Student

Casey Hanauer

Mentor

Tahar Messadi

Sibelius by Kimmo Lintula and Hannu Tikka in Lahti, Finland

National Forum of Music by APA Kuryłowicz & Associates in Wrocław, Poland

Musikhuset by C.F. Møller Architects in Aarhus, Denmark

National Sawdust by Bureau V in New York City, New York

University of Arkansas, Fay Jones School of Architecture + Design, Architecture

Casey Hanauer is an Honors College Fellow, fifth year architecture student, sustainability minor, and oboist at the University of Arkansas, Fayetteville. As a child, she dreamed of designing beautiful buildings that would create a permanent and positive impact on the world. In middle school, she joined concert band as an oboist, eventually becoming one of the top five high school oboists in the state of Tennessee and was accepted on full scholarship to the Governor's School of the Arts and 83% scholarship to Sewanee International Music Festival. While in college, she pointed her sustainability minor towards an emphasis on sociology and became acutely aware of the world's inequities. She won a Student Undergraduate Research Grant for her proposal to study gentrification on Jefferson Street, a historically black neighborhood in Nashville, Tennessee. This then gave her the opportunity to travel to Nashville and conduct on-the-ground research and an emotional interview, which is where she learned how important music had been to Jefferson Street and how gentrification led to displacement and the near loss of a

great musical history. Through this experience, she uncovered a passion for designing buildings that act as musical community beacons that aim to reincarnate lost or declining forms of music while socially and economically supporting existing communities. She intends to graduate in the Spring of 2025 and attend graduate school to focus on acoustics so that one day she can accomplish her goal of becoming a world-renowned concert hall designer.

Subjective Acoustics: The Building as an Instrument for Sound

A musician rarely sees his or her audience when standing on a strongly lit, concert-ready stage. Although the musician looks into the auditorium to see only pitch black articulated by exit lights, the musician must forge an emotional connection with each member of his or her audience. The audience has a much better view; they can see the lit stage, often designed to illicit an emotional response and showcase the musician who has been practicing for a lifetime to stand on this stage and perform. If the audience sits on the balcony, they cannot read the musician's face; they only see the outlines of each feature. Yet the audience attends the concert to connect with the musician and be entranced or entertained by the practiced music.

As the musician, I have some hints that the audience sits in the vast darkness. The hot temperature of the room from the number of bodies keeps my limbs warm as I press keys on my instrument. The high humidity from the collective breath protects the wood bore of my oboe from cracking. And the soft echo of coughs off the walls and ceilings of which, if I am really paying attention, I can tell where each grumble came from by how loud it was. The most important way I connect with the audience is through my sound.

When that audience and the performer leave the room, the space becomes an idle instrument that an architect or acoustician molded to precise measurements based off computer analysis and algorithms. These designers shape the building's materials, geometries, and acoustic mechanics to highlight sound qualities of brilliance, clarity, intimacy, liveliness, spaciousness, and warmth. These qualities are

not solely to the benefit of the audience. For the musician to connect with the audience, he or she must be able to play the space like an extension of his or her instrument. It is not until the musician performs on the stage that these qualities of the hall are exposed to the audience. The musician has already crafted his or her playing to the properties of the hall to create a strong sense of intimacy.[1]

Through this research I aim to address the subjective experience of a musician on stage by analyzing through self-recordings the experience of performing on stage compared to the experience in the audience and further analyzing this in accordance with the objectives of acoustic design through materials, form, and geometries of four buildings with four different goals. I will order the analysis of these buildings by their infamy in technical acoustics as chosen by critical audiences. First, the Sibelius Hall (Sibeliustalo in Finnish) in Lahti, Finland is often ranked as among the best acoustics in the world.[2] The Musikhuset in Aarhus, Denmark balances low costs with outstanding acoustics. The National Forum of Music in Poland is nearly

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[1] David Griesinger, "Acoustic Quality, Proximity, and Localization in Concert Halls: The Role of Harmonic Phase Alignment," essay, in *Psychomusicology: Music, Mind, and Brain* , vol. 25 (Cambridge, Massachusetts: American Psychological Association, 2015), 339–44, http://dx.doi.org/10.1037/pmu0000116.

[2] "10 of the World's Best Concert Halls," The Guardian, March 5, 2015, https://www.theguardian.com/travel/2015/mar/05/10-worlds-best-concert-halls-berlin-boston-tokyo.

completely tunable from the ceiling to the walls to the stage, despite its large size. Finally, the National Sawdust is a small but incredible venue in Brooklyn, New York that services a wide range of music and styles. By the conclusion of each study, I will analyze how each building supports the musician's experience through geometries, materials, and sound.

Methodology

Marcello Oboe Concerto in D Minor

The Marcello oboe concerto is just over 10 minutes long and has 3 movements of varying tempos.

First Movement – Andante e spiccato

The first movement is played at a walking tempo with separated but not shortened notes. Many pauses in the piece allow the listener to hear how the ends of phrases interact with the space. Particularly, the G5 in measure 43 held out for four beats and one sixteenth will be a good way to listen to the brilliance of the space. The transition from the Gb/F#5 to D4 in measure 40 is a perfect spot to listen to the brilliance of the space since the D4 is below the C4 threshold and a more open note while the Gb/F#5 is a higher ranged note that requires more pressure on the oboe, leading to an open transition to the D4. The range of this movement is D4 to Bb5 placing the movement in the lower to middle range of the oboe. It is crucial to point out what I am listening for as I review the tapes ahead of the time because it explains how a musically trained brain naturally hears and listens for these changes and exposed sections to further analyze the acoustics of

the space. As a musician, I analyze the music and my own skills before entering a hall and can hear how each hall treats my consistently practiced piece differently.

Second Movement - Adagio

Movement two Adagio is played slowly and fluidly. In this movement, longer phrases connect notes across multiple bars. The notes are sequential and scalar with consistent and predictable. The range is from a G4 to a C6, placing the movement in the middle range of the oboe and entirely higher pitched than C4 (middle C).

Third Movement - Presto

The third movement is played at a faster tempo; typically, the faster the tempo, the more the notes get clipped. To avoid this and to play more accurately, I slowed the tempo down slightly while keeping the bouncier character of the notes. The range of this movement is E4 to C6 placing the movement in the lower to upper range of the oboe. Because of the speed of the piece, the notes are helpful in listening for liveliness, amplification, and delay in the spaces.

The Warmup- What to Listen for

Scales

I will start with a quick warmup of scales and long notes, crescendos and decrescendos. I will play for 15 minutes on each stage total. The warm up will consist of a chromatic scale, the attack of the clearest notes on oboe (F 698 Hz and D 587 Hz), and proportionately scaled crescendo and decrescendo on low F 370 Hz.

The Recorder Placement

One recorder will be placed behind the stage in the choir space. This placement is important to measure the clarity and amplification of the sound. From the choir seats, the performer faces away from the audience, and the sound extends out into the space in front of the performer, often creating issues with experiencing the same sound behind the stage.[3]

Fig. 1. one of the three H6 series Zoom audio recorders used to record the student playing, 2024.

Essential Characteristics of a Music Note

A note has three parts to the sound which become the tone. There is the overtone which is a higher tone not actually played by the musician but that can be heard because of the vibrations of the instrument. The fundamental or main tone of the sound is the pitch or frequency (in Hz) of the note being played; and the ring or the suspension is what the audience hears as the note ends.

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[3] 1. Robert Harris, "Advantages and Disadvantages of Surround-Type Concert Halls," *Acoustics* 1, no. 3 (July 22, 2019): 582–89, https://doi.org/10.3390/acoustics1030034.

A single note is split into three chronological parts. The attack is how the tongue and fingers work together to express the sound and can be sudden and aggressive or soft and hesitant. The center is determined mainly by how loud or quiet the musician plays the note. The tail is how the musician chooses to end the note with his or her air. There are four endings I discuss in the following analysis:

1. Staccato is an abrupt ending in which the tongue cuts off the sound completely.
2. No accent is a separated way of playing notes in which the tongue stops the sound about halfway in between each note.
3. Tenuto is also a way to separate notes, but the tongue stops the air at the very last second before the next note is played. The air never stops so that as the tongue releases from the reed, the next note is immediately started.
4. Legato is a connected way of playing in which the air does not stop, and the tongue does not move, allowing two notes to be abutted.

While the musician has much control over each of these qualities of the sound, the space can alter each part of the note for the audience, meaning that the musician must be able to hear how the space alters these qualities of sound.

This understanding of musical terms and features is critical to understanding my analysis and notes in the following four essays. Below, I include hyperlinks to anonymous Youtube links I have uploaded of myself playing in each of these halls. I have divided them into two

parts; the first is my phone recording on the stage, which is a close reference to my actual experience on stage. The second is a set of three recordings of myself playing the piece, all at the same time but compiled together into one video.

Catalogue of Recordings

On-Stage

National Forum of Music on Stage Recording

National Sawdust on Stage Recording

Sibelius on Stage Recording

Musikhuset on Stage Recording

Audience

Sibelius

National Forum of Music

Musikhuset

National Sawdust

Sibeliustalo: An Out of Body Experience

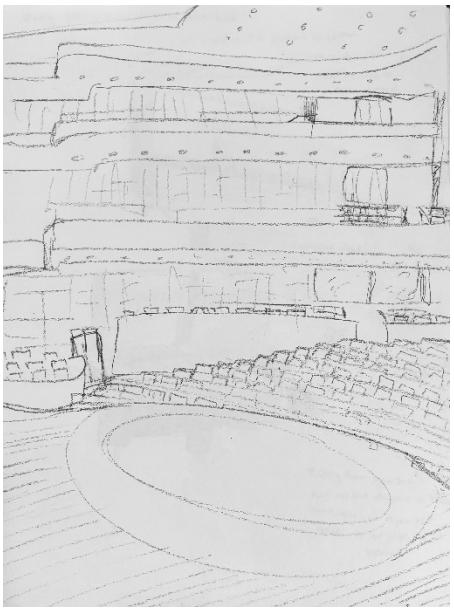

Fig 1. Kimmo Lintula and Hannu Tikka, onsite sketch from the stage, Sibeliustalo, Lahti, Finland, 2024.

Introduction

Jean Sibelius was the most beloved composer in Finland. During the Romantic period, his 1899 piece "Finlandia" became a nationalistic symbol of pride and a resistance against Russian occupancy; Finland won its independence in 1917.[1] To honor Sibelius, the Sibeliustalo in Lahti, Finland was designed in 2000 with innovative and advanced acoustics. An industrious glass box wedged between old brick timber factories sits on the coast of Lake Vesijärvi. Its heavy glulam timber construction is lit by soft yellow lights that illuminate the interior of the gathering space outside of the auditorium and expose the wood

[1] "Finlandia," Encyclopædia Britannica, accessed December 20, 2024, https://www.britannica.com/topic/Finlandia.

structure in a glorious way that gives a hint to the expertise and care given to the design of the concert hall it hides while paying tribute to the old timber industry district on which the concert hall sits.

Although downtown Lahti is urban and dense, the city itself is quite small. It boasts a population of 120,000 people and is only a 40 minute train ride outside of Helsinki. My walk from the train station to the Sibelius was about an hour long in a nearly straight line down what must have been the main street of Lahti. As I moved from the train station, the urban context shifted from concrete underpasses and colorful buildings to tall trees and open views. Looking down the streets, I spotted reveals of the rural outskirts of the town. Picturesque housing, dense forests, old ruins, and views of the Olympic ski ramp appeared in dotted randomness around the city. As I reached the lake and the concert hall, the streets turned suburban, and I walked up a hill lined with apartment houses. Then at the top, a field appeared with the concert hall sitting proudly on the water, eight stories tall in the distance overlooking Lake Vesijärvi.

Fig. 2. Kimmo Lintula and Hannu Tikka, the Olympic Ski ramp view from the city of Lahti, Sibeliustalo, Lahti, Finland, 2024.

Fig. 3. Kimmo Lintula and Hannu Tikka, the first glimpse of Sibeliustalo, Lahti, Finland, 2024.

Fig. 4. Kimmo Lintula and Hannu Tikka, the box office in the historic brick factory building, Sibeliustalo, Lahti, Finland, 2024.

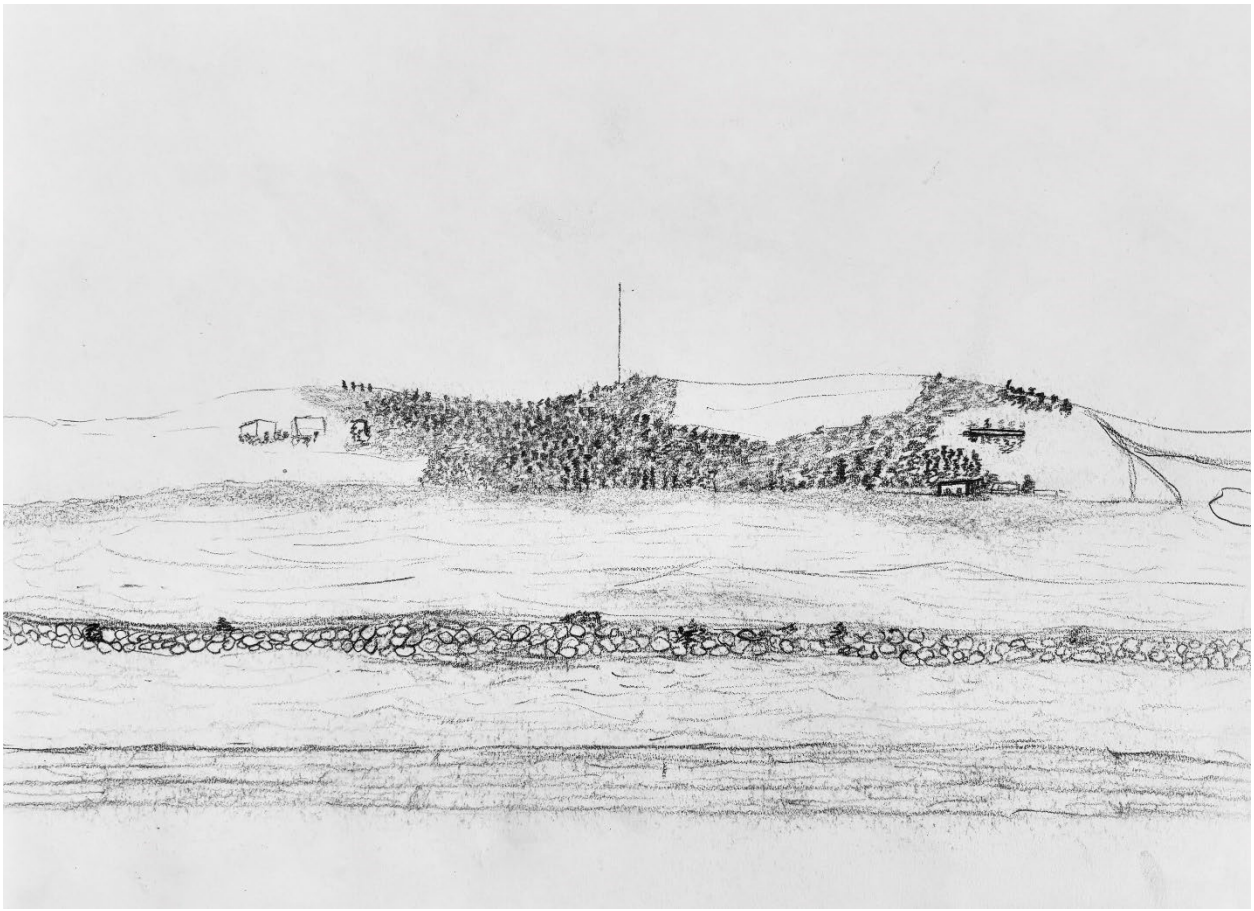

Fig. 5. Kimmo Lintula and Hannu Tikka, sketch of the lake next to the concert hall, Sibeliustalo, Lahti, Finland, 2024.

Form and Space

The 1,250 seat hall was designed in 2000 by architects Kimmo Lintula and Hannu Tikka and acoustic engineers at Artec Consultants in New York. The box within a box architecture isolates the auditorium on each side from the surrounding building, connected only by thick wood trusses and supporting structure that circumnavigate the perimeter of the interior of the building. These trusses line thin corridors that are used as circulation to get from the main halls to the auditorium

and from the auditorium to the supporting spaces, offices, practice rooms, and bathrooms, behind the auditorium.

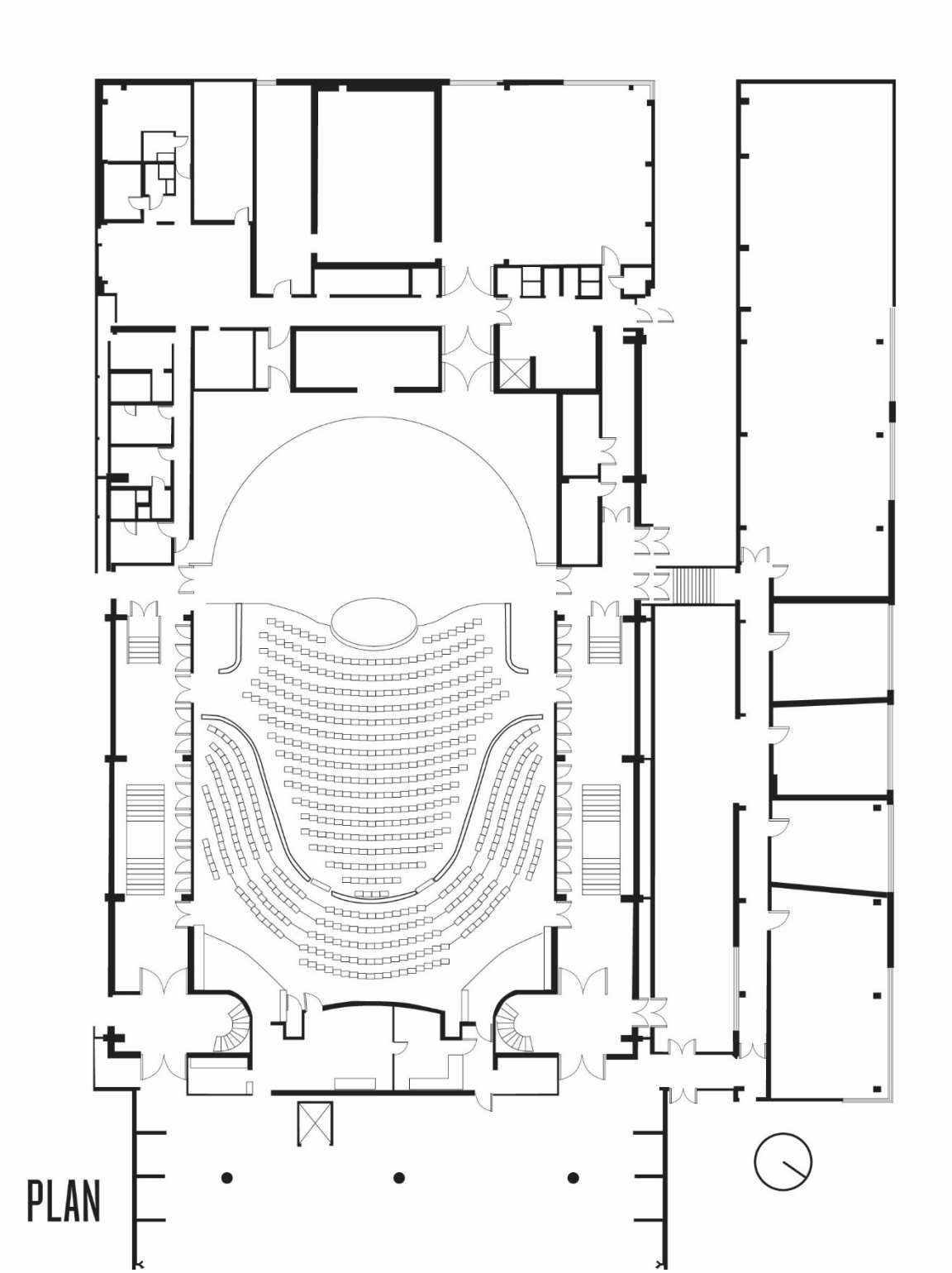

Fig. 6. Kimmo Lintula and Hannu Tikka, author reproduction of first floor plan, Sibeliustalo, Lahti, Finland, 2024.

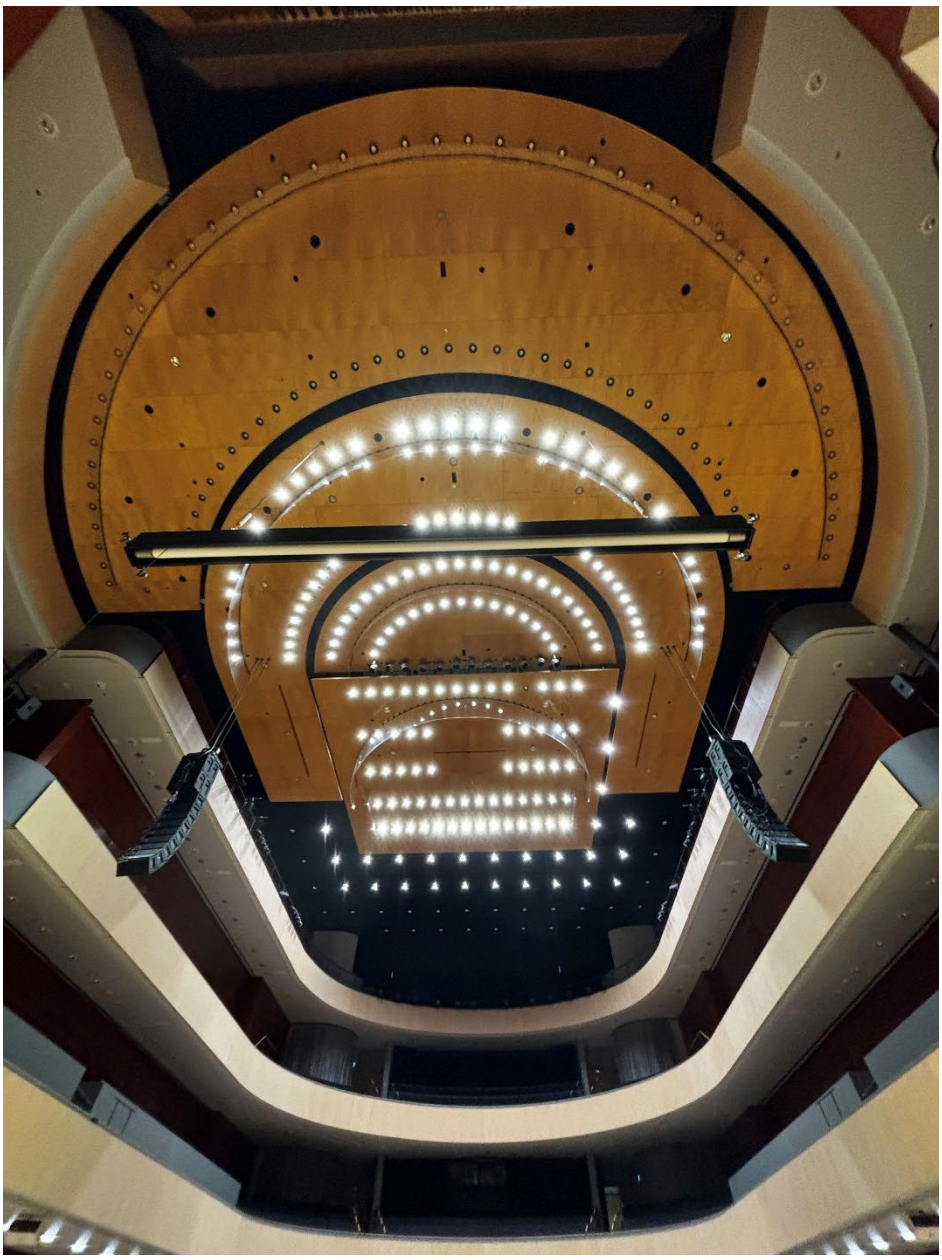

Fig. 7. Kimmo Lintula and Hannu Tikka, ceiling of the interior showing acoustic panels, speakers, and lighting, Sibeliustalo, Lahti, Finland, 2024.

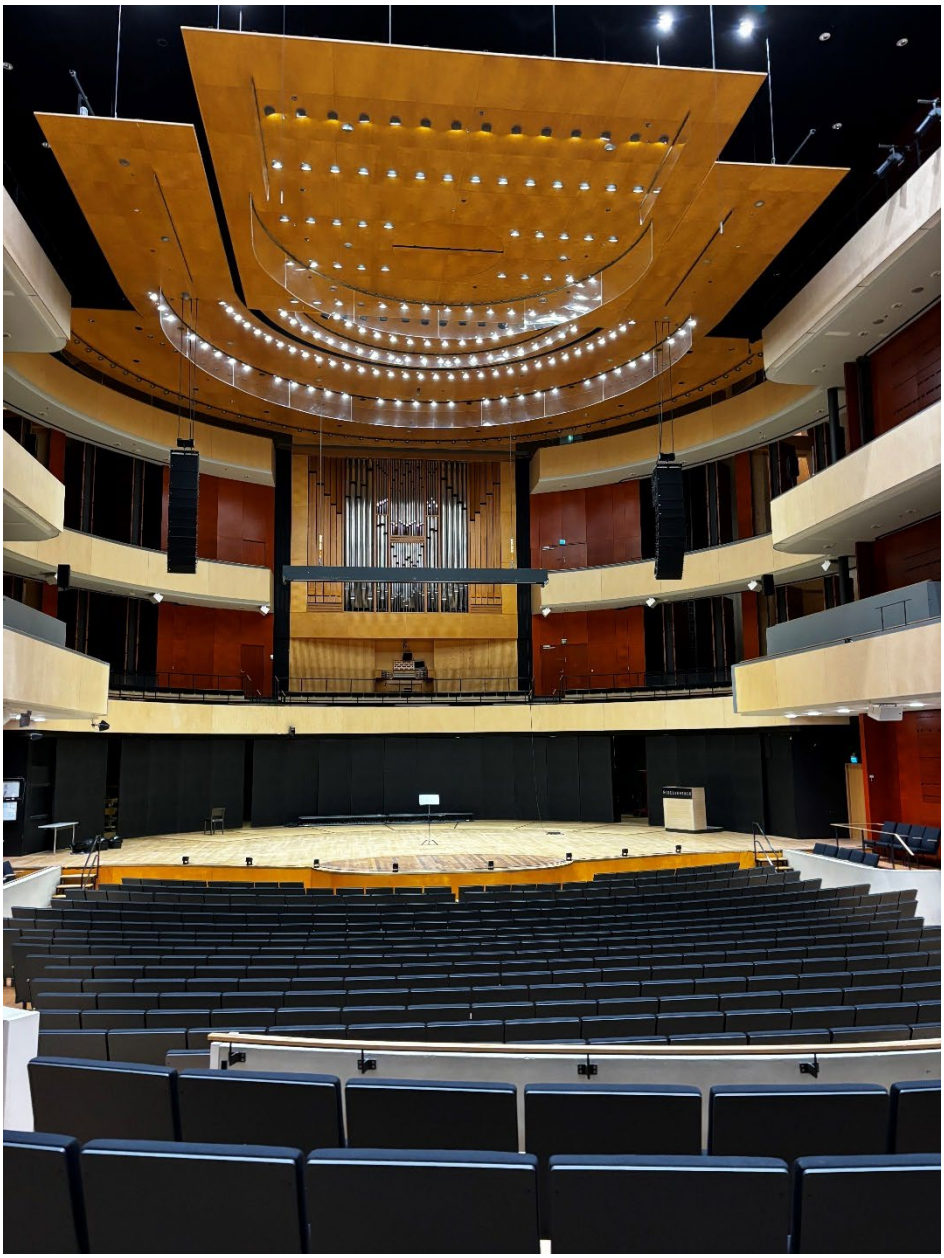

Fig. 8. Kimmo Lintula and Hannu Tikka, interior of auditorium facing stage, Sibeliustalo, Lahti, Finland, 2024.

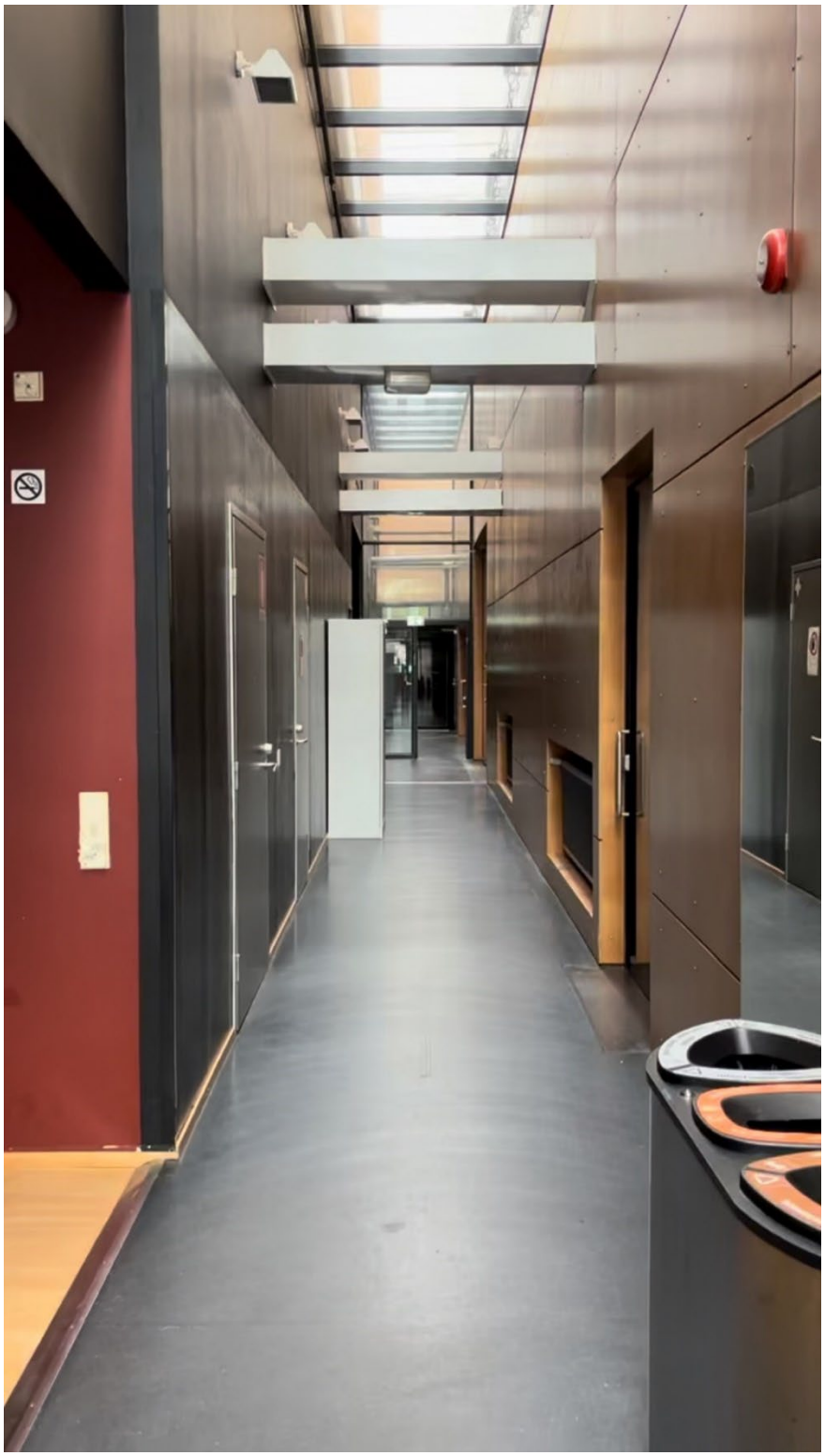

Fig. 9. Kimmo Lintula and Hannu Tikka, the box within a box isolation hallway behind the auditorium of the Sibelius, Lahti, Finland, 2024.

Fig. 10. Kimmo Lintula and Hannu Tikka, the large curtains in descended position in the hallway void chamber that the audience uses to enter the auditorium, Sibeliustalo, Lahti, Finland, 2024.

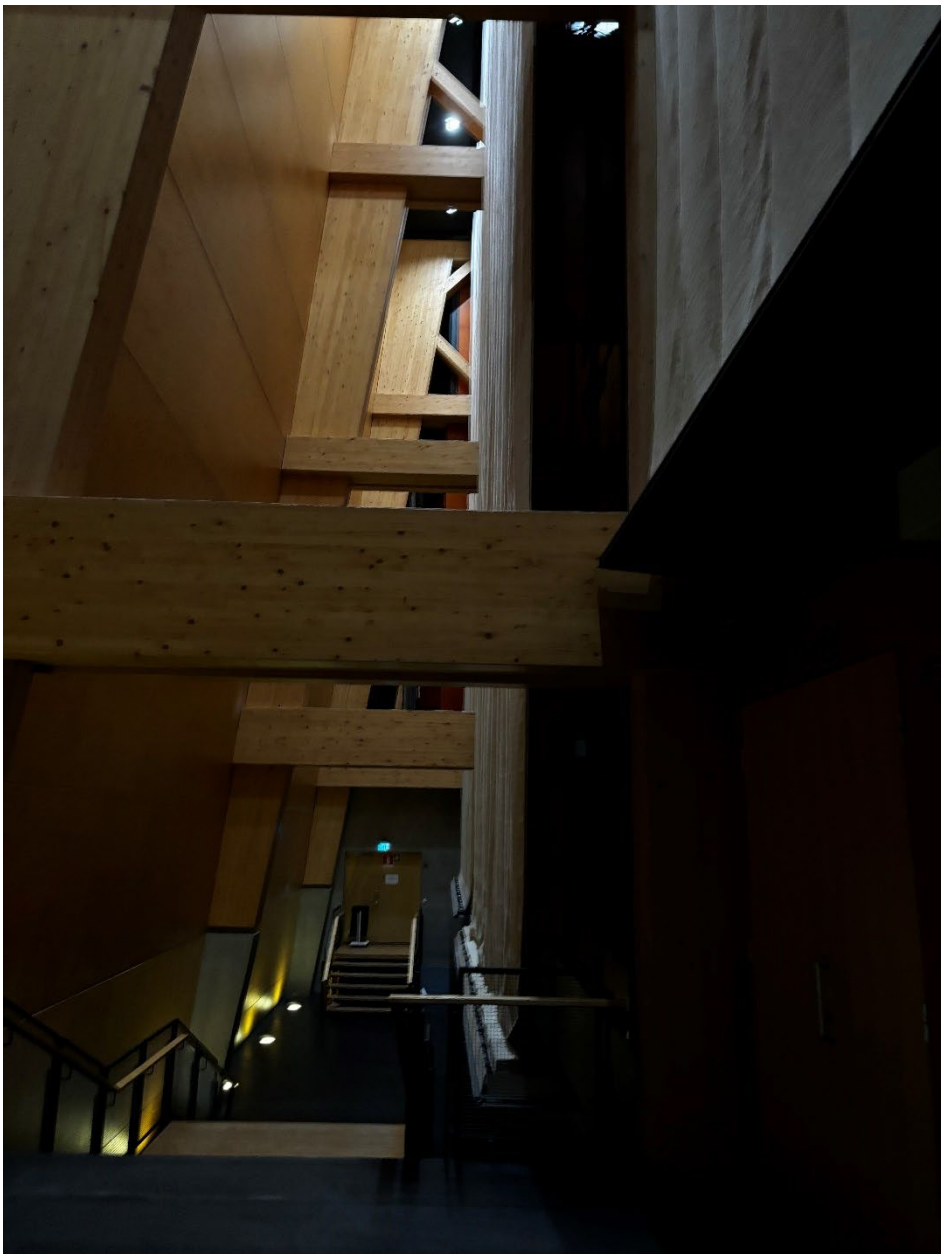

Fig. 11. Kimmo Lintula and Hannu Tikka, echo chamber and audience entrance, Sibeliustalo, Lahti, Finland, 2024.

Materials

The hollow textured painted black wood panels separate the main stage from the storage area behind in a porous semicircle.

The soft wood floor on the stage has sections where the stage can be lifted by hidden mechanics in the isolation under the stage to create risers for orchestral seating. The first two rows of the audience can sink into the ground to become pit orchestra seating.

Behind the stage and around the sides of the auditorium are a series of reddish brown, wood panel doors. These doors can be opened or closed to reveal echo chambers that are lined with massive grey curtains that can be lowered or raised depending on the acoustic reverberation needed.

As shown in figure 13, the ventilation for the space rests in perforated vent caps that sit directly under the chairs. This considerably perforates the floor allowing for a quiet and steady flow of continuous ventilation that does not make much noise.

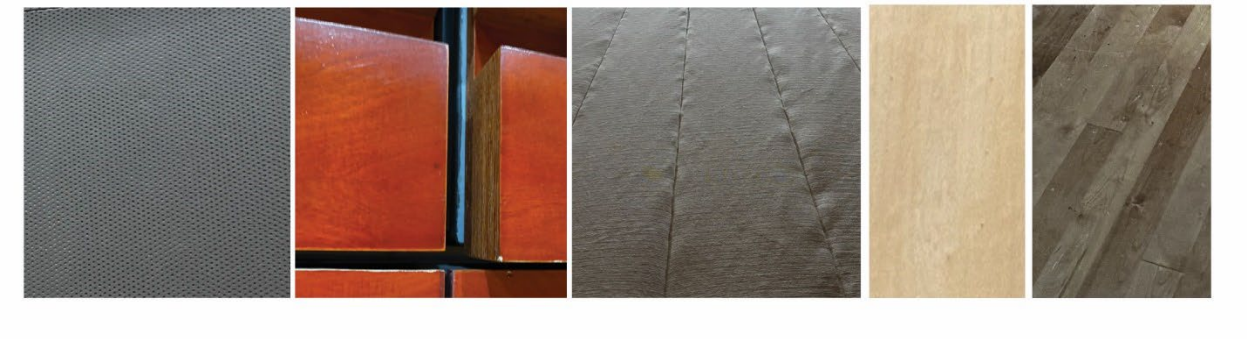

Fig. 12. Kimmo Lintula and Hannu Tikka, Sibelius Hall materials details from left to right textured wood acoustic paneling behind the stage, acoustic red wood panels, acoustic curtains, wall wood panels, and stage wood, Sibeliustalo, Lahti, Finland, 2024.

Fig. 13. Kimmo Lintula and Hannu Tikka, Sibelius Hall chair material and ventilation system, Sibeliustalo, Lahti, Finland, 2024.

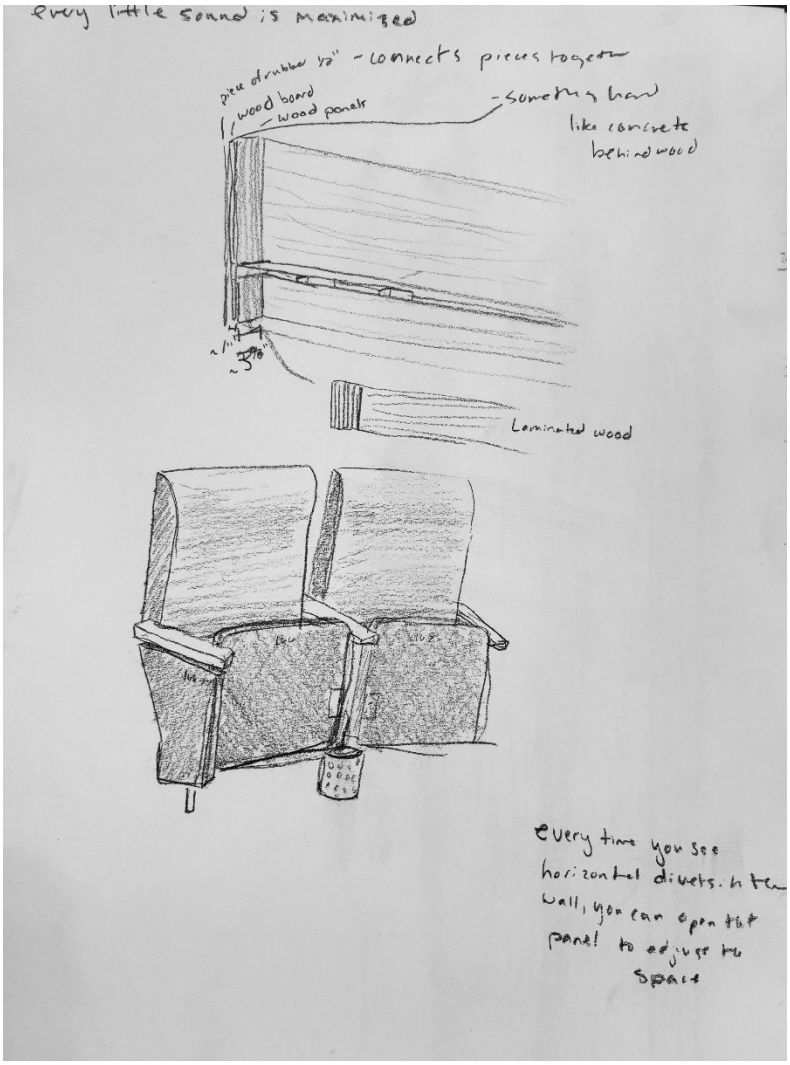

Fig. 14. Kimmo Lintula and Hannu Tikka, chair sketch and material sketch, Sibeliustalo, Lahti, Finland, 2024.

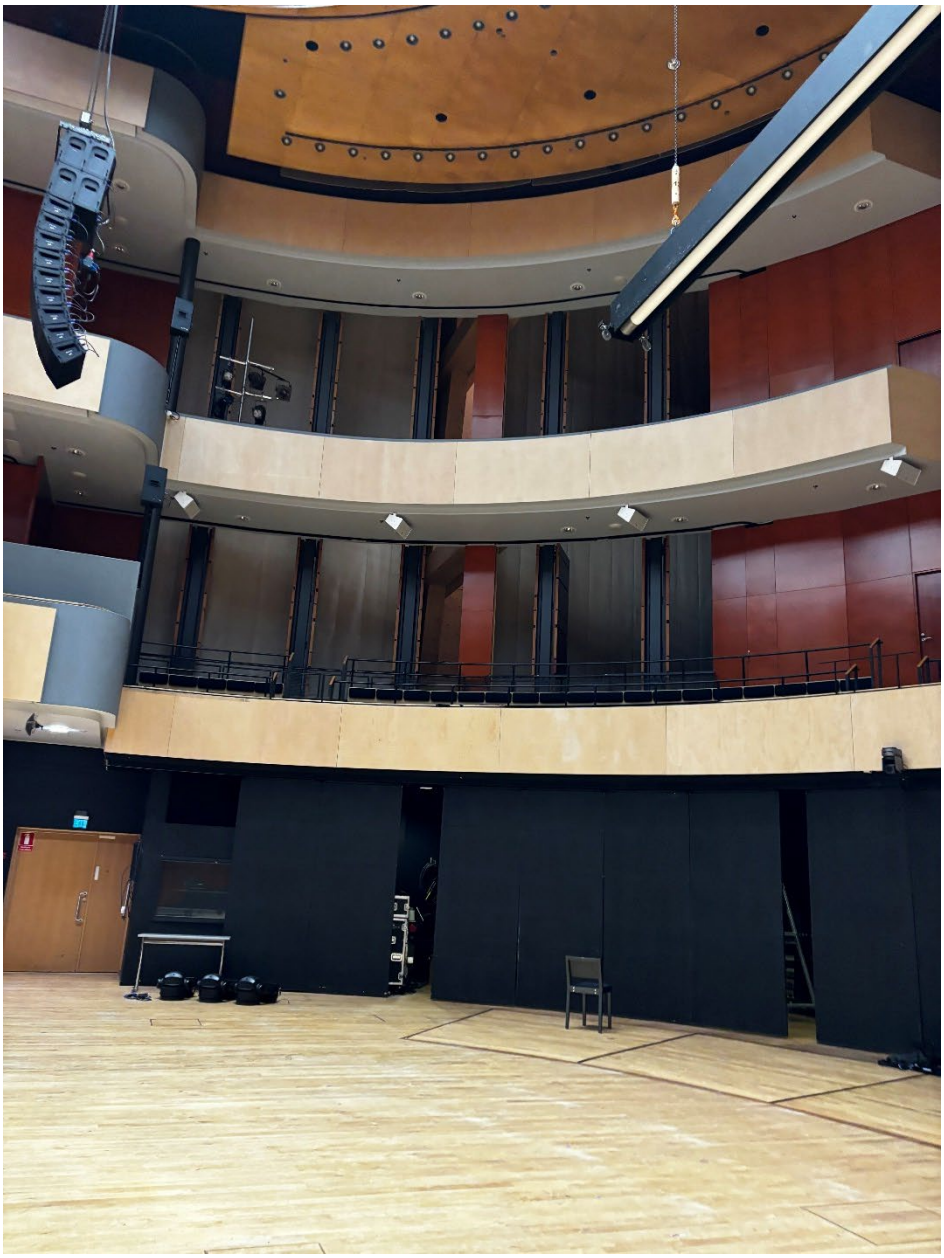

Fig. 15. Kimo Lintula and Hannu Tikka, photo of open acoustic doors above stage in balconies, Sibeliustalo, Lahti, Finland, 2024.

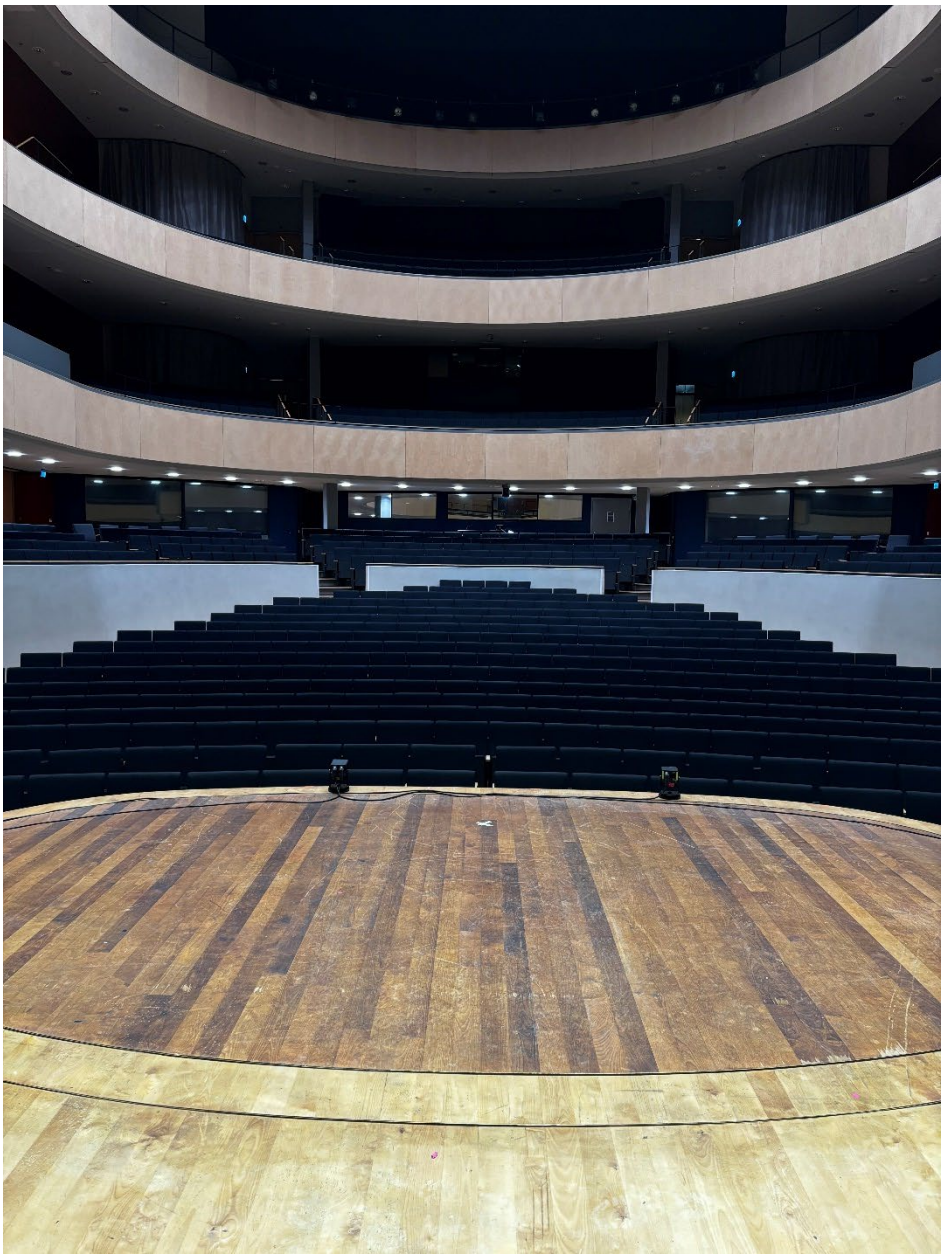

Fig. 16. Kimmo Lintula and Hannu Tikka, interior from stage showing balconies, slanted floor, and curtains along the back walls, Sibeliustalo, Lahti, Finland, 2024.

The following set of notes consists of an on-stage analysis and an audience analysis. The on-stage analysis consists of my mental scribblings as I performed, written down directly after performing and

edited after for clarity. These notes also include my notes from listening to the on stage recording after the fact to fill in any gaps.

The audience analysis consists of three recordings all taken at the same time from different parts of the audience. My analysis is my own thoughts listening back to these recordings, writing what I heard, and explanations for each sound.

Acoustic Analysis

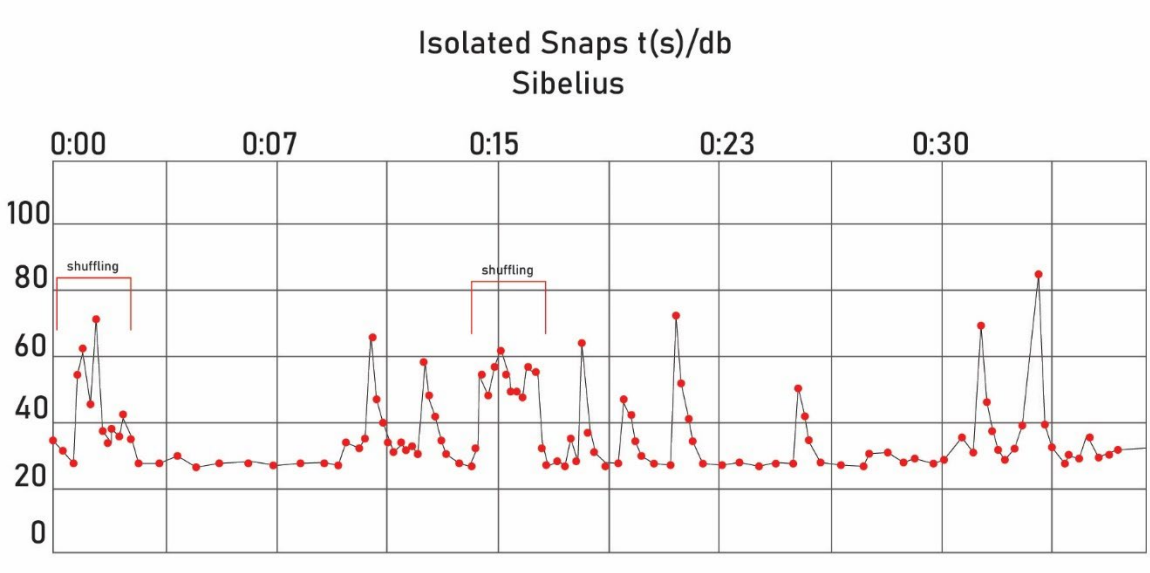

Fig. 17. Kimmo Lintula and Hannu Tikka, acoustic chart showing the decibel reverberation pattern of singular finger snaps in a quiet auditorium, Sibeliustalo, Lahti, Finland, 2024.

When it was empty, this hall was incredibly quiet. At one end of the stage sat a small control box with a soft humming, but despite this sound, the minimal reading on Decibel X was only 25.8db. The stage was the second smallest of the four halls I studied, and the audience felt very close from where I stood on the edge of the stage.

The maximum decibel reading was 85.4db, suggesting that the auditorium amplifies the sound, and the average reading was 63.4db.

The peaks of the snaps as shown in figure 17 jump up suddenly and fall evenly, potentially portraying the even tails and gentle coddling of notes as indicated in the following analysis.

On Stage Analysis-

While performing on the stage, I note that the oboe feels full of sound and the notes seem to be louder than how I play them. The notes also echo out into the space. I felt like I was playing inside of the sound, which reveals a level of intimacy to the space. Although no one sits in the audience, I can imagine that the congregation of bodies and Finnish winter clothing would muffle the sound slightly.

In this hall, I had the opportunity to walk around the audience for a couple of minutes while a French hornist of the Sibeliustalo orchestra played on the stage. As I moved under the balcony, in the ground floor of the audience, the sound became less resonant, and I perceived more direct sound in all places except for the very back which has some indirect reflections. It was as if I could feel myself inside of the music in the audience seats on the floor level, the intimacy and clarity of the space were so high. There was more echo in the back and the front and center were the most resonant. The dullest area was by the doors in front and to the side of the audience; this is likely because of how deep into the underside of the balcony this spot was along with the heavy curtains absorbing sound near me.

The softer volumes tended to be cocooned in the sound. It very much sounded like I was playing inside the circle of the notes instead of pushing through them. The notes rang less than in previous concert halls. I could not hide my mistakes in this hall, every note and error rang clearly out into the space. The sound did not surpass an unbearable level of brilliance and sounded full but not energetic. It created a serious sound, as if the space was designed for professionals who know how to manipulate space with their instrument better than I do. As I played, I started to understand the space better; I held out each note just a little longer than I normally would. I did not let the ends of the notes stop so suddenly, and I put more effort into creating a round tone. Interestingly, the third movement of shorter notes sounded more brilliant than the first and second movements of the Marcello oboe concerto. The hall worked in favor of quicker notes and longer phrases. It reminded me of string orchestras and how their bows and fingers deftly play in space over long passages; that grandiose phrasing would be well suited for this space.

The one sector I would in which the hall seemed to lag in performance was the liveliness scale. And after reviewing my notes and recordings over and over, I think this was author error; my skills do not match the level of professionalism to play in the space. The sound that reverberates across the room was pretty, and it made me want to sound and play pretty. Because of the clarity, volume, and spaciousness of the sound, I held back from adding enough air to lend a rich timbre and vibrance that would have added to the liveliness to

the space. Although a personal error, the occurrence relates directly to my experience on stage as a musician and will be included in the report below.

Post Analysis: Audience Zoom Recorders

Recorder 2: First Balcony, Ground Floor

The notes are so clear and similar to how it felt on stage from this spot so close to the stage. The shuffling on stage is easy to hear, adding to the sense of intimacy. I imagine this space to be better suited to an energetic large band. I am playing the piece slower than I practiced in this recording, and it sounds like I am unsure of the sound coming from my oboe. This can happen when the sound I hear in my head is bigger than what I think I am playing, so my fears try to control the sound too much. During the slurred parts of the first movement, my confidence seems to grow because the notes come across much better in this space than the plucky notes of the beginning of the movement. Another criticism is that every noise on was so amplified that I got distracted when there was a sound in the audience; I can hear the shuffling noise, probably from the other person in the audience very clearly from the recorder and the sound of me placing my tuner on the ground is much louder than the audience shuffling to the recorder. The stage acts like a drum; each of these percussion sounds are amplified by the auditorium. Some notes are muddled in the second movement, which is much more legato than the first. The crescendos in this space have more impact than the decrescendos and softer notes which sound like they are fighting

against the amplification of the stage. The third movement with the shortest notes is working well in the space; this is likely because the notes are not chromatic and do not repeat the same note multiple times in a row, which would be muddled by the hall's lively reverberations.

Recorder 3: Choir Seats

I find myself incredibly impressed with the quality of sound I hear in the recording from behind the stage in the choir seat.

Movement one

Although the echo of the large, empty space prominently occurs in these reverberant notes, the way the echo tapers more softly at the tail end of the note than right after the fundamental suggests that in a full auditorium, the quality of the note that reveals the hall to be empty becomes hidden.

Movement two

The richness of the connected notes creates a haunting quality to the tail end of the notes and provides warmth and clarity to the fundamental part of the tone that resonates somberly. Each note fills the space with the exact level of intensity intended and does not lose its clarity by becoming too connected or overlapping from the reverberation.

Movement three

The tail end of the notes begins to connect too much for such a bouncy movement. The liveliness seems shrouded when juxtaposed to the liveliness of the National Forum of Music or the Musikhuset, but this

simplicity of tone sounds more professional. The warmth of the lower notes is deep and rich, and the brilliance of the higher notes has the timbre of a voice singing as opposed to a bell ringing. It makes the timbre of the oboe seem darker and more solemn.

Recorder 1: Ground Floor, main audience

Warm up

The crescendos are so powerful. The scales are deep and connected and lifted and gorgeous

First movement

The wall of sound that hits this recorder is incredibly clear and loud like I am standing right in front of it. This is the best seat in the house, and this is the last recorder I am listening to; I did not think it could get any better than it already was.

Second movement

It’s a bit loud, which I wish I had known; it did not sound quite as loud on stage, and I would have softened myself. The amplification is tremendous. I could play an absolutely quiet note and hear it as clearly as the loudest note of the piece.

Third movement

The notes sound extraordinarily lively from this spot in the audience, and the layers of the tone of each note balance perfectly. The notes are amplified in a bright and brilliant way while maintaining warmth in the fundamental timbre of each note. The front, middle, and end of the notes are perfectly spaced with the emphasis being in the middle and the end being softer. The accents are clear and easy to understand. The attacks are slightly delayed in the sound. The longer reverberation time does make the notes hard to isolate.

On Stage

Clarity - high

Intimacy - high

Liveliness - medium

Spaciousness – high

Warmth – high

Brilliance – high

Rating: 17/18

First Recorder

Clarity – high

Intimacy – high

Liveliness – high

Spaciousness – high

Warmth – high

Brilliance – high

Rating: 18/18

Second Recorder

Clarity – high

Intimacy – high

Liveliness – high

Spaciousness – high

Warmth – high

Brilliance – high

Rating: 18/18

Third Recorder

Clarity – high

Intimacy – high

Liveliness – high

Spaciousness – high

Warmth – high

Brilliance – high

Rating: 18/18

Total: 18/18

Conclusion

The rounded shape of the auditorium and stage carry the sound through the entire space of the auditorium equally while limiting undesirable reflections. The echo chambers and heavy curtains flanking the entire auditorium wonderfully capture the final passes of reverberations and stop the sound from replaying to the audience. Acoustic panels behind the perfectly semi-circular stage eliminate the risk of focalization of sound; the wood material of these panels capture sound while the textured dots reflect some of the sound back in non-orthogonal angles contributing to the sense of intimacy and warmth being equal both on stage and in the audience. While the full flank of curtains may have contributed to the decrease in liveliness on stage, this may have been user error. The professional French hornist seemed to have a livelier sound than the author, and he performs on this stage often.

Critically, the amplification and liveliness of the auditorium were two areas that struggled to find a balance. The reverberation and amplification of the sound interfered with staccato sounds and muddied the endings of the notes. This was likely due to a lack of an audience as well as the rounded balcony materials.

The liveliness of the hall created difficulties on the part of the performer to control how his or her sound resonated in the space. Since the liveliness was mostly impacted in the immediate presence of the stage, I assume it was caused by a fear on the musician’s part to create too much timbre and liveliness and created by the warm materials of the wood and the shallow divots in the acoustic panels

behind the stage which supported the sound into the audience and around echo chambers.

Overall, the experience of playing on this stage and listening to the sound in the audience was nearly equivalent. This hall portrays to my student ears a perfectly balanced hall with a glorious sound.

Musikhuset Aarhus Addition: A Nordic Experience

Fig 1. Klaus Toustrup, Sketch onsite showing the sloped floor towards the stage, Aarhus, Denmark, 2024.

Introduction

The Musikhuset sits one street off the downtown city of Aarhus, immediately in between the historic downtown and a more modern part of Aarhus. The Musikhuset is surrounded by a conference center and the Kunsthal Arts Museum established because of the Aarhus Art Association of 1847, one of the oldest in Denmark. The area is an hour walk out of the contemporary center of the city which boasts a vibrant ocean coast, lined with boardwalks and water activities. Impromptu graffiti, sculptures, and art exhibits are littered around the city and provide a sense of being surrounded by art.

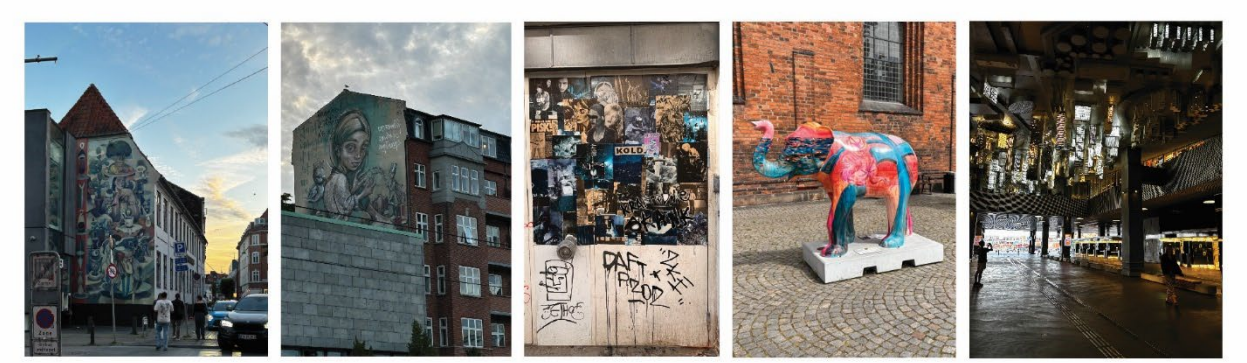

Fig 2. Pictures of street art, Aarhus, Denmark, 2024.

The Musikhuset auditorium was designed in 2008 by architecture firm C.F. Møller to be an addition to the original concert hall in Aarhus, Denmark established in 1985. The new addition would provide a Nordic experience through its material and textural palette while having completely new technologies to adjust sound through material, form, and movable walls. An original glass box within a box hall sits on the site that was designed in 1982 by Kjaer & Richter architects. The new addition, clad in yellow brick, doubles the size of the hall while creating a more modern space for more modern music. As I walked down the soft light ash wood slope of the Aarhus auditorium, Klaus Toustrup, the architect, cheerfully pointed out the features of the that allow the Aarhus Symphony Orchestra to record music for radio and he even mentioned that the hall has hosted such illustrious guests as the Queen of Denmark.

C.F. Møller is a firm I personally admire for their dedication to sustainability goals from both a material and economic standpoint and a social one as well. The hall is one example of the firm's dedication to using local resources in construction, a sensible budget while

maintaining high quality, and creating centers that activate citizen participation in the social realm.

Fig. 3. Photos of historic Aarhus, Denmark, 2024.

The exterior of the Musikhuset is unassuming. The original concert hall has a celebrated glass façade with a tortuous garden in front of it. The Musikhuset is the golden brick building that is attached to the back of the glass façade. When I entered through the standard sized doors, I was immediately greeted by a reception space. When I was brought to the concert hall which sat behind leagues of teal painted stairs, the hallway that connected to the original hall was pointed out to be in axis with the center entrance of the Musikhuset addition.

Fig. 4. Klous Toustrup, exterior entrance looking North, Musikhuset, Aarhus, Denmark, 2024.

Form and Space

The auditorium fits the exact model of a shoebox hall; the stage is out in front of me as I walk down the hall, but the bright red walls contrasting against the soft, Nordic wood catch my attention immediately drawing me into the warm hall. This hall is also a box-within-a-box although somewhat less isolated on the ceiling and below the floor than the other halls.

It became immediately evident that the architect made something beautiful out of unassuming materials.

Because the hall is situated on a hill, the audience sits on a slant. This was very evident as I slid down the aisles towards the stage, feeling myself keen forward. My vantage point of the stage was bettered by the experience of walking from a higher point towards it.

From the ceiling, hangs a single canopy made from glulam wood in a patchwork pattern that can be lifted or lowered to control the acoustics of the space.

Fig. 5. Klous Toustrup, the single canopy and striking contrasts, Musikhuset, Aarhus, Denmark, 2024.

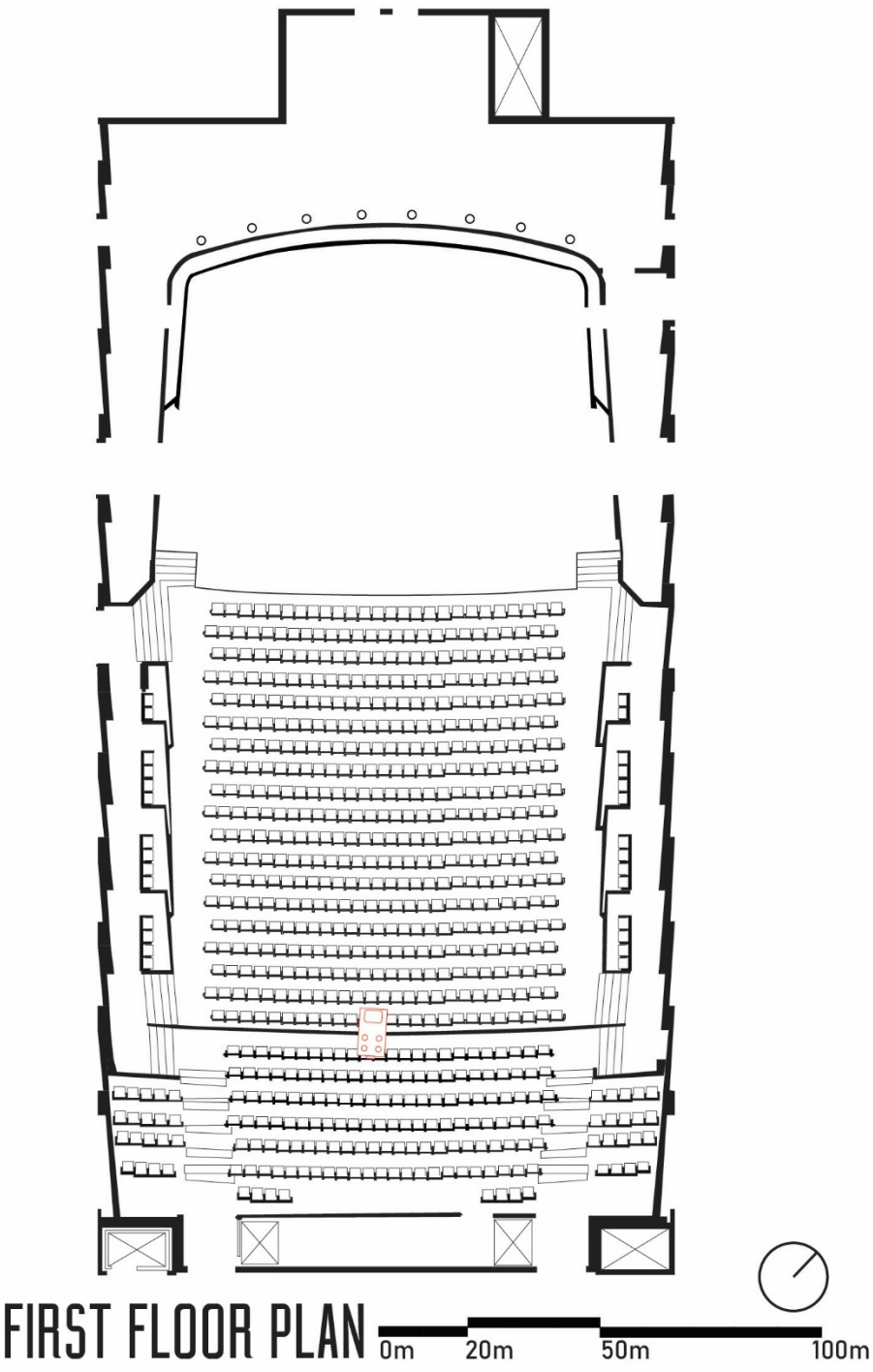

Fig. 6. Klous Toustrup, author reproduction of first floor plan showing audio recorder 3, Musikhuset, Aarhus, Denmark, 2024.

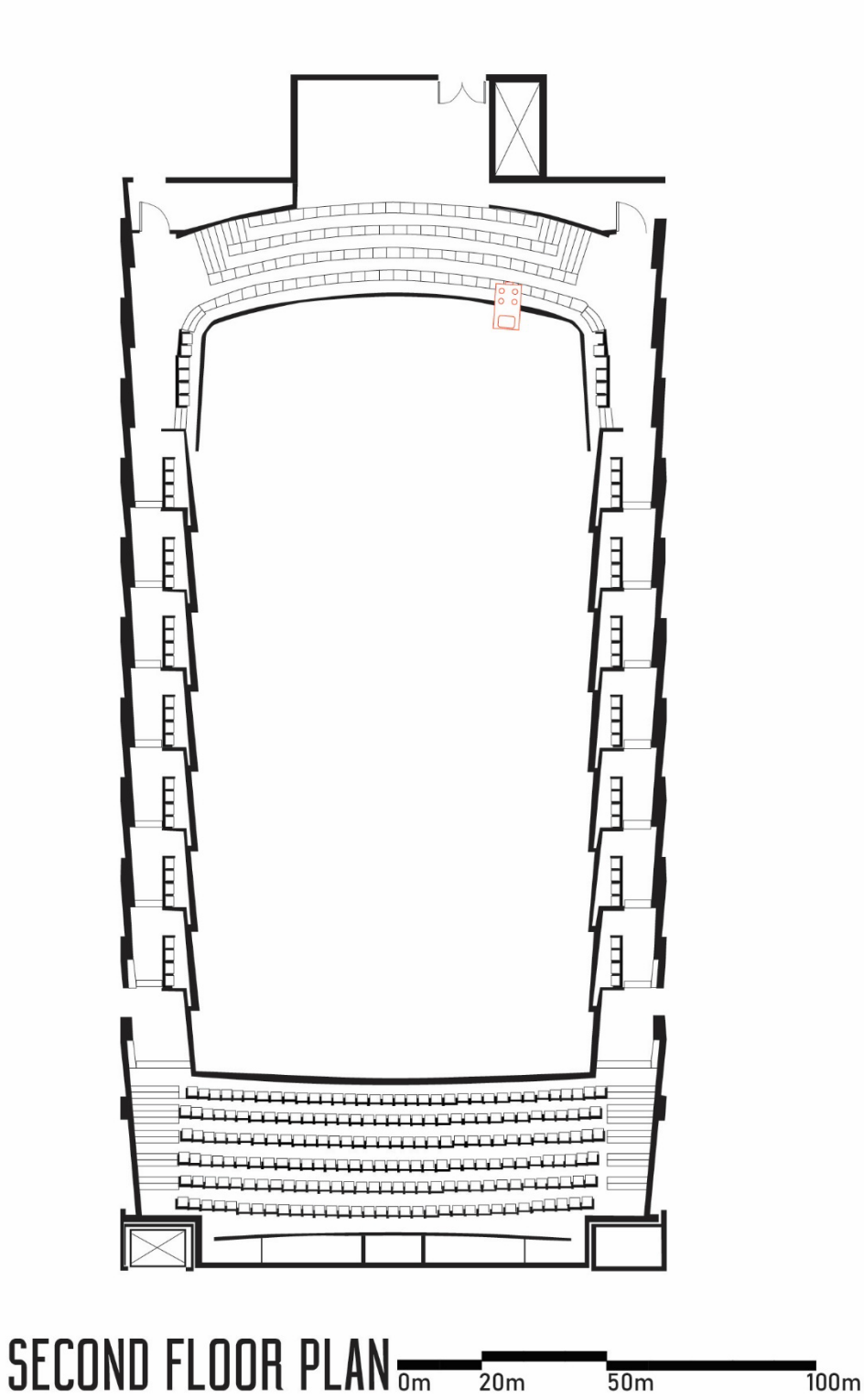

Fig. 7. Klous Toustrup, author reproduction of second floor plan showing audio recorder 2, Musikhuset, Aarhus, Denmark, 2024.

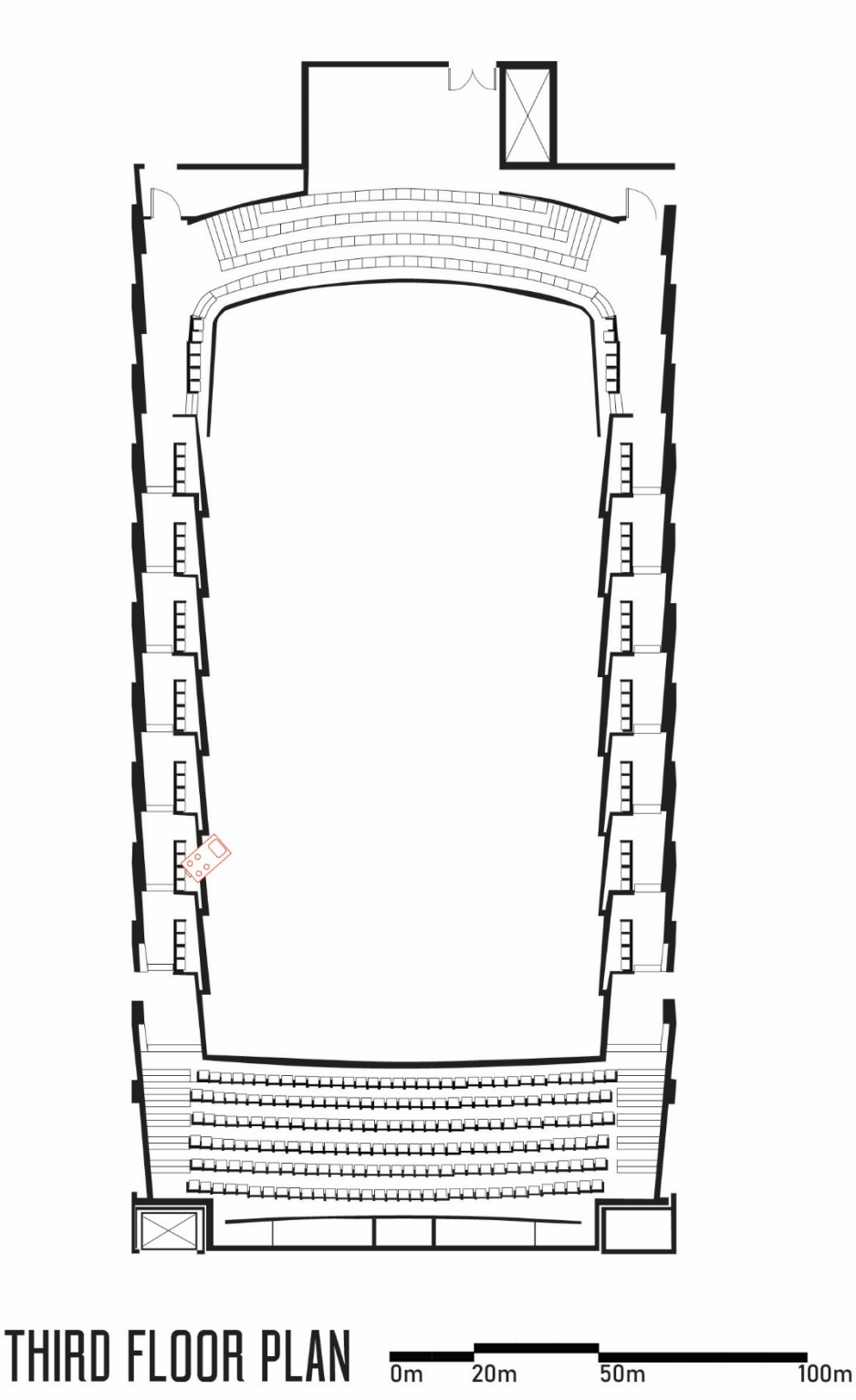

Fig. 8, Klous Toustrup, author reproduction of third floor plan showing audio recorder 1, Musikhuset, Aarhus, Denmark, 2024.

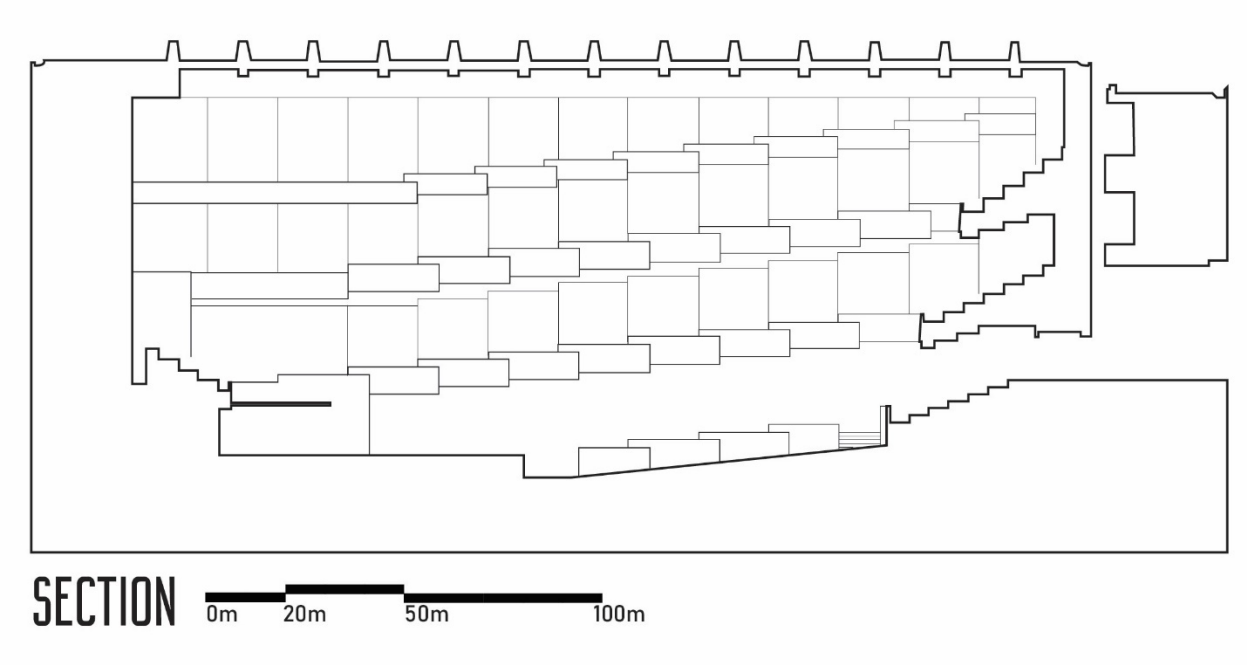

Fig. 9. Klaus Toustrup, author reproduction of section, Musikhuset, Aarhus, Denmark, 2024.

Materials (500)

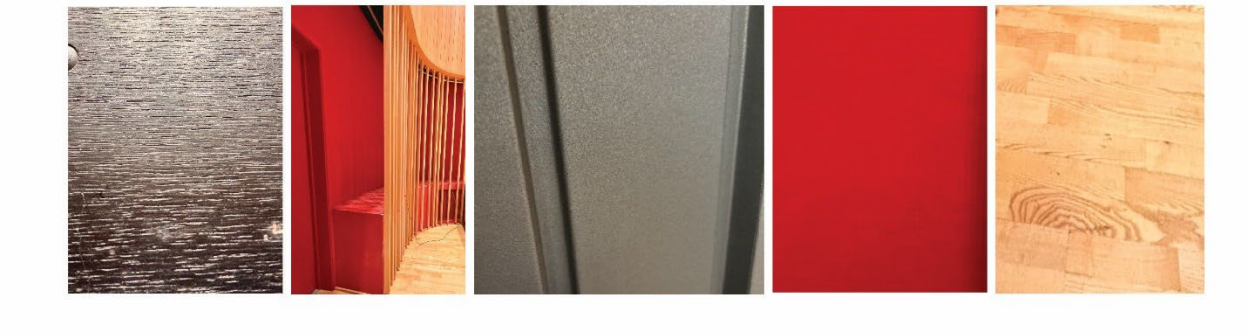

Fig. 10. Left to right balcony handrail, red paint and hollow wood tubes, fiberglass-concrete siding walls, red fabric acoustic panels, ash wood floor, Musikhuset, Aarhus, Denmark, 2024.

Pale sandy wood, dark ceiling dotted with LED lights, and thrasher red glowing panels: these are the materials of the Musikhuset

addition in Aarhus, Denmark. While recalling a familiar pattern, the Musikhuset transforms common materials into an acoustic experience. The pale wood stage and panels that line the walls create both an experience and a sound of warmth. The dotted ceiling recalls a dark, winter Nordic sky so high and far away; a canopy of patchwork wood panels that can descend upon the stage to create a more intimate experience or be raised to open up the space to the symphonic level of sound conceals some of the stars.

Tubes line the back wall of the stage and the back of the choir section. Toustrup, the architect, told me that they were inspired by a hall in Budapest that had these hollow wood tubes that would rattle when deep bass sounds would play; Toustrup decided to fill these tubes with concrete to create a solid form that sound would pass around and not rattle. This becomes an interesting study in the form that creates an allegory to the volumetric form of a concert hall. The cylinder has no edges; no edges means that the sound bounces back in a way that fills the space and does not just vibrate back in forth. For the same reason concert halls are not circles in plan, C.F. Møller discovered that hollow cylindric tubes make a poor backdrop for sound.

Red cloth lined acoustic panels have the ability to slip into the wall on thin tracks that disappear behind grey concrete ribbed walls. Toustrop related this bright red color to the intensity and experience of sound which becomes critical to the experience of a musician on stage when you realize that the most permanent red in the auditorium derives from massive red curtains that flank the back wall behind the audience. In the same way that the audience can view red paint peeking

through wood tubes behind the concert stage, the musicians can view the bright red back lighting the audience.

Red curtains line the back of the auditorium as well, giving the performers a similarly powerful view of the audience. These curtains also stop the sound from reflecting off the back walls and back into the audience.

Fig. 11. Klous Toustrup, audience from stage showing red curtains in back of auditorium, Musikhuset, Aarhus, Denmark, 2024.

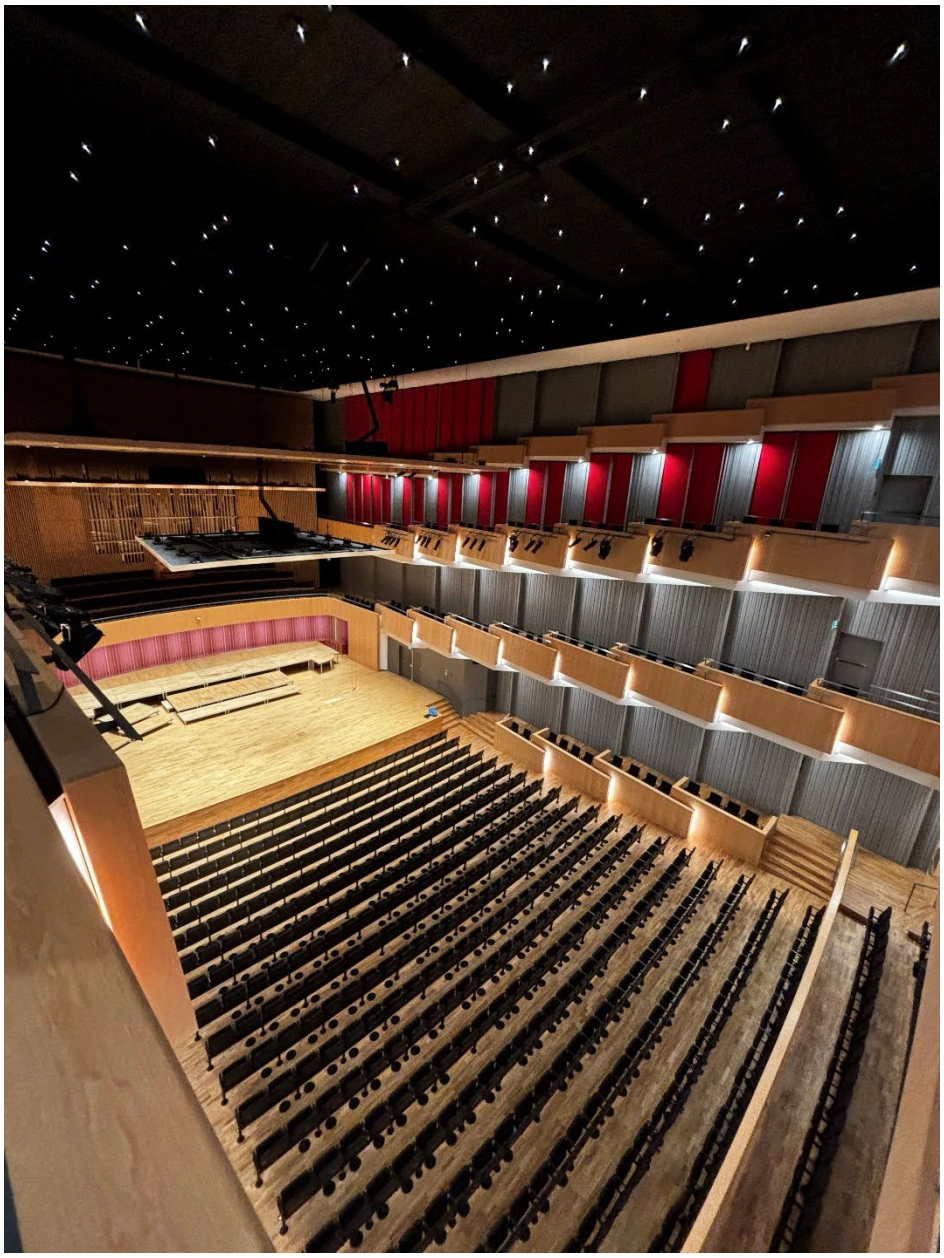

Fig. 12. Klous, Toustrup, view from highest balcony showing night sky LED lights as well as flat seating towards stage in ground level, Musikhuset, Aarhus, Denmark, 2024.

Fig. 13 Klous Toustrup, upper balcony showing red panels pulled out from their tracks, Aarhus, Denmark, 2024.

The material of the chairs in the audience is soft and absorptive so that even without an audience, the orchestra can record themselves without much of a difference in sound.

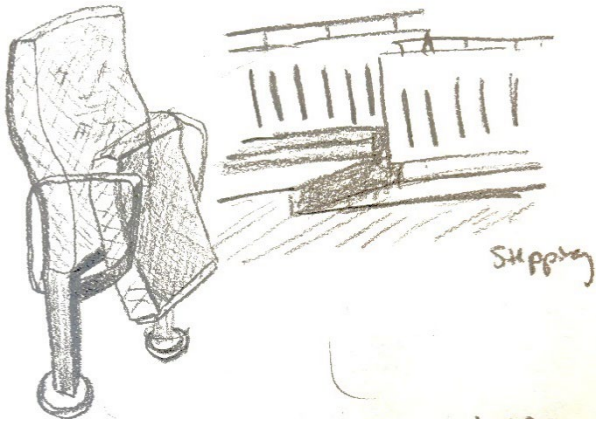

Fig. 14. Klous Toustrup, Onsite sketch of chair and wall slits, Aarhus, Denmark, 2024.

The wood siding along the terraced balconies of the auditorium has thin, long slits in them that allow sound to travel into the slits and echo silently inside of the material, absorbing sound from being reflected back into the audience. The stage is this same ash wood, a reference to Nordic materials and a material that gives sound warmth and the experience of the audience and musician a visual sense of warmth. Walking on it felt like walking on a hollow basketball court.

The grey wall siding material consists of alternating fiberglass and concrete vertical layers that are painted over in a metallic color since fiberglass and concrete have two separate finishes. Fiberglass acts to absorb sound while concrete reflects sound waves.

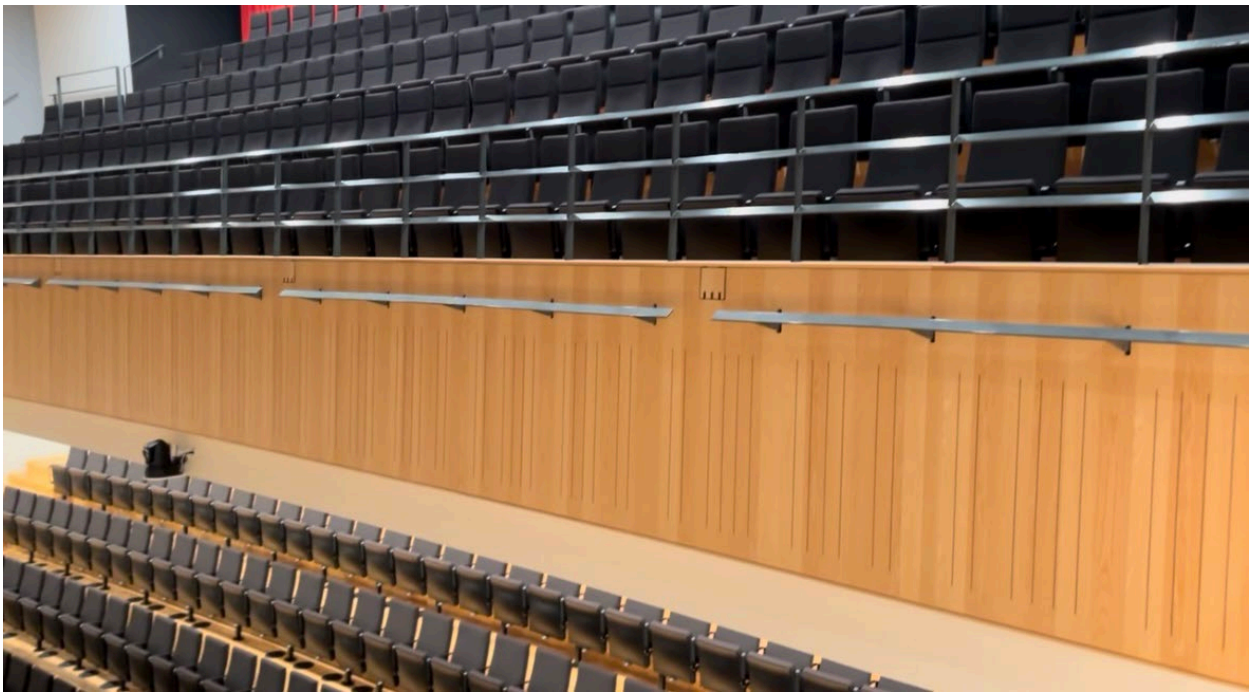

Fig 15. Klous Toustrup, back balcony showing acoustic slits, Musikhuset, Aarhus, Denmark, 2024.

Acoustic Analysis

Standing alone on the stage in the Musikhuset was eerie because of how quiet it was. The Decibel X app measured the complete silence of the empty auditorium to be 25.4db, making it tied with Sibelius for the quietest hall I studied on this trip. The app measured my average decibel rating at 65.6db and the maximum was 91.3db. This was the highest maximum out of every hall, which supports my following analysis that the space is successful in amplifying the sound.

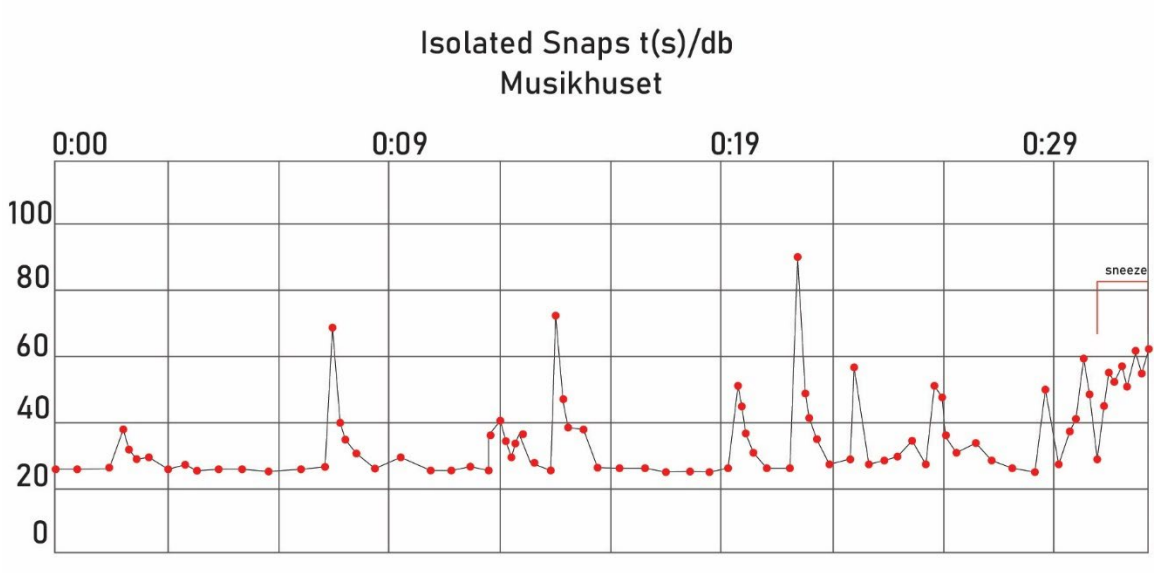

Fig. 16. Klous Toustrup, acoustic chart showing the decibel reverberation pattern of singular finger snaps recorded on stage, Musikhuset, Aarhus, Denmark, 2024.

Figure 16 suggests that the attack on the snaps was more assertive and clearer since the slope is very steep. The tail end of the snaps decreases suddenly initially with a taper at the end suggesting that the surfaces that the sound reverberates off are further away from the stage.

On-Stage Analysis

My first thought playing on this stage was that it was echoey. Many of the fiberglass and concrete walls were in the closed position and the canopy above the stage was too high because the technologies were set up for a multiple instrument ensemble. This combined with the lack of audience contributed to this level of echo. Another issue I faced during my duration on stage was the heat of the auditorium. Either from the stage lights or lack of air conditioning during the off-season, the stage was unusually warm which pulled my pitch sharp and contributed to some issues with my reed. The higher levels of echo also became somewhat disorienting as I tried to configure how to play on this stage.

During the first movement, I noted that the space had a gorgeous level of brilliance that I called "dancy." The sound was light and bright, especially in the higher register. The lower notes were full-bodied and warm to contrast with this brilliance. The reverberation time seemed higher than it should have been although the sound did seem to fill the entire volume of the space and the end of the notes seemed to taper and settle slowly like dust. The sound comes across big, or spacious, and causes the movement to sound almost grandiose. This amplification of the sound means that even different parts of the stage feel less intimate and instead the sound in front of me felt further away. I also wrote in my notes that some of the notes sound as if they are playing back on top of other notes and occasionally create

a shrill dissonance out in the space of the auditorium; this is not something that came across in listening back to the video.

The second movement sounds bright in the space but properly reverberant. In the recordings, it becomes obvious that the heat of the stage is interfering with the tuning and timbre of the long-held notes, although this is something that can be overcome by the musician. The crescendos are magical in this space, as if the louder end is being amplified. The higher notes in this movement seem to lose some warmth, which I did not notice as much in the first movement. The middle range of the oboe sounds vibrant and full in this space.

The third movement sounds wonderful from the stage, but I was worried that the liveliness of the space would change the way the sound was read in the audience. Each note feels playful as opposed to shrill because the brilliance is not too high. While playing the staccato notes, the tail end of the notes seemed to overlap with the attack of the next note, which became disorienting. I also noted that it sounds like the note is echoing back twice; one of the echoes is in the audience while one is on the stage with me. I moved around the stage to figure out what was happening, and as I got closer to the sides, the echoes increased making me think the sounds are bouncing off the stage walls.

Post Analysis: Audience Zoom Recorders

Recorder 1: Stage Left, Second Balcony

Warm-up

During the warm-up, I note that my crescendos do not seem to be getting louder, which is not something I felt on stage. The sound is

very bright from this spot and the timbre of the oboe feels reedy, which I initially thought was a personal error amplified by the sound of the space, but on listening back to the stage recording, it does not sound so reedy, which makes me think the position in the balcony has a brighter sound. The higher notes do not seem to be warm. I can hear the air conditioning so loudly in the background. The lower notes are much warmer than the higher notes and are somewhat cradled by the sound.

First movement

In the first movement, I can hear the sound louder in my left headphone than in my right which seems backwards but makes sense considering the zoom recorder microphones face inwards, so the left would have been facing the stage and the right would face away. I note that the sound is more coherent and clearer as a tune than as singular notes or during a warmup. The clarity is embarrassingly amazing from this location; I can hear every single one of my mistakes as if it is right in front of me and happening in real time. The strong accents and the attacks are noticeably clear. The crescendos are still not very prominent from this seat. Everything sounds loud. The space is very lively and active, not dull at all; the notes ring out into the space.

Second movement

I note that from this seat, my tuning issues due to the heat are clear and prominent. The lower notes are more brilliant than in previous halls, but I think that makes them livelier. They are still cradled by the sound and sit in more in the fundamental pitch than in

the overtone, which is preferrable for an oboe. The higher notes ring more in the overtones which is what causes them to sound so much brighter. The sound is very loud considering I am about as far away as I can get from the stage, and I am impressed by the clarity.

Third movement

The third movement sounds so amplified and alive in this space. The notes perfectly overlap from this seat as if they are merging as if the reflections have more space between them and are more clear than they seemed to have while I was playing on the stage. The highest notes in this passage get a little lost in the reverberations and sound much quieter than the surrounding notes.

Recorder 2: Behind the choir, mostly centered, slightly stage right

Warm-up

The sound is clear still. The crescendos are more noticeable behind the stage than in front of it. The sound feels far away; you can tell that the oboe is facing away from the back of the stage as if I am not the target audience. The echoes are even less extreme behind the stage; the sound feels more balanced.

First movement

The echoes are traveling away from the location of the recorder and seem much quieter than in the other seats in the auditorium. The trills start to become somewhat muddled. The air conditioning is very loud in the choir section and every shuffle on the stage is amplified. The higher notes sound less bright in this spot and the lower notes

sound equally as warm and full. The lower notes are a bit more brilliant.

Second movement

This movement sounds nice from behind the stage. The highest notes in the range tip the scale to too brilliant (which will be reflected by a lower rating below although it is more brilliant). The attack of the notes is suitably soft and not articulated or amplified by the space in this direction. The trills are a bit muddied and get lost in the space.

Third movement

The third movement sounds light, bright, and short. Shorter than the other seats which matches the character of this movement. The notes still reverberate past their end, but they are sound controlled by my air, and they do not seem to echo around in the space as much. The notes also seem to float and suspend themselves in the space less in this spot.

Recorder 3: Ground Floor, stage right

The architect Klous Toustrup noted that this would be the best seat in the auditorium for the acoustics.

I note that the sound is sincere, and somewhat quieter sitting under the balcony. The quiet notes of the crescendo feel quieter but so do the crescendos. I can hear the sound shift from each side of my headphone very clearly as I move around the stage during my warm-up.

First Movement

I hear the reflections and direct sound almost in tandem, but not exactly since the reflected sound lingers longer. There is not a lot

of ring to the sound. It feels like playing in a room at school. I know that this hall was inspired by the Sibelius, which seems accurate considering the sound more closely resembles it than the other halls. The range of notes all seem equally bright, equally resonant, and equally full.

The second movement sounds better suited to this space. The space makes the movement sound sad and wistful. The delicacy of the sound and the quietness of the space makes focusing on anything but the soft notes impossible. I am fighting turning the volume on my recorder up; the notes sound so soft on this balcony. I know the recorder is sitting directly on top of the wood balcony, since the seats would not support the recorder. I wonder if it would be even quieter behind the balcony.

The third movement also sounds sad; this might be because the attack of the note is softened by the reflections or the distance of my seat, lending more emphasis to the middle of the sound. The end of the notes here seem to disappear in the reflections. It's an eerie feeling to have to strain to hear when each individual note ends considering this section is faster than the other two. The playfulness is lost in the sound.

Conclusion Ratings

Musician Score:

Clarity – low (1)

Intimacy – medium (2)

Liveliness – high (3)

Spaciousness – high (3)

Warmth – medium (2)

Brilliance – medium (2)

Rating: 13/18

Audience Scores:

First Recorder

Clarity – low (1)

Intimacy – low (1)

Liveliness – medium (2)

Spaciousness – medium (2)

Warmth – high (3)

Brilliance – high (3)

Rating: 12/18

Second Recorder

Clarity – high (3)

Intimacy – high (3)

Liveliness – high (3)

Spaciousness – high (3)

Warmth – medium (2)

Brilliance – medium (2)

Rating: 16/18

Third Recorder

Clarity – medium (2)

Intimacy – low (1)

Liveliness – high (3)

Spaciousness – medium (2)

Warmth – medium (2)

Brilliance – low (1)

Rating: 10/18

Total

Clarity – (low, high, medium) 2

Intimacy – (low, high, low) 1.67

Liveliness – (medium, high, high) 2.67

Spaciousness – (medium, high, medium) 2.33

Warmth – (high, medium, medium) 2.33

Brilliance – (high, medium, low) 2

Rating: 13/18

Conclusion

The shoebox form, Nordic materials, and general technologies of the Musikhuset in Aarhus combine to create a powerful experience of amplified sound. The large space of stacked balconies works with its materials to bring the sound up to the highest balconies, successfully creating a forceful wall of music. While the on stage experience lacks some of the intimacy that smaller halls with more dampening materials or more controlled ceiling panels would provide, the liveliness of the hall still produces an enjoyable experience while on the stage, if not somewhat disorienting.

I found that it was difficult to perform at my best since I had a difficult time controlling and parsing out the sound. The sound did

not carry well to the balcony due to too much dampening in the hall. The HVAC noise was also too loud in the balcony, potentially due to vents being added so far away from the ventilation under the seating in the audience. The last issue was the heat of the auditorium, possibly due to the HVAC not being able to keep up with the summer heat coupling with the number of lights pointed at the stage. This interfered with my instrument, pulling the pitch sharp and making the performance somewhat unpleasant.

The audience experience was equal to that of the stage experience but in a different way. The reverberations in the auditorium seemed to be more distanced and softer than the fundamental sound, and the heavy curtains behind the seats absorbed some of the reflections that caused a lack of clarity. The wood tubs behind the stage and the narrowness of the stage created some awkward reflections that muddied the sound.[1]

The overall experience of performing on this stage was positive. The hall's level of amplification created an atmosphere of liveliness and spaciousness which did not inhibit the intimacy of the space.

[1] 1. Hung-Yi Lai and Wei-Hwa Chiang, "Generative Design of Terraced Concert Hall - a Case Study of Taipei Music and Library Centre," essay, in *Building Research & Information*, vol. 52 (New Taipei, Taiwan: Routledge, 2023), 49–67, https://doi.org/10.1080/09613218.2023.2256433.

National Forum of Music: History and Fantasy

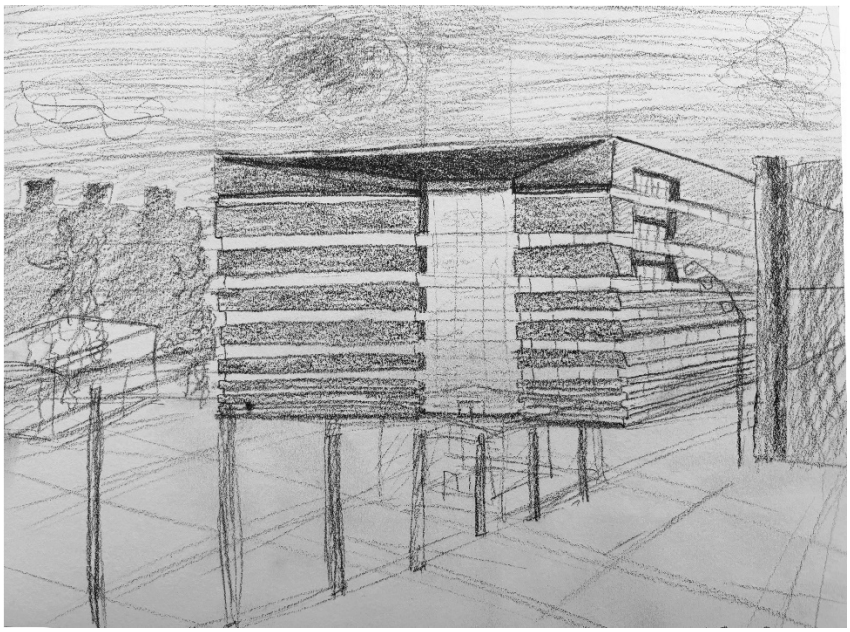

Fig. 1. On site sketch of National Forum of Music, Wrocław, Poland, 2024.

Introduction

Moreso than most of the halls I studied during this summer, the National Forum of Music(NFM) relies on the story of its history to fully understand its experiential and acoustic nature. The National Forum of Music sits on the Plac Wolności or what was previously the Royal Forum in the heart of historic Wrocław, Poland. The red-brown, metal box sits aside an entrenched moat that encircles the city and over a palimpsest of defensive wall ruins and a hidden world of gnomes. The Plac Wolności previously acted as an agora for Polish citizens outside of the original Sejm of the Silesian States to meet for art, culture, and markets. Before World War II, Wrocław was occupied by Nazi German forces and called Breslau. In 1945, the siege of Breslau, an incredibly bloody battle between the German and Soviet

Union, occurred in the square. Three months later, the Allied powers had won the war, pushed the Germans out of Wrocław, and granted the city back to Poland.[1]

As I walked through Wrocław with my tour guide, he pointed out small bronze dwarfs (also called gnomes or krasnale) scattered around nearly every building in the city. His stories about the fantasy and humor of the history of Wrocław brought the square I sat and sketched in to life. He explained the dwarfs, saying during the Cold War, Wrocław citizens artistically protested communism through a movement called the Orange Alternative. Students dressed as dwarfs and graffitied walls during the martial law period in Poland. Students stood up to the powers during peaceful protests in which students embarrassed police by telling them to arrest all the dwarfs and make them ask the students if they held an illegal meeting of dwarfs.[2] The square also has a partial glass floor near the museum entrance. I later learned that I had been walking over the ruins of fortifications from before that battle in 1945 that had been mostly destroyed but preserved in the square and alluded to in the design of the National Forum of Music.

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[1] "Wrocław," Encyclopædia Britannica, December 10, 2024, https://www.britannica.com/place/Wroclaw.

[2] www.media-d.com Media Designers, "The Orange Alternative," Pomarańczowa Alternatywa, accessed December 19, 2024, http://www.orange-alternative.org/material.php?tytul=pomaranczowa-alternatywa&wybor=232&zmianajezyka=angielski.

In 2005, an international competition was held to fill an empty space on the Plac Wolności; the task was to create a concert hall to return the square to an art forum as it had been before the siege of Breslau. Polish architect Stefan Kuryłowicz, an architect who held his doctorate in acoustics, won the competition and designed the National Forum of Music with equal regard for the history of Poland and the innovative forms of acoustics in mind.

Surrounded on one edge by a moat, the concert hall has a public and semi-private passageway into the interior. The more private path follows along the edge of a small cliff above the moat, lined with thick trees and benches. The public square is completely open, gridded on the stone ground and features protrusions of glass boxes that are elevators into the three underground levels of the NFM including an entire parking garage situated next to ruins and a museum. The 35,500 meters squared concert hall consists of four concert auditoriums, a recording studio, rehearsal rooms, conferences, offices, spaces for nursing mothers, an exhibition space, a grand entrance stair, restaurants, and a music shop.[3]

Not far from the site, the architecture in the Old Town center is an architecture blended between the old and new styles. Multiple occupations, destruction, and war has led to a liberality in architectural design and also an attempt by Kuryłowicz to create an object that contrasted historic design and blended with contemporary

[3] The venue, accessed December 19, 2024, https://www.nfm.wroclaw.pl/en/about-us/the-venue.

design to become a beacon to the city. The exterior material is called Prodema, which consists of layers of veneer glued together with resin.[4]

The façade depicts imagery of a music box or the soundbox of a musical instrument. This motif continues into the interior which resembles a piano; black and white Corian acrylic contrast in the foyer. The back of the concert hall darkly contrasts with white switchback stairs that outline a pit that sits at the bottom of a grand stair.

Fig. 2. Kuryłowicz and Associates, Axonometric showing the scale of the courtyard in front of the NFM, Wrocław, Poland, 2024.

[4] "The National Forum of Music in Wrocław," Culture.pl, accessed December 19, 2024, https://culture.pl/en/work/the-national-forum-of-music-in-wroclaw.

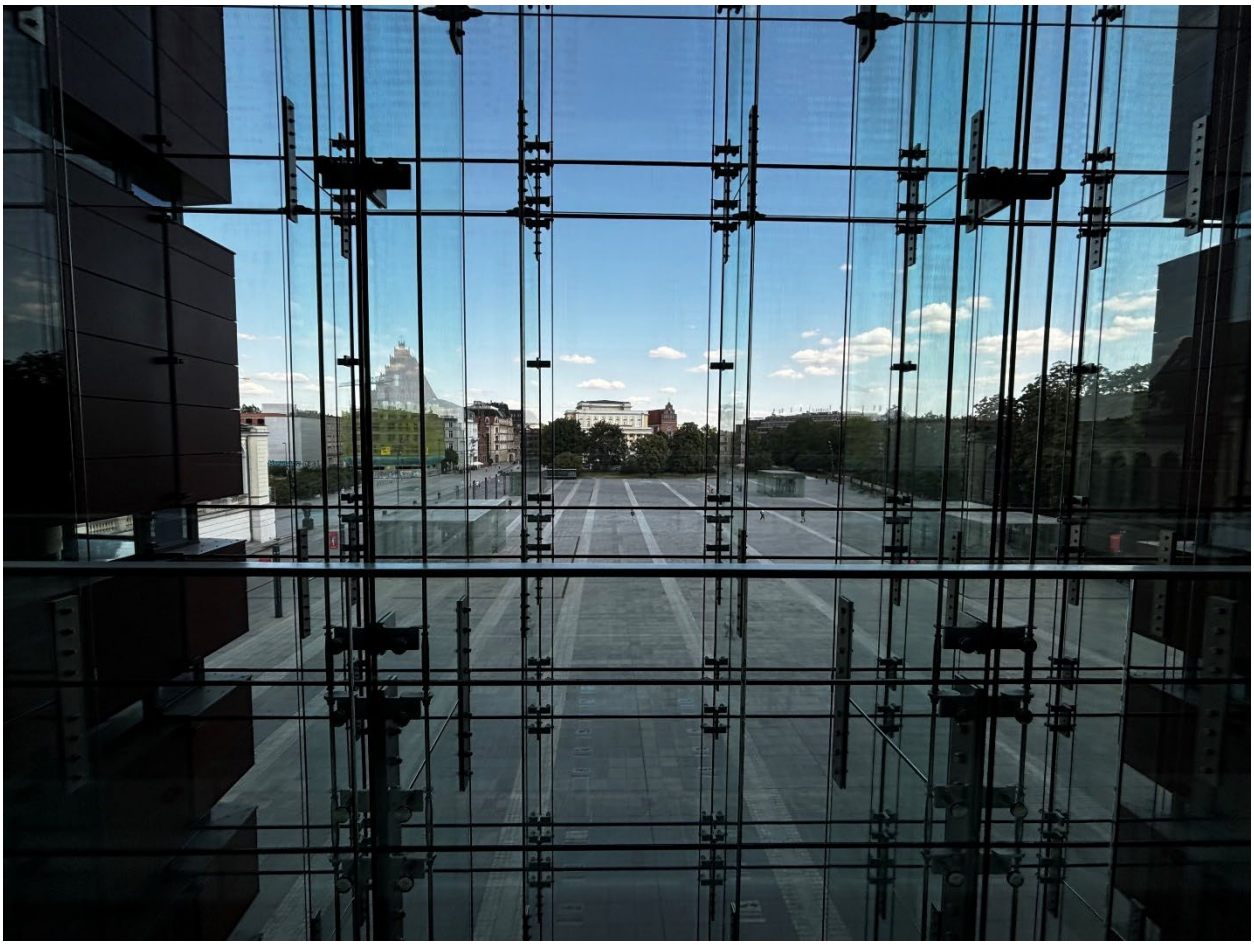

Fig. 3. Kuryłowicz and Associates, courtyard from the interior facing East, National Forum of Music, Wrocław, Poland, 2024.

Fig. 4. Kuryłowicz and Associates, exterior facing South, National Forum of Music, Wrocław, Poland, 2024.

Fig. 5. Kuryłowicz and Associates, exterior facing West, National Forum of Music, Wrocław, Poland, 2024.

Fig. 6. Kuryłowicz and Associates, interior of carved entrance, National Forum of Music, Wrocław, Poland, 2024.

Fig. 7. Kuryłowicz and Associates, interior of carved entrance facing the concert hall, National Forum of Music, Wrocław, Poland, 2024.

Form and Space

The National Forum of Music sits parallel to the moat and in a continuous line with the grid of the courtyard. When approaching the NFM, the building appears to be a box, not a rectangular prism. Although the auditorium rotates off the axis of the building, moat, and courtyard, it does not appear to be skewed because it aligns with the massive carved entry which leads one either down a grand staircase or up switchback stairs into the concert hall.

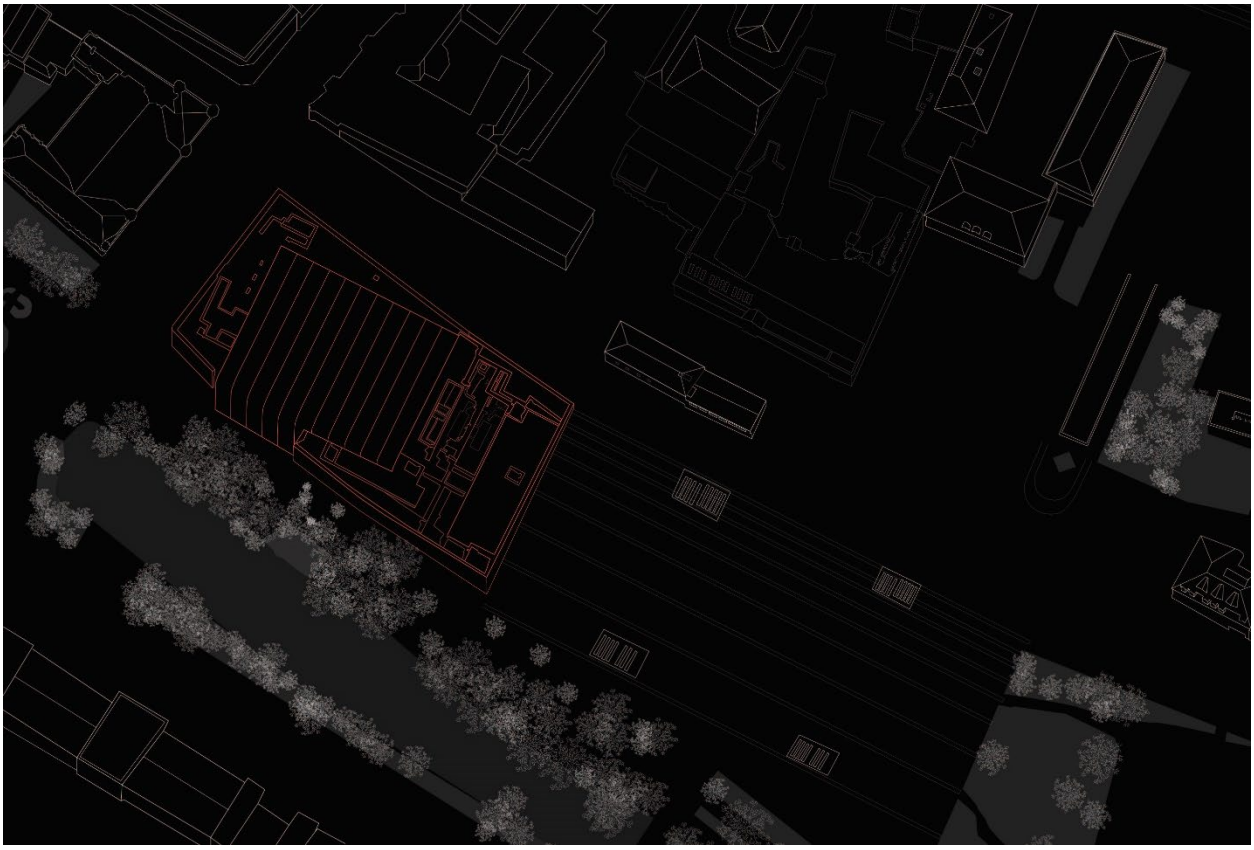

Fig. 8. Kuryłowicz and Associates, Site plan, National Forum of Music, Wrocław, Poland, 2024.

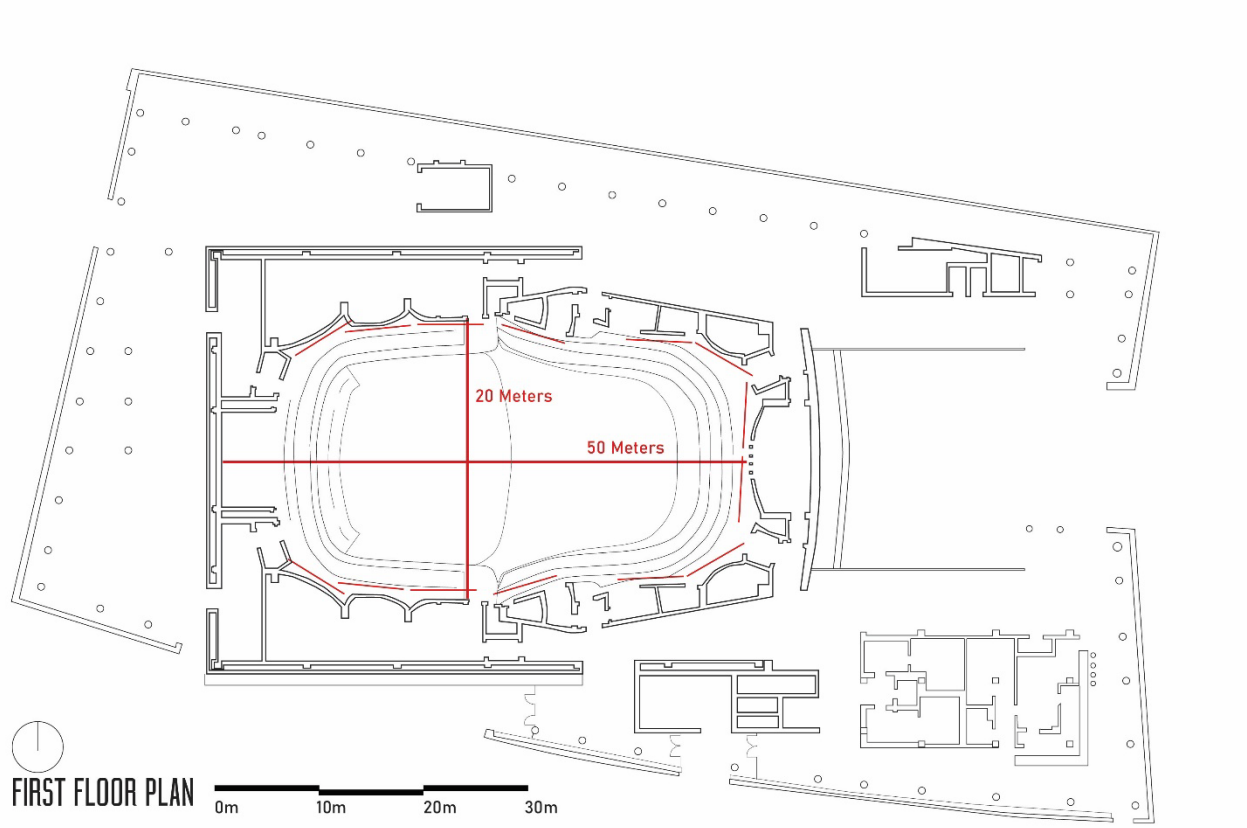

Fig. 9. Kuryłowicz and Associates, author reproduction of floor plan of auditorium, National Forum of Music, Wrocław, Poland, 2024.

When I entered the hall, I was immediately struck by its massive depth. The hall itself can seat 1,800 people and rises to six stories tall. Despite its massive height, the acoustic ceiling hangs down by delicate chords to obscure this height, and it was not until I was granted rare access to the sixth-floor balcony from which brave souls lower the massive speakers and changed the lights that I realized just how much distance separated the floor from the ceiling.

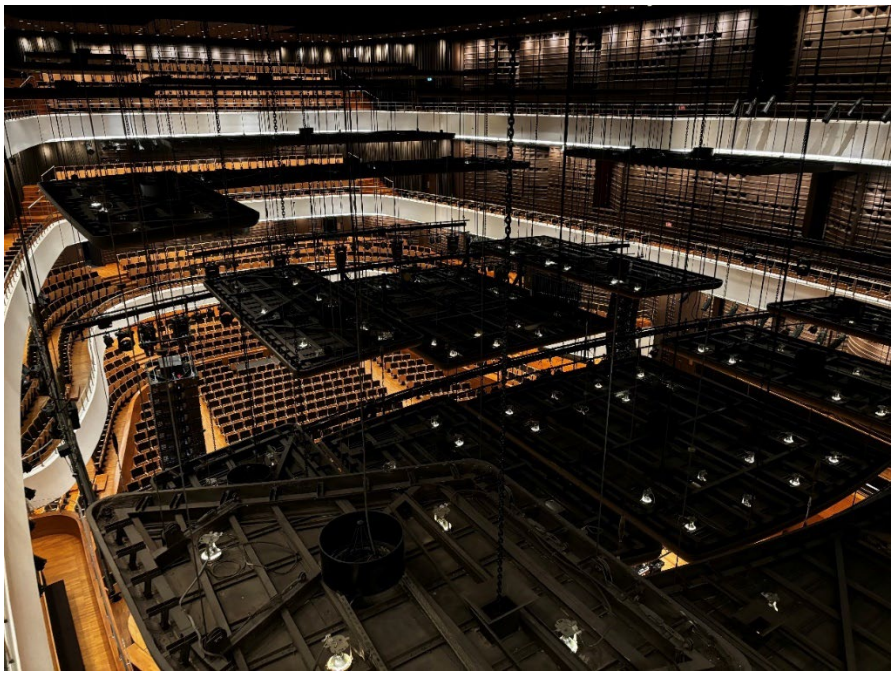

Fig. 10. Kuryłowicz and Associates, View from above the highest public balcony above the acoustic ceiling structures, National Forum of Music, Wrocław, Poland, 2024.

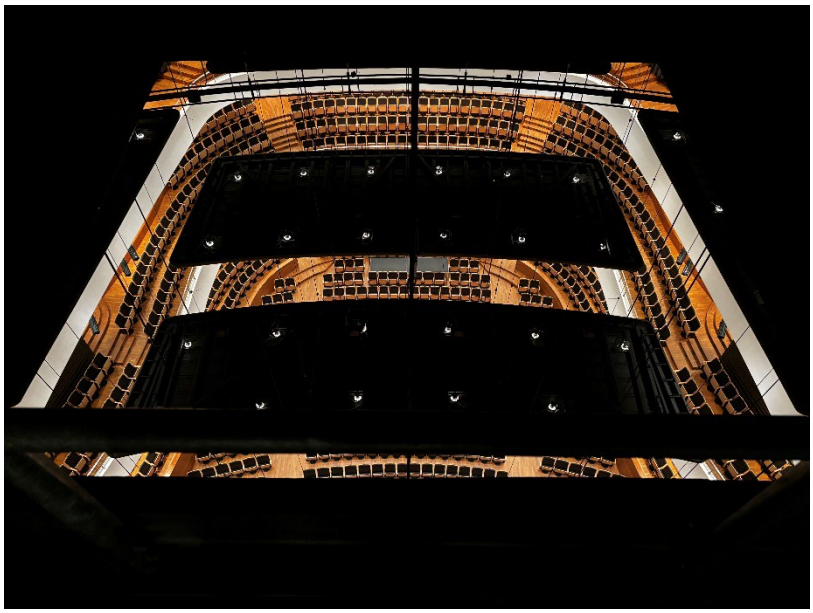

Fig. 11. Kuryłowicz and Associates, view from the work balcony above the auditorium, National Forum of Music, Wrocław, Poland, 2024.

The balcony in figure 11 extends into a space above the concert hall alongside HVAC ducts wider than I am tall and large trusses covered in insulated foam. This space, the height of an entire story, was crucial beyond the practical aspects of adjusting the acoustic technology. It was also a part of an isolation system that wrapped entirely around the hall which is a box-within-a-box construction method. This isolation dampens outside sounds, allowing for a neutral environment for an architect or acoustician to design the space to their exact specifications. The concert hall was isolated on each side by long hallways for circulation, and it was isolated underneath with a somewhat smaller space than the story above. This space underneath the auditorium was used for ventilation and to place the stage on lifts to both isolate the stage from any building vibrations and allow the stage to be reconfigured for different performance layouts. In a symphony setting, for example, the stage would be stepped with the brass in the back, then the woodwinds, and finally the strings would sit directly on the stage unelevated. This allows each instrument to project into the audience without being obstructed by the other bodies of the orchestra.

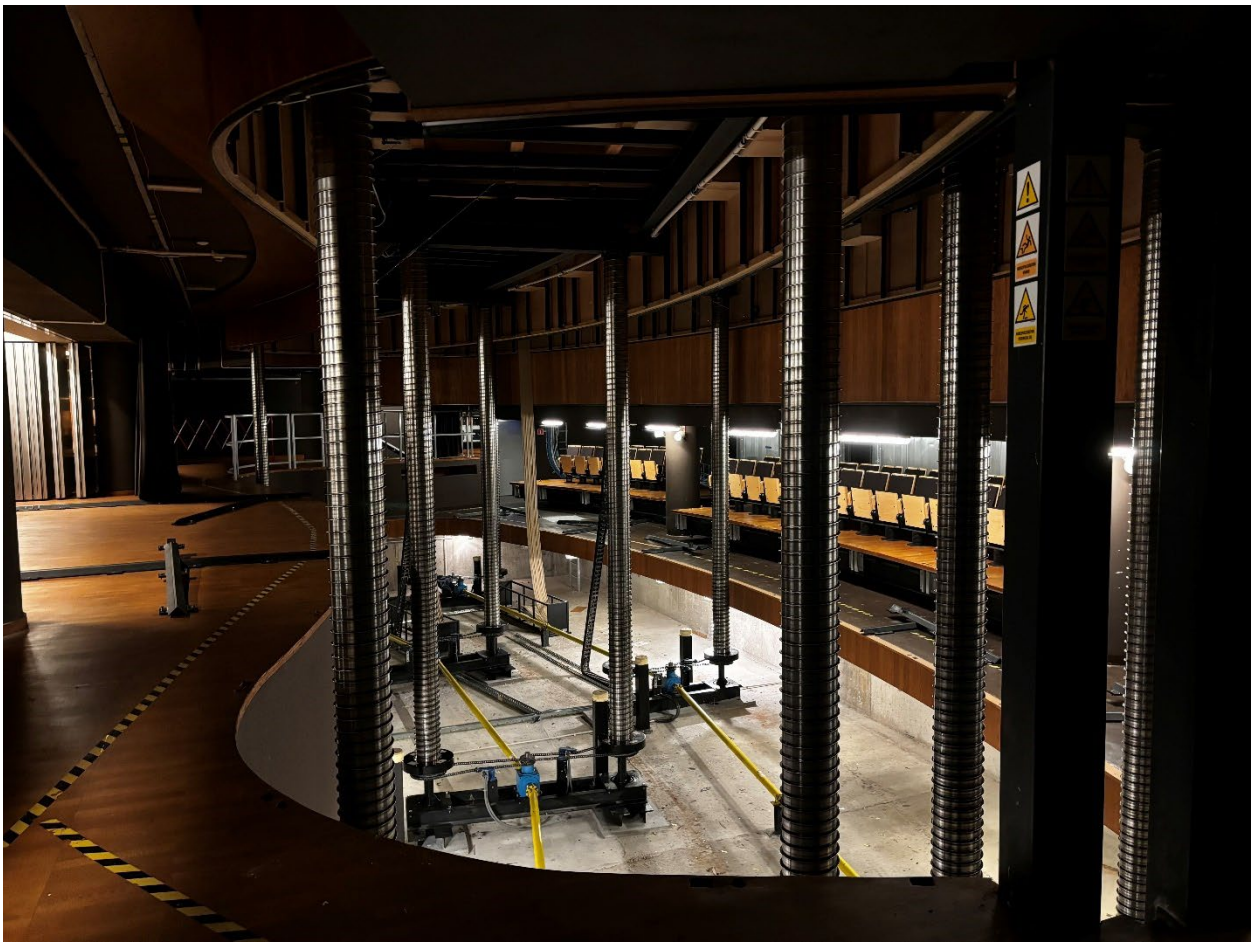

Fig. 12. Kuryłowicz and Associates, the lifts that elevate sections of the stage and isolate it from the surrounding structure, National Forum of Music, Wrocław, Poland, 2024.

The shape of the hall, a long rectangle with beveled edges, provides an example of how the architect, working with Artec acoustic consultants, shaped the hall to allow for the optimal acoustic experience. The massive size of the hall creates an equally massive challenge in dealing with echo. The architect rounded the edges of the balconies and created smooth surfaces to help the sound travel to the back of the hall and bring reflections closer to the audience as opposed to the sound hitting the back walls and ceilings and echoing

back. For the sounds that did make it to the walls behind the balcony, roughly textured and horizontally extruded wall panels acted as doors that could be opened to reveal heavy curtains when more dampening was needed like in the case of a full orchestra. The suspended acoustic ceiling was designed so that each panel could be moved individually as opposed to most systems which move in a unit. This was necessary because of the size of the hall. These panels projected out into the audience as opposed to staying only above the stage to help guide the sound to the balconies, which were over 20 meters away from the stage. The acoustic designer who guided me on a tour told me that this system is frustratingly complicated to use because of how many separate panels need to be adjusted to satisfy each performance. Because of this complication, I played on the stage in the harpsichord recording mode, not totally off from the sound of an oboe or the projection needed for a soloist.

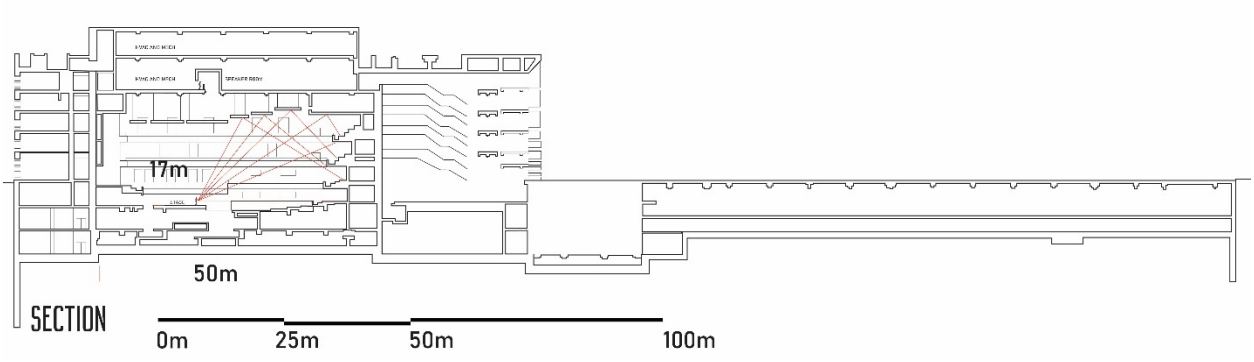

Fig. 13. Kuryłowicz and Associates, author reproduction of site section including courtyard, National Forum of Music, Wrocław, Poland, 2024.

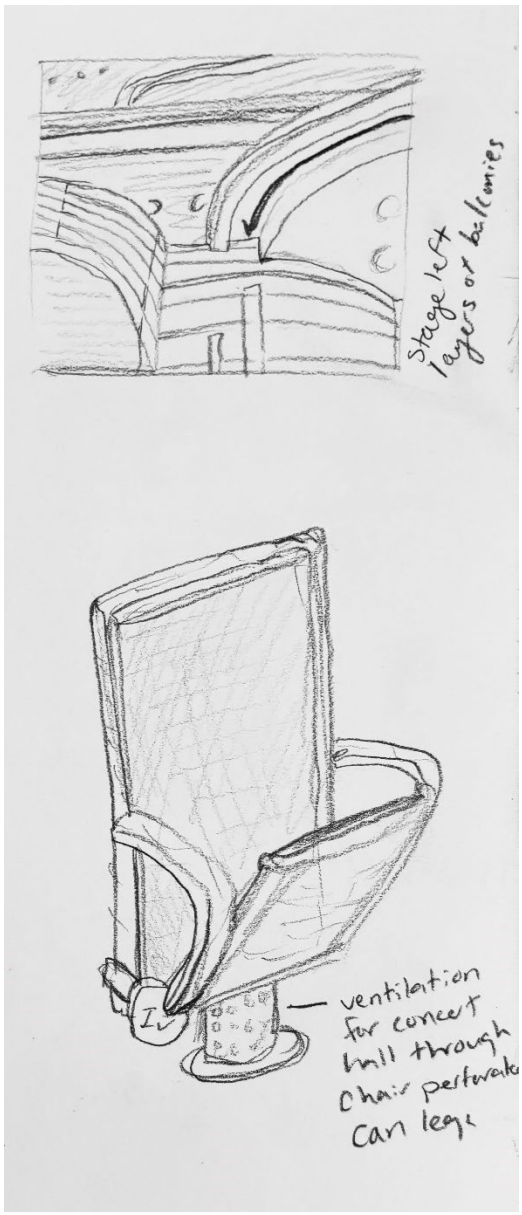

Fig. 14. Kuryłowicz and Associates, Sketch of the chairs and balcony layers onsite, National Forum of Music, Wrocław, Poland, 2024.

Materials

The stage of the auditorium was completely surrounded by different woods. Reddish wood panels lined the back and sites of the hall with small cracks to capture higher frequency sounds. The stage

was a soft light-colored wood that created a visual and acoustic warmth. Solid black walls with horizontal acoustic reflectors could be opened to reveal a series of reverberation chambers lined with thick, heavy red curtains.

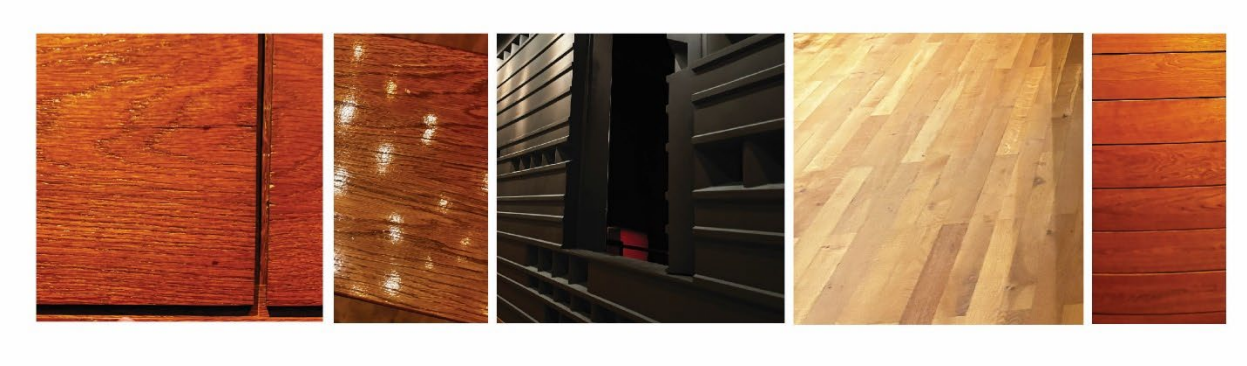

Fig. 15. Kuryłowicz and Associates, Materials used from left to right, stage wall wood panels, details in audience wood railings, metal acoustic walls, ash wood stage floor, and side wall wood panels, National Forum of Music Wrocław, Poland, 2024.

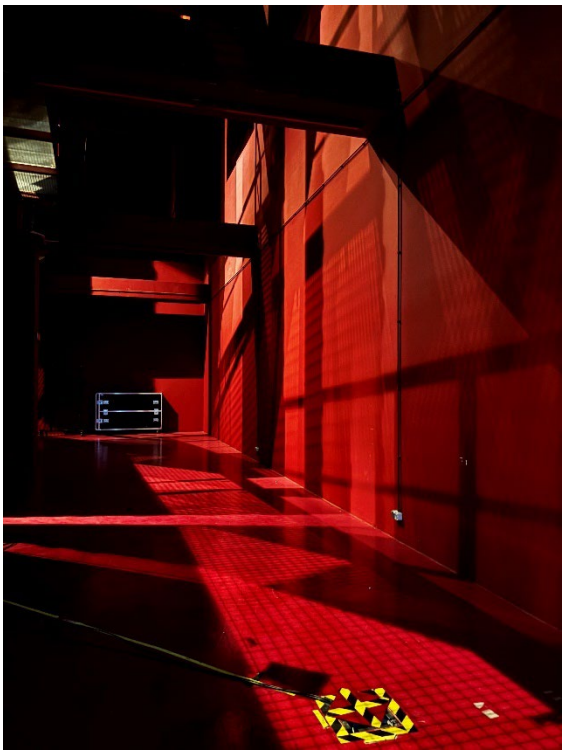

Fig. 16. Kuryłowicz and Associates, Reverberation chamber behind the acoustic walls, National Forum of Music Wrocław, Poland, 2024.

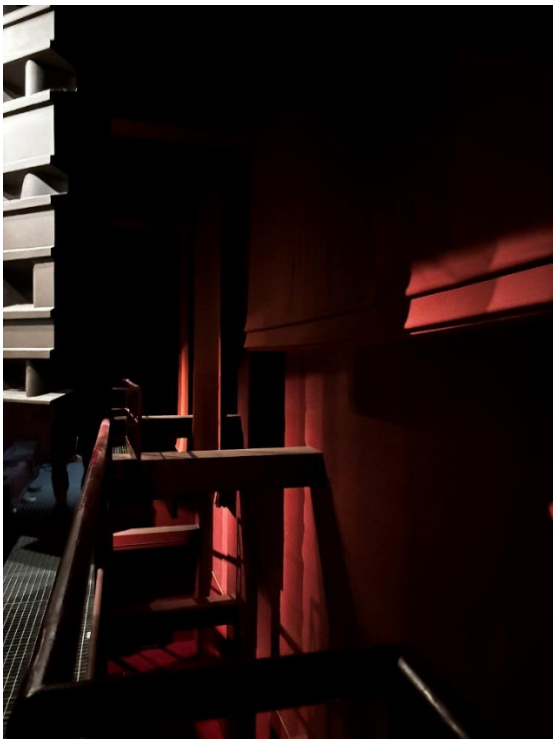

Fig. 17, Kuryłowicz and Associates, Acoustic curtains behind the heavy slat doors, National Forum of Music, Wrocław, Poland, 2024.

Fig. 18. Kuryłowicz and Associates, Auditorium with the lights off, National Forum of Music, Wrocław, Poland, 2024.

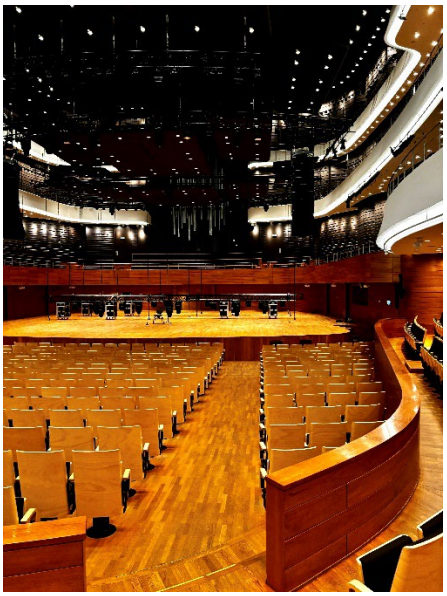

Fig. 19. Kuryłowicz and Associates, Auditorium with the lights on, National Forum of Music, Wrocław, Poland, 2024.

Acoustic Analysis

Walking onto the stage at the National Forum of Music was an immediate magical experience; from the variety of materials to the vastness of the empty audience and even the racing strips of LED lights under the balconies, every visual experience suggested I was about to have a life-changing experience.

The hall was not technically the quietest hall of my studies. I could occasionally hear the soft sounds of cars from outside and the hum of the massive air conditioning systems filling the immense room. The room while still and empty read on my Decibel X app as 26.8db as I stood completely still and held my breath. The room when full of silent people would likely be around 10 decibels louder, so achieving a reading under 30db in a room the size of a six story complex was impressive.

In this hall, I had to record myself snapping on my phone and analyze the snaps in a room that measured at 26 decibels on a later date. This was because the hall was so thick that there was no internet connection and no way to save any data on the Decibel X app. Therefore, the decibel high and low of the following graph are incorrect, but the shape of the snaps is still the same. In the auditorium, I measured my snaps to be a decibel high of 73.7 db and an average of 60.3 db.

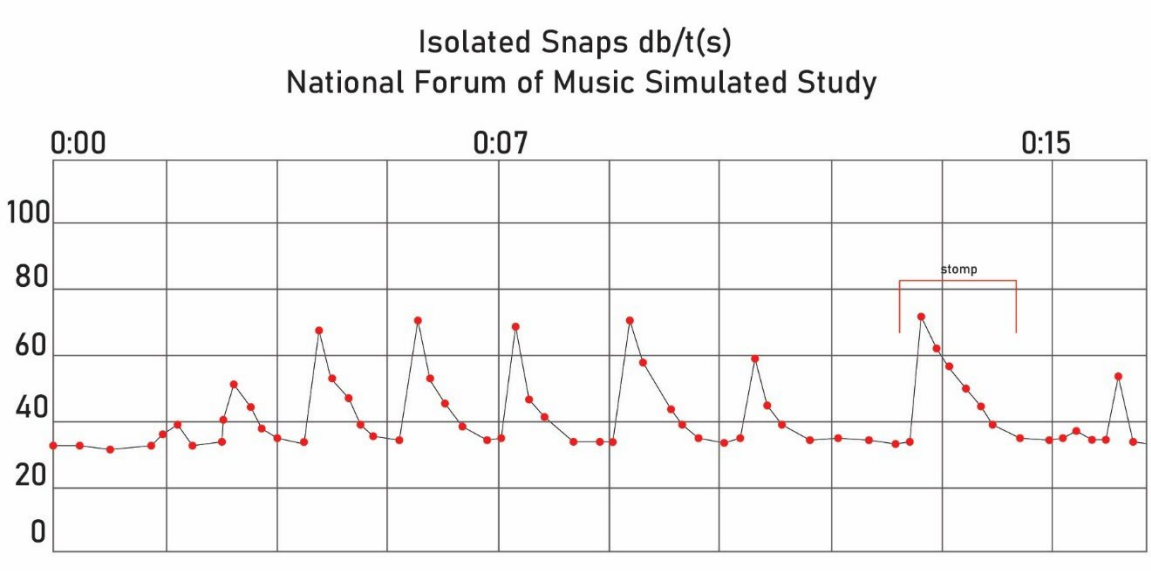

Fig. 20 Kuryłowicz and Associates, acoustic chart simulation showing the decibel reverberation pattern of singular finger snaps recorded on stage and measured in a quiet room, National Forum of Music, Wrocław, Poland, 2024.

Figure 20 shows a crescent shaped, elongated drop in decibels after the immediate snap. By looking at the slope of the period in between high and low peaks, this graph suggests that the hall has a longer reverberation time than typical as well as a gradual reduction of sound which would come across as smooth. While I listened to my snaps, I also found that the snaps seemed to linger, and I even noted at the time that it sounded like I heard five different reverberations of the snap each decreasing in volume.

After my warmup, I noted, "I fell in love playing on this stage. The reverberations sound so quiet, and the core of the sound is full and strong. The notes are warm and seem to ring somewhere far out in the distance. I walk around the stage while playing scales and

discover that playing near the walls results in more feedback and reflections than in the front of the stage.”

On-Stage Analysis

The first movement felt powerful and loud. The nuances in volume, crescendos and decrescendos are distinct and clear, creating a sense of spaciousness at the large volumes and a sense of intimacy in the quieter register. The notes overlap slightly, and the reverberations are not overwhelming although they are long. The shorter notes sound clear as do the trills (quick repetitions of two notes back and forth) and they ring out into the space creating a large sense of brilliance. The vibrato floats to the top of the auditorium, maximized by the space.

The second movement was my favorite to play in this space. This space sounds like it was made for drastic, legato sounds and long, connected notes. I can imagine a small orchestra with a single woodwind leading a solo and the soloist’s voice floating over the sound of the orchestra, while the symphony of instruments blends in the background.

The third movement rings well although the staccato notes seem to get muddled by overlapping reflections. The higher notes ring very well and stand out as bright against the lower notes in a nice way. They aren’t so bright they sound bad, just bright in a way that feels more distinct and triumphant. I can hear the attack and ring of each note, and I am curious if they will stay this clear in the audience or if they will become more muddled.

Post Analysis: Audience Zoom Recorders

Recorder 1: Ground Floor Audience, stage left

Warm-up

The sound cascades and falls in such an elegant way. The notes have a full, round sound to them full of warmth. I can hear my footsteps as I walk on stage while I play scales on either side and in the center.

In the first movement, the space amplifies the higher part of the sound, which instead of sounding uneven, sounds light and dancing. The lower notes ring, balancing the emphasis on the attack of the notes. The notes ring out in the space after playing them but are soft and decrescendo in the background. The crescendos are less amplified than in the previous space. The lowest note I play sounds more resonant and fuller bodied than the notes just higher than it in pitch. I can imagine that the brass instruments, which have a lower range than the oboe, sound loud and powerful in this space.

The second movement of the Marcello was so perfect for this space. The ringing between the notes and rests was the perfect length. The sound aggregates on the right side of my headphones. This occurs because the angle at which the audience sits on the sides of the concert hall turns towards the stage. The sound would hit the right side of the head a fraction of a second before it hits the left ear. The effect would be minimal to a general audience member.

The third movement, which sounds good in every space so far, sounds particularly magical in this space. I did not remember it sounding almost slower and more connected on the stage than in earlier

spaces, but from the audience, it almost sounds like I am slurring more notes than I actually am.

I started playing around with sound on the stage. I noticed that the high notes sounded like they sparkled, so I played the highest notes on the instrument, and imagined a piccolo trilling on the stage, not needing to worry about being heard over the orchestra or band.

Recorder 2: Choir behind the stage: stage right

Warm-up

The volume of my notes is considerably louder than on the previous recorder. The reflections have more body to them and are a bit more distracting from the main sound source. The notes are warm, clear, and vibrant.

The first movement rings out into the space. I cannot tell the difference between this spot and the ground level recorder other than this spot sounds louder. It does feel like being on the stage, but just slightly removed. I like the sound quality much more than I thought I would. The lower notes feel boosted by the space from back here, like I can feel the recorder vibrate from the lower frequencies. The crescendos come across as more powerful from this part of the audience.

Because of my intention to project my sound into the audience, the second movement feels a bit louder and more powerful from this position than I intended it to sound once it has reached the audience. I can hear my adjustments to play louder to fill the space than I usually would at the start of this movement. The crescendos are still audible, but the softest part of the crescendo does not sound as quiet

as I intended while I was playing. The trills sound clearer from this position than out in the audience.

The third movement still lacks some of its staccato from this position. I do not like this movement as much from this location. It feels like the reflections are closer to the sound than out in the audience which muddles the clarity. This is due to the placement of the choir behind the stage.

Recorder 2: Third Balcony: stage left

Warm-up

The sound seems to float across the audience to the ears but also seems delayed from the initial sound.

The sound echoes from multiple points after the direct sound reaches up to this point in the audience. The direct sound feels right in front of me and the reflections are soft and far away. The sound feels like it settles below me. The higher notes sound delicate and magical while the lower notes feel more full-bodied. The higher notes sound less warm at this height, but the lower notes still sound warm and brilliant. The notes are coming across more legato than staccato or tenuto because of how much overlapping sound there is. The crescendos are less pronounced this high up but still noticeable.

The second movement, which has notes being held legato has an effect of total overlap where it sounds like the notes I am playing are sitting in the middle of other notes. It almost sounds like multiple instruments are being played at once, at least until a note held for longer than a beat occurs, in which it becomes more singular and clearer. I feel like I can hear the sound bouncing off objects and

hitting my ears at multiple different angles. This is likely because the third balcony seats are higher than the acoustic canopy.

The third movement sounds magical from this height. Staccato notes are coming across longer and connected. The third movement makes me realize that this concert hall feels less intimate and more spacious. From this height, the direct sound exhibits clarity and brilliance, but each reflection feels far away, softer, and longer. The hall surrounds the listener with the music at all spots in the audience, but it had to overcome the obstacle of its size, which was not perfectly overcome in terms of intimacy.

Concluding Ratings

Musician Score:

Clarity – Medium (2)

Intimacy – Medium (2)

Liveliness – Medium (2)

Spaciousness – High (3)

Warmth – High (3)

Brilliance – Medium (2)

Rating: 14/18

Audience Scores:

First Recorder

Clarity – Medium

Intimacy – Medium

Liveliness – High

Spaciousness – High

Warmth – High

Brilliance – Medium

Rating: 15/18

Second Recorder

Clarity – Low

Intimacy – High

Liveliness – Medium

Spaciousness – High

Warmth – Medium

Brilliance – High

Rating: 14/18

Third Recorder

Clarity – Medium

Intimacy – Medium

Liveliness – Medium

Spaciousness – High

Warmth – Medium

Brilliance – High

Rating: 14/18

Total

Clarity – (Medium, Low, Medium) 1.67

Intimacy – (Medium, High, Medium) 2.33

Liveliness – (Medium, Medium, Medium) 2

Spaciousness – (High, High, High) 3

Warmth – (High, Medium, Medium) 2.33

Brilliance – (Medium, High, High) 2.67

Rating: 14/18

Conclusion

The massive size of the hall and the echoing and high reverberant acoustics set a challenge for architects at Kuryłowicz and Associates, but I believe the sound emphasizes and adds to the fantastical history of Wrocław creating a magical and awe-inspiring experience on stage for a soloist.

The reverberation of the hall seemed further away from the stage, providing an enjoyable experience on stage while keeping the notes clear. The distance between the stage and back walls created delays in the sound that contributed to a sense of spaciousness, but the low ceiling and the softness and prominence of the wood material absorbed any near reflections that would have caused multiple layers of sound to be heard at once.

The criticisms of this hall are that reflections being too close together in the choir space behind the stage muddles the clarity making these seats less enjoyable than the seats in front of the stage. The reverberation connects the tail ends of notes too closely, causing short, staccato phrases to sound connected. Also, the seating above the canopy, while allowing more people to enjoy the hall, does not provide the best experience due to the notes reflecting multiple

times too closely together and resulting in what sounds like multiple notes being played at once.

Overall, this was the most enjoyable stage for the subjective experience of a musician.

National Sawdust: Community First

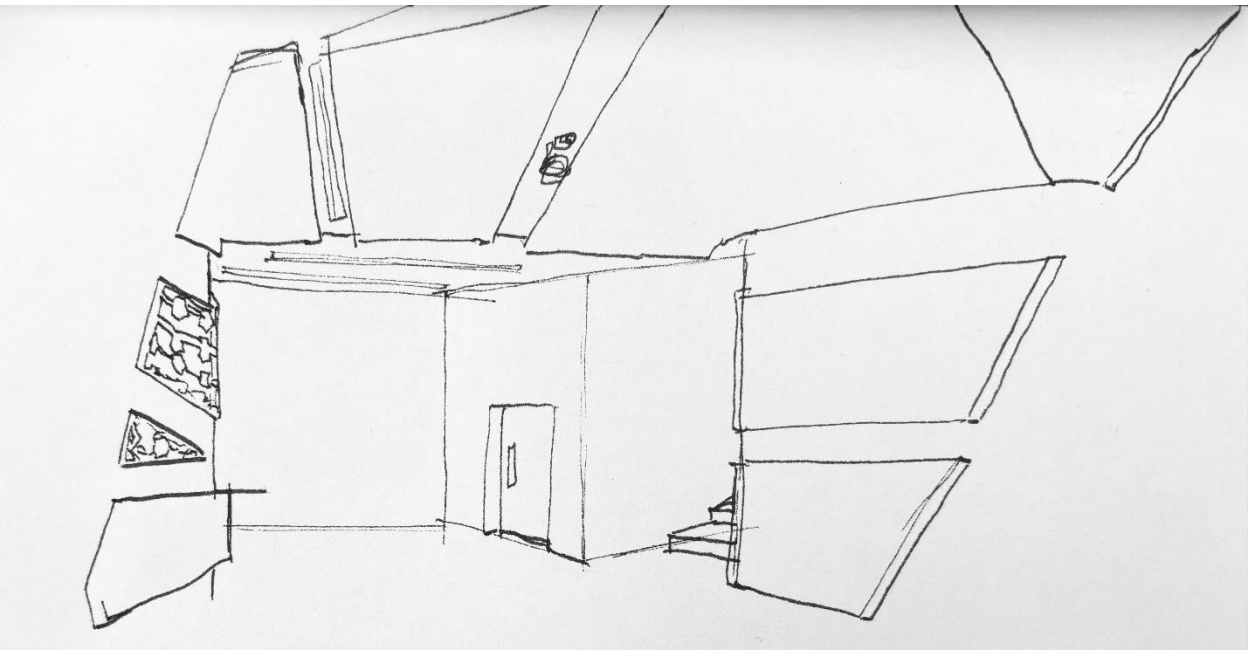

Fig. 1 Sketch of entrance to National Sawdust performance space, Williamsburg, Brooklyn, 2024.

Introduction

The heavily graffitied, brick building in the heart of Williamsburg, Brooklyn sits in between the water edge boardwalk that gives one of the best views of Manhattan, the underground L that connects the two burrows. The brick block is out of place surrounded by glass and metal facades of residential construction. The National Sawdust, once a sawdust mill in the late 1920s, is situated on a corner so that from one street view it reveals only its graffitied brick wall with a hidden door and the perpendicular street, which leads directly to the water has a coffee shop and a box office carved into its thick façade. Entering the heavy door on the brick wall side feels like walking into a cave; the bright New York summer light

glaring off of pale sidewalks makes the eyes have to adjust to dark, black, jagged walls and ceiling, which feels like a dark hole.

Fig. 2. Bureau V, entrance to National Sawdust theater with the door open, National Sawdust, Williamsburg, Brooklyn, 2024.

The National Sawdust was a retirement project of Kevin Dolan, a New York tax lawyer and composition admirer. In 2008, Dolan came up with an idea for a nonprofit that supported young composers; his

"philanthropic investor model" enticed philanthropists with the skyrocketing values of surrounding big, glass residential buildings and a budding Williamsburg. The National Sawdust has since appreciated 3 or 4 times in value, an auspicious outcome for a building attempting to sustain the arts.[1] The project focuses on the development of young musicians, giving them commissioning support and opportunities to be mentored and on small, indie, opera, rock, or punk artists. It's goal is to attract patrons of the arts and loyal commissioners, not fans of certain musicians. The goal is to be a refined, small concert hall with the experience of a rock concert and excellent acoustics. Kevin Dolan says, "this is a way to maintain the culture of live performance for types of music that would otherwise not be sustained and introduce patrons to music that they would otherwise never hear."[2]

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[1] Katherine Flynn, "A Second Act for a Former Factory at Williamsburg's National Sawdust: National Trust for Historic Preservation," A Second Act For A Former Factory At Williamsburg's National Sawdust | National Trust for Historic Preservation, May 3, 2017, https://savingplaces.org/stories/a-second-act-for-a-former-factory-at-williamsburgs-national-sawdust.

[2] Fixsen, Anna. "National Sawdust." Architectural Record RSS, November 6, 2019. https://www.architecturalrecord.com/articles/11370-national-sawdust.

Fig. 3. Bureau V, coffee shop and ticket box, National Sawdust, Williamsburg, Brooklyn, 2024.

Form and Space

Through an angled entry and large door, emerges a spectacular, small room that is the performance space of the National Sawdust. It smells a little musty but it is cool, air conditioned and softly hums from the sound equipment in its ingle, half wrapping balcony. The

white, laser-cut, polygonal aluminum panels are stark against black acoustic mesh lining the walls which makes it appear as if black, continuous streaks are slashing through the panels. The pale, wood floor would feel out of place if you could remember to look down at it. The stage is lifted a few feet off the ground by steel, industrial scissor lifts in rows under the thin stage. It looks almost too thin to stand on and it creaks as you jump up onto it before you realize there is a small set of black stairs tucked away on the side of the stage.

The control booth at the balcony level has operable walls that change for live or recorded performances. The geometric custom-fabricated wall panels are cut from aluminum and lined in the back with high-end speaker fabric. The materials give a 65 percent openness which was decided by the computer modeling tools in Arup SoundLabs.[3] Behind each panel are acoustic curtains hidden behind the acoustic transparent panels which allow musicians to fine tune the room to their individual needs. The room is 100 feet long, 50 feet wide, and a minimum ceiling height of 25 feet, although I felt in the space like it was shorter than that.

The hall is a box-in-box construction method crucial because of the nearness of the L subway and the reliance on the hall as a recording studio. The building is meant to work holistically to control and mitigate sound; the mechanical system supplies air at low

[3] "All Projects," Arup, accessed December 20, 2024, https://www.arup.com/projects/national-sawdust.

velocities and the light fixtures are designed to give off no humming which I can attest to; I walked right up to the slanted tubes of light tucked in between the white panels and heard nothing. Inside of the brick façade and geo-crystalline obsidian angled walls are multilayered 8-inch concrete slabs that insulate the interior concert hall space from exterior noise and vibrations by isolating the space on a "chassis of springs."

A ten-foot by ten-foot, two-pound door from London designed by Arup acoustics works also to isolate the sound acoustically. The Arup SoundLab in New York was used to computer analyze the acoustics in the volume of the room and allow the team and Dolan to fine-tune and decide on the acoustics of the venue.[4]

[4] "All Projects," Arup, accessed December 20, 2024, https://www.arup.com/projects/national-sawdust.

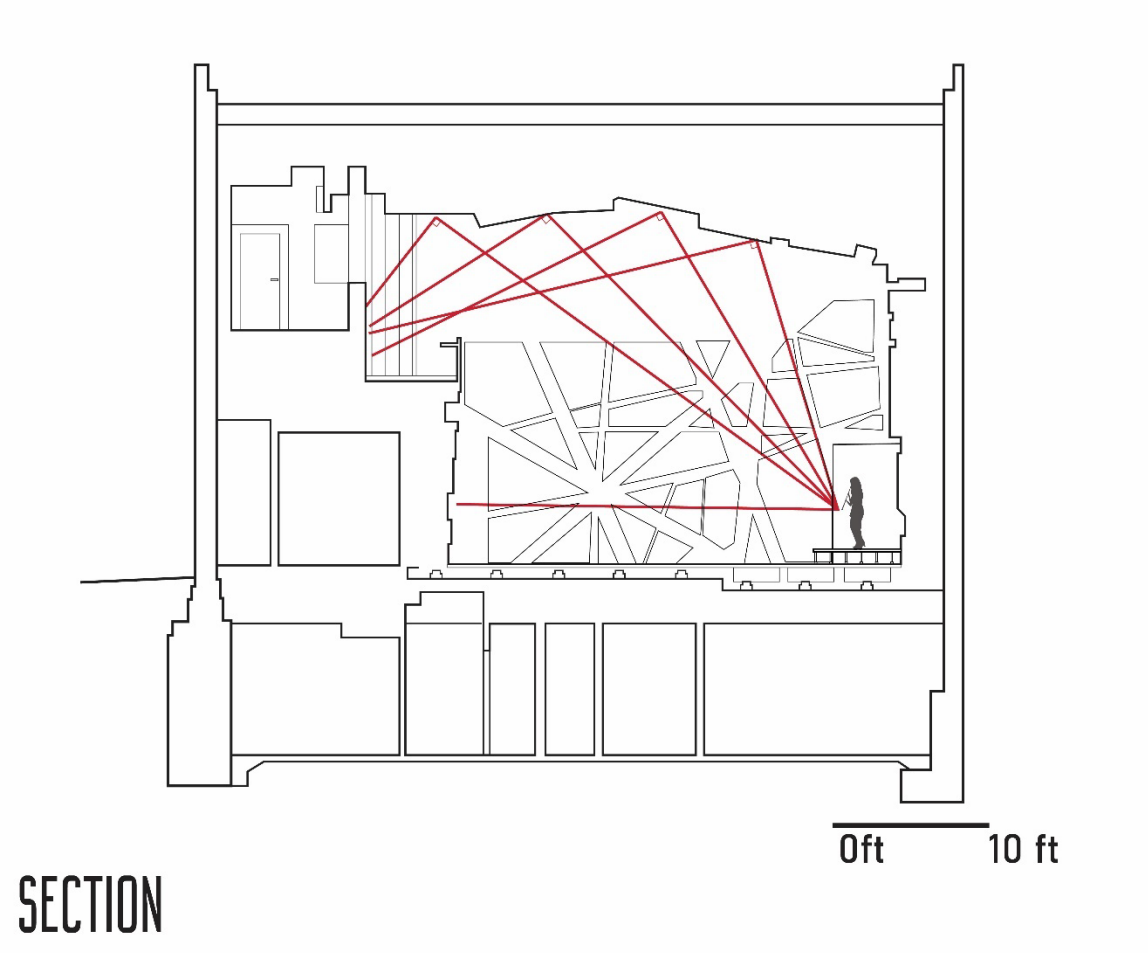

Fig. 4. Bureau V, author reproduction of section of the National Sawdust, National Sawdust, Brooklyn, New York, 2024.

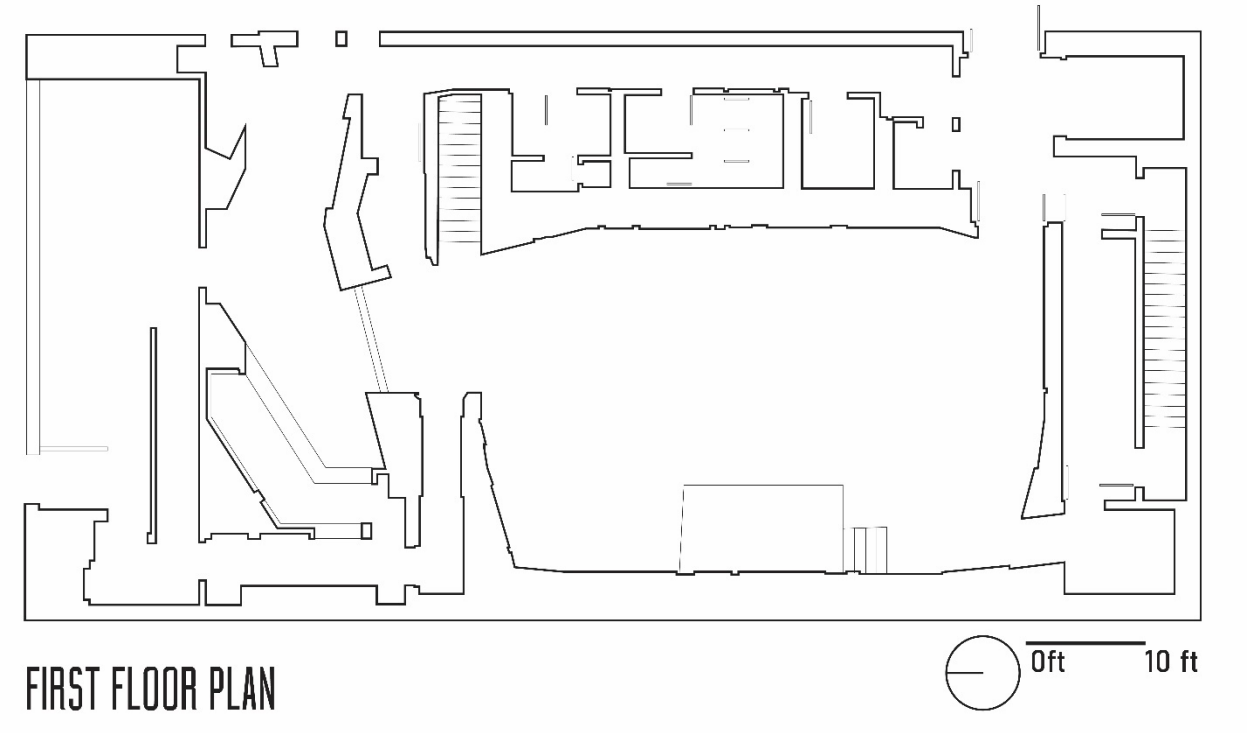

Fig. 5. Bureau V, author reproduction of first floor plan of National Sawdust, Brooklyn, New York, 2024.

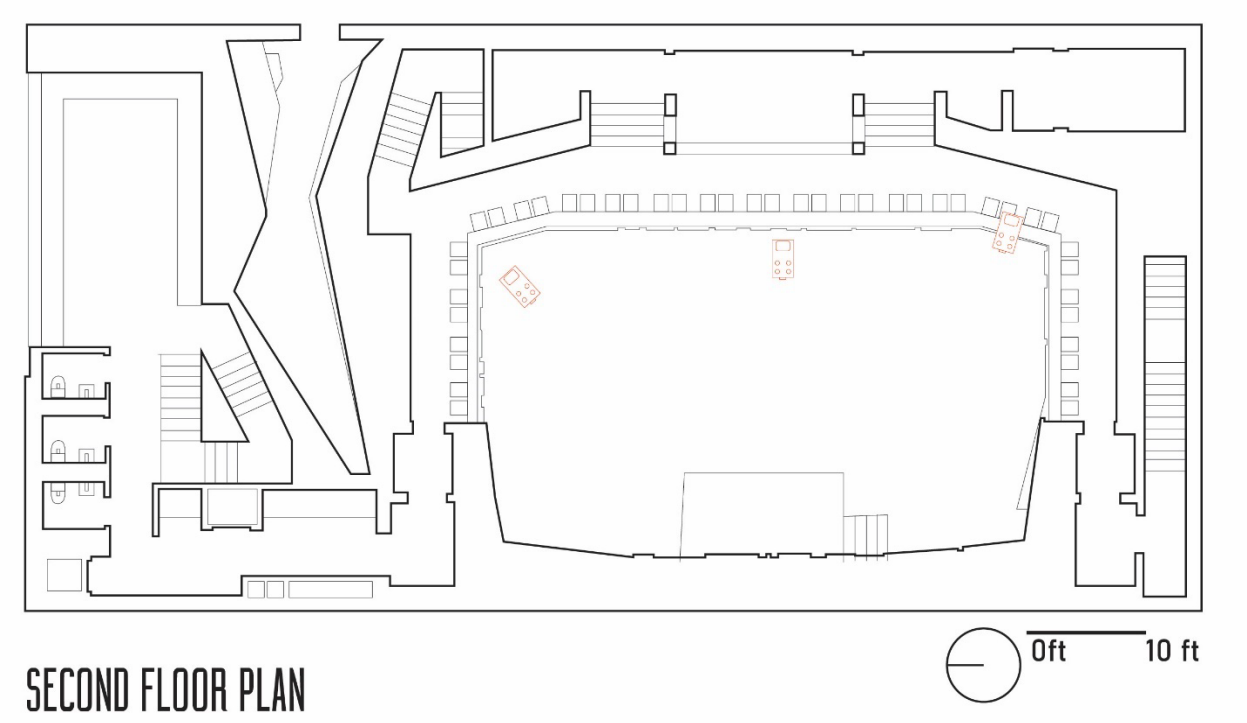

Fig. 6. Bureau V, author reproduction of second floor plan of National Sawdust, Brooklyn, New York, 2024.

Fig. 7. Bureau V, interior of National Sawdust taken from balcony, National Sawdust, Williamsburg, Brooklyn, 2024.

Fig. 8. Bureau V, interior showing upper balcony above entrance and angled ceiling, National Sawdust, Williamsburg, Brooklyn, 2024.

Fig. 9. Bureau V, interior from stage towards the upper balcony, National Sawdust, Williamsburg, Brooklyn, 2024.

Materials

The most important material used in the performance space is the aluminum laser cut white panels. These panels are important to the reflections of the sound. Since the room is small and rectangular, the perforated panels control echo and flutter acoustics by redirecting sound waves.

Behind these panels sits an acoustic fabric that absorbs the sound that is not reflected. This decreases the overall volume of the sound in the space as well as capturing multiple reflections to completely obliterate flutter acoustics. Wall panels are metal with a soft lining fit behind the hollow shell.

The floor is all on isolation springs, and the stage is raised about two to three feet on these sort of scissor lifts.

The wood floor stage and balcony railings add both a visual and acoustic warmth to the space by softening the stark black and white color palette as well as absorbing sound.

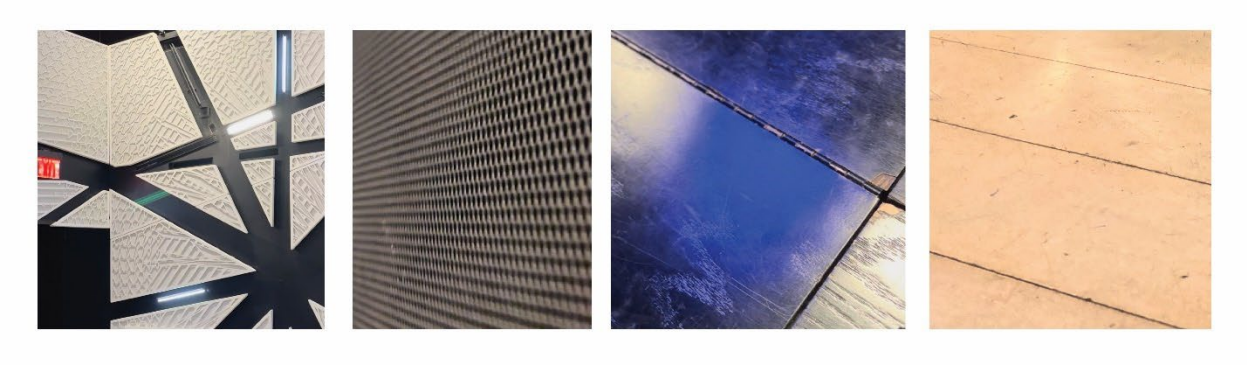

Fig. 10 Bureau V, textures in National Sawdust left to right laser-cut aluminum backed with speaker fabric, upstairs textured wall, wood balcony lip, wood floor/stage floor, National Sawdust, Brooklyn, New York, 2024.

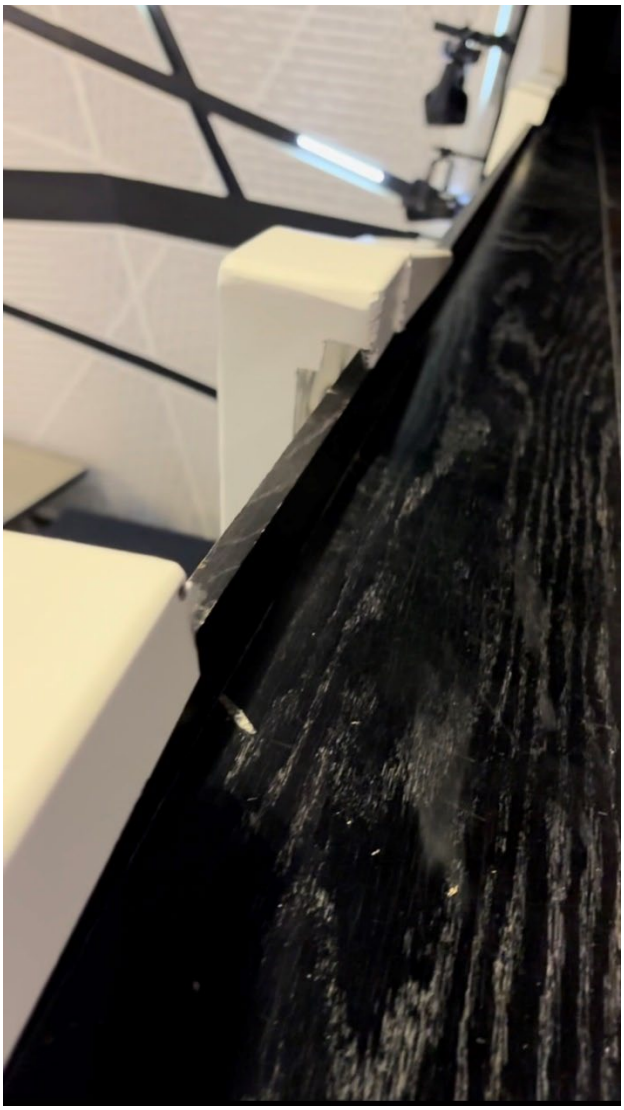

Fig. 11. Bureau V, detail showing how white acoustic panels attack to upper balcony, National Sawdust, Williamsburg, Brooklyn, 2024.

Acoustic Analysis

This venue has a highly adjustable set of microphones and electric settings that drastically change the sound of the hall to match the instruments and number of musicians needed. Before I started performing in the space, in the deadness of the quiet room, only the hum of the air conditioning stood out to me. As the operator

introduced me to the room, he ran up the stairs to the balcony and into the audio booth. He started changing the control and clapping loudly as he asked which setting I would want. I said, "what do you have?" He flipped in between settings so quickly, I was astonished. Recital mode has a one second reverberation time, and this was the setting I chose. Other options included chamber mode, 1.4 second reverberation time; piano; cathedral; large concert; and small concert, all with much longer reverberation times.

The room at its quietest was the loudest one of this research with a minimum Decibel X reading of 36db. The average decibel reading was 62.5db, and the maximum snap decibel reading was 80.9db.

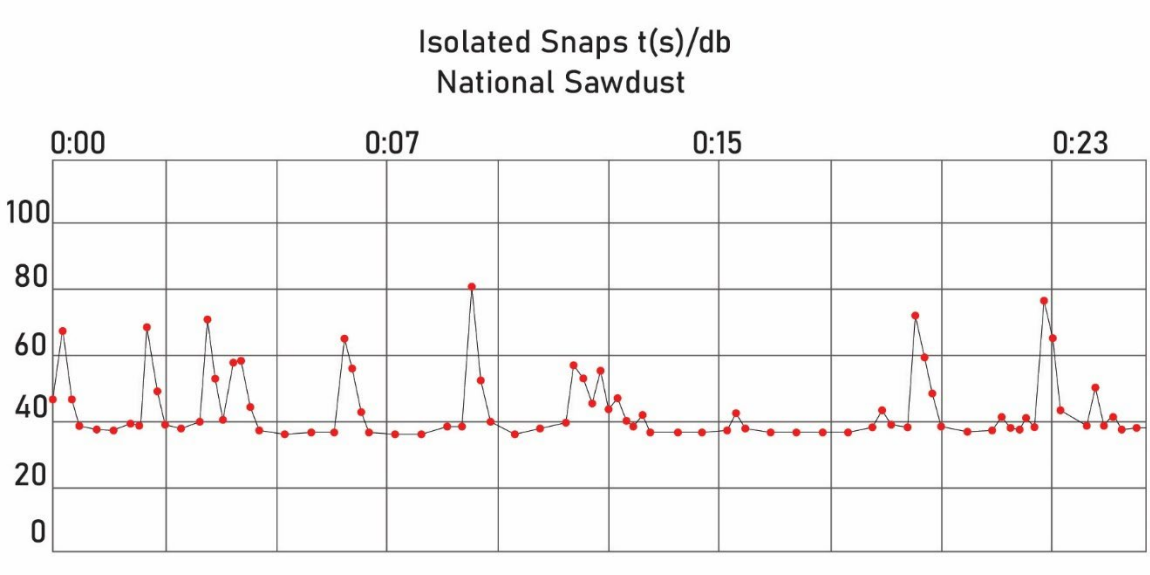

Fig. 12. Bureau V, Acoustic chart showing the decibel reverberation pattern of singular finger snaps in a quiet auditorium, National Sawdust, Williamsburg, Brooklyn, 2024.

On-stage Analysis

The hall is essentially made to sound as dead as possible to drown out the outside noise of Brooklyn, which especially at night, hosts parties, bars, sirens from ambulances, and cars.

Playing in this room made the technology make sense- each note is followed quickly by the same note played back at you. This creates a "me and them" experience where I can imagine what I hear on stage will likely be different than what the audience hears.

The note played back wasn't so quick you'll miss it, but it was close. It was brighter and less full sounding than what I felt on stage. It took me a second to get used to it. I enjoyed playing here although empty, the hall feels cool but lifeless- this is certainly a hall for people.

Post Analysis: Audience Zoom Recorders

Recorder 1: Stage Right by the Staircase

Warm up

The sound seems to be very dead and dull and almost retreats into the hall. The higher notes are bright and brilliant while the lower notes are very warm. The crescendos are even sounding and clear.

First movement

The air conditioning is so loud. This feels like I am playing at home except more clear and open, less dampened. Very clear notes across both the higher and lower registers. The notes are perfectly brilliant and ringing the exact amount. Very American. Short and clear and consie. The notes do not run into each other or abut. What I attempt to play is what is heard. Vibrato is more clear than in previous

halls.The lower notes have some brilliance to them in that they ring well. You can hear their overtones.

Second movement

The second movement from the staircase floor seating reads too lively as if it more dampening material could have been used. The notes are not facing any resistance from the space, which means they are ringing in a fashion that is not best supported by this sound setting. It desires more reverberation. The warmth in the lower notes transmits here. The space is so small and intimate that clarity is inevitable.

Third movement

I like the third movement here. The warmth is the perfect level to add some moodiness to the movement without taking away the lightness of it. The notes do not congeal and run together; they are perfectly separated, ringing out, and lively.

Recorder two

Balcony stage left, next to the mechanical room- (recorder number two)

The sound during the scales sounds so far away, but very clear. I feel more inside the lower notes. The higher notes sound further away, and the lower notes sound like they are surrounding my audio recorder up on the balcony. The crescendo is way more impactful up here than down on the ground. The first movement already sounds like it has more impact and emphasis on the notes up here on the balcony compared to on

the floor. In the recording, it feels like the sound is below you. The recorder is placed right next to the mechanical room, and the sounds from that room are pretty obvious on the recording. The reverberation is more obvious at this level than on the ground, which is interesting. The vibrato is also less clear than it was on the ground.

The second movement lacks some of the clarity that derived from being closer to the stage on the ground level of the auditorium. I prefer the first movement on the balcony, but I preferred the second movement on the floor. The sound is more pronounced up here, less soft, more powerful and amplified which adds a sense of drama to the second movement.

Movement three has more energy in the notes up on the balcony than it did on the lower floors. The notes ring a bit more than on the ground, and they lose some of their clarity but are still separated enough to hear the individual notes. Overall, I would describe this as having less clarity than the floor of National Sawdust but more clarity than the larger concert halls. I like the way the third movement sounds better than the second movement in this location as well. The lower notes have more body and warmth to them than the higher notes. The also resonate for a bit longer than the higher notes. As I walk around the stage, the reverberation does seem to change slightly based on where I stand. Maybe the technology used to control the sound is affecting the timbre of the sound; the timbre is more mellow and less bright and lively.

Recorder 3: center stage, center of floor

The scale sounds quiet and bright from the ground (which is a bit lower than the stage).

The crescendo is less obvious and more subdued at this setting. The higher notes lack some of the ring that they should have. This point in the audience sounds like being below the sound, as if the initial sound and reflections are going up above the ground floor's head. This is likely because of how short the room is and that every floor spot is a few feet below the stage. According to figure 4 the sound waves seem to travel up and bounce into the balcony.

The slower second movement sounds better than the first movement in this space. The sound lingers a little longer on the more legato notes than on the shorter, peppier first movement but still maintains brilliance. The vibrato and trills come through clearly and are not muddled by the space or overlapping reflections on the ground level. It sounds like when I am performing for my professor in a classroom setting. This reverberation setting (1 second) allows the solo sounds to be very transparent and clearly articulated; it is easier to hear mistakes and errors but also easier to hear the piece of music.

Movement three sounds better than movement one, despite having shorter notes. The space does not imbue energy into the notes; as I am playing, I realize I have lost that handicap from previous halls and must add more effort into giving the notes energy. There is so much clarity in between the notes that I can hear the starts and ends of the notes, as it should be, but I can also hear some fuzziness that I assume is air conditioning running in the background as I play. As I walk around the stage and play some long tones, the tone and

reverberation do not change which I assume is due to the acoustic controls set up in the room.

On stage

Clarity - high

Intimacy - high

Liveliness - medium

Spaciousness – low

Warmth – high

Brilliance – high

First Recorder

Clarity – high

Intimacy – high

Livliness – medium

Spaciousness – low

Warmth – high

Brilliance – high

P4- second recorder – where it is – ranking the:

Clarity – high

Intimacy – high

Livliness – high

Spaciousness – medium

Warmth – medium

Brilliance – high

Third Recorder

Clarity – high

Intimacy – high

Liveliness – low

Spaciousness – low

Warmth – high

Brilliance – high

Conclusion

The highly tunable nature of the hall mixes with its petite size perfectly captures the essence of an elevated club. The hall can adapt to a bevy of new and retired styles of music and groups of instruments; its strength is its versatility.

The balcony sounded so much nicer and louder than the floor but then during analyzing that the ceiling is reflecting all of the sound up into the balcony.

The difference in elevation between the stage and floor contributes to false refractions of sound returning to the musician, which is confusing to the musician and the audience in the front section of seating.

The use of VAC HVAC creates interference in sound projection and background noise that distracts from the soft notes.

In conclusion, the technology used to adapt sound quality to various musical styles becomes useful when it can be precisely turned to each scenario. However, limitations of the stage elevated over the floor space and the HVAC create disruptions in sounds that work against the efforts of the musician. Given the limitations in the space the structure of the National Sawdust, its ability to create a sense of intimacy and warmth for the balcony audience is incredibly impressive, and its unique appearance made it a visual pleasure to perform in the space.

Thanks to the opportunity afforded to me by this grant and the findings I reported herein, I have realized how important the intersection the materials, geometries, integrated systems, and experience of the musician are to creating wonderful music in beautiful spaces. Without this opportunity, I would not have understood the importance of this multi-disciplinary approach to design in creating optimal conditions for the audience’s enjoyment.

I would like to thank and acknowledge the wonderful halls that opened their doors to me and allowed me to not only sit and sketch in their building but also play my instrument on their stages. I promise I did not break anything. Thank you for turning the lights on, giving me tours, and providing me with music stands after mine did not fit in my suitcase.

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