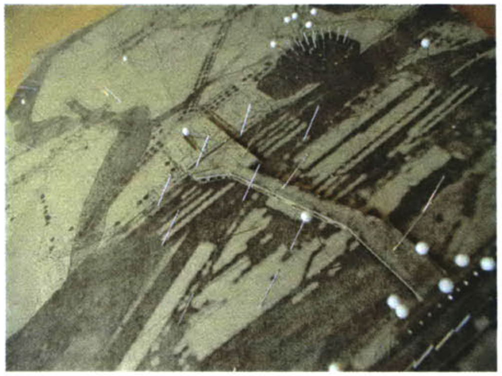


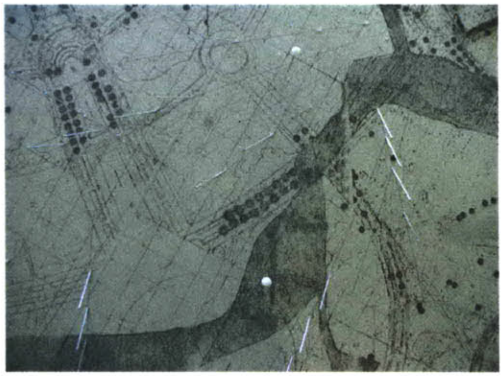
[6.0.0 a] perspective view of the in-between space

thoughts

To abandon the familiar concept/tools of design and to begin designing based on the discovery of an alternative design method is the challenge I proposed in the thesis project. The exploration of sound enabled me to start from scratch, abandoning familiar design methods and begin by understanding what sound and acoustically experienced space means. The non-physical and dynamic aspect of acoustically experienced space is fascinating. However, using a non-physical material as a building material, and as an architectural material created many questions I had to find answers for in the process of the project.

The project started with very little definition or direction. There was no design method or program to start from as a stepping-stone to develop the project. The only element I knew about in the project was the use of a non-physical material = sound, and to find ways to design spatial experience. It was a difficult and challenging process trying to make sense of the project. However in the process of understanding and constructing the project, I had a chance to revisit some of


[6.0.0 b] needle model


[6.0.0 c] needle model

the foundational concept and methods in my design. Questioning and challenging my own knowledge proves to be one of the most valuable lessons I learned from this thesis project.

Besides the many things I learned about my own design process, I would like to share some thoughts and my experience on what I learned from designing through sound.

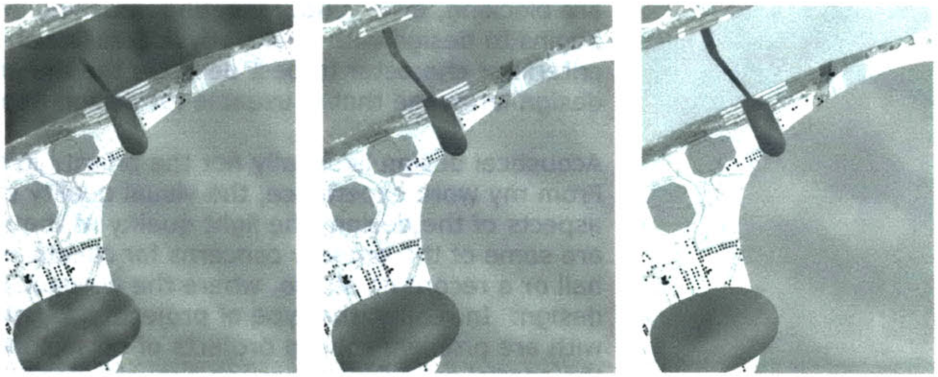
The following are some the issues I would like to address.

a) What did I learn about designing with sound?
What are some of the method in representing sound or other non-physical material?

b) How could this work influence the general design practice?

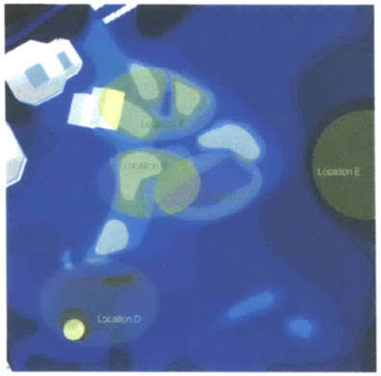
c) Why is designing with sound relevant and what are the benefits by including sound in one's design language?

[6.0.0 d] mylar model



[6.0.0 e] to [6.0.0 g] flash animation models

[6.0.0 h] previous sound diagram causing confusion to the advisors



[6.0.0 i] simplified and refiend sound diagram

One of the first elements in designing with sound that I began experimenting with was how to represent a non-physical material. How does one begin to visualize what is not visual? After learning how sound behaves in space, I tried to use non-conventional ways of demonstrating the character of sound. First I made two physical models using needles, piano-wires and mylar on site maps to demonstrate the direction, height, movement, density, intensity and zones of sound. I felt that the time aspect of sound was missing in the first two models, so I created a diagram of sound through digital animation. None of the representation proved successful mainly for the reason of the designs subjective point of view of the site. The reviewers looked for objective data of sound from the existing site from which I could learn and develop a design method. This comment lead me back to the site where I measured the decibel level using a Decibel level to eventually create a sound level map. This digital model became an important source of information I based the initial design process. The diagram I created from the raw decibel numbers of the site was a very simple step model of sound levels, using color tone variation. Many of the later sound diagrams followed this model using the simplest shapes with few color tone variation. These simple and somewhat familiar diagrams were more successful in communicating the essential information of the sound character. After creating the 3 dimensional sound level map, I find that this simple step model is able to give me more information than I had imagines on the existing sound condition of the site. It seems that the purpose of the representation is not to accurately depict the sound behavior, but to give an idea of the essential character and of the acoustic spatial experience, such as location, size of the zone, direction, intensity and boundary condition. In addition, as the project proceeded, I described the sound quality of the space by developing a sound control language in five basic words. They are blocking, absorbing, reflecting, masking and canceling. As in this example, if one begins to design with a non-physical material, it is important to find the essential criteria or character to best describe the material. Only then can one develop a design language that is usuable for design analysis.

Acoustical design is usually not the priority in the architectural design process. From my work experience, the visual quality of spaces, functional and programmatic aspects of the design, the light quality of the space and the cost effect of the design are some of the primary concerns for clients and designers. An exception is a concert hall or a recording studio, where the acoustic control is the primary function of the design. In reality, the type of projects acoustic consultants spend most of their time with are problem solving projects of noise control, rather than projects improving the spatial experience through acoustic design. However, one will be surprised how great of a role acoustics play in an individual's spatial experience. In some of the greatest architectural spaces I have experienced, they have perfected the relationship between the acoustic quality of the space, visual quality and functional aspect of the design. The most commonly used acoustic quality of the space is silence. If I take the MIT chapel designed by Eero Saarinen as an example, the experience of a silent space from a noisy outside environment is noticeable. Furthermore, the cylindrical architectural form, the natural skylight highlighting the central stage and the silence naturally makes me concentrate on the central space, and create self-awareness with the surrounding space. In this space, I am relieved from all the information I am overwhelmed with walking outside or inside the school building. I can even hear my breathing, which I usually never hear. I am alone with myself and can think with ease. I also feel relaxed and peaceful in this space. From my experience, it seems that Saarinen's intention with the chapel design is to do just this, to relieve one from everything and to give one time with oneself, whether for religious reasons or for self contemplation.

Perhaps architects do not include acoustic design in their design language because they are not familiar enough with it to make a difference in the design. As an architectural student, I am not fully trained to understand the body of acoustic design knowledge. However, as I began learning more in depth about the acoustic design and working with Carl Rosenberg (lecturer at MIT, a practicing acoustic consultant), I realized I relied more on my intuitive understanding of sound behavior to apply to design. We experience acoustic space every day. If one has played instruments, like in my case, one is even more conscious of sound behavior. Our spatial consciousness is sharper than one thinks.

Therefore, I don't see the necessity to understand all the technical aspects of acoustic design, but start from the intuition, and place the sound effect of space in the design process together with visual quality and programmatic organization. For example, if one wants a quiet room (low sound level), then the surface material needs to be more porous, soft with some mass rather than thin, hard and sound reflective material. People may not instantly see the effect like seeing an expensive stainless steel detail of a glass curtain wall, but users of the space will react to the space consciously or unconsciously. If there are acoustic problems, people will complain and hire acoustic consultants for modification. Beyond the minimum acoustic requirement, there is also the possibility of adding richness to the spatial experience. Although I realize it is a different kind of context from the thesis design proposal, I was consistently reminded of an acoustic spatial experience I had in a small side alley in Italy during my travels. An empty uninteresting alley was suddenly activated and given warmth by the sound of a person singing and another

[6.0.0 j] Eero Saarinen's MIT chapel

person's cooking from the apartment upstairs. I suddenly realized the connection of myself with the other person through sound filling the space. I did not see or meet the person making those sound, but I felt that I had experienced a piece of the culture and the humanistic quality of the town through those alleys that made my experience very rich and meaningful. Trying to understand the spatial experience through sound was my way to re-evaluate my knowledge of spatial design and discover another way to experience space.

Title icon.

When I was stuck with a drawing, my drawing teacher often told me to rotate the drawing 180 degrees. Ground becomes sky, background becomes foreground and negative becomes positive. The familiar drawing is transformed into an unfamiliar drawing. Perhaps this unfamiliar drawing embodies new possibilities I didn't witness before. Like the simple trick used in a drawing class, I always prefer to search for different ways to approach a site.

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8.0.0 Image credits

Unless otherwise noted all other illustration is by author.

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[2.1.1 b]	Ibid
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[2.1.2 c]	Japan Honda Motor Co., Inc., *Accord Wagon*
[2.1.2 d]	Ibid
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[2.1.2 k]	Ibid
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website

http://architecture.mit.edu/~junko

Software

Microsoft Word 2000
AutoCAD 2000
Rhinoceros® 3D Modeling/CAD Application
3D Studio Max 4.0
QuickSlice V6.0
Adobe Photoshop 6.0
Adobe In Design 1.5
Adobe Acrobat Reader 5.0
Apple computer iMovie 2.0.3
Adobe Premiere 6.0
Macromedia Dreamweaver 4
Macromedia Flash 5
Quicktime Player