



TRI ANGLE
PROPOSAL FOR A UNIVERSITY OPERA

EBBA GREGEFALK
BACHELOR PORTFOLIO
ACEX15, 2024

TRI ANGLE

OPERA HOUSE

COLLABORATIVE WORK
 EXAMINER
 LOCATION
 COURSE
 YEAR
 TOOLS

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 New Haven, New York
 ACEX15, Bachelor Thesis
 2024, year 3
 AutoCAD, Illustrator, Indesign,
 Photoshop, Rhino, Vray

BACKGROUND

As part of the Bachelor's degree program in Architecture & Engineering (AT) at Chalmers, a bachelor's thesis is conducted aiming to:

"Integrate, deepen, and advance knowledge and skills within a specific area covered in prior courses within the program."

The overarching goal of the AT program is to merge architectural design with natural science and technology. Over a span of three years, the projects gradually escalate in scope and complexity. Successively, more disciplines are applied, and with the new addition of acoustics, the bachelor's thesis offers an opportunity to integrate, apply, and develop all the knowledge and skills garnered throughout the education. What we gain is an arsenal of knowledge and tools to present qualitative solutions to complex problems.

CONCEPT

The name *TriAngle* refers to the angled surfaces and triangular shapes that serve as the fundamental elements for both the architectural and acoustical design. Here you can explore room acoustics for different types of performances through adaptable acoustic settings, allowing for a truly customizable auditory experience.

Accessible to the public, the venue offers space for all to immerse in music, architecture, and the view from the Red Plateau, 30 meters above ground from which you can overlook the entire city. The building features two distinct components: a glass enclosure shields against external noise and weather, while a red volume houses the opera's functions. This bold red hue defines both the interior and exterior, blending classical tradition with contemporary design, creating a stunning visual and sensory experience.



[1]

PROJECT PROGRAM

THE COMPETITION MATERIAL

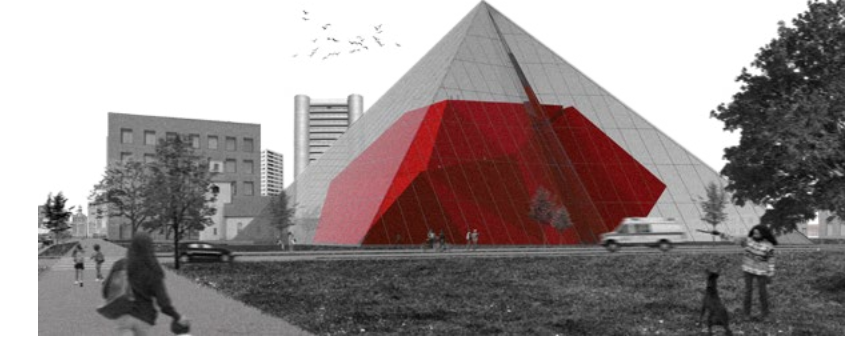
TRI ANGLE

THE COMPETITION

The project is a contribution to an acoustics competition annually announced by *the American Acoustical Association*. A college with strong music and vocal program intends to construct a new performance hall primarily for opera. Although the main purpose of the hall is to support their opera program, the hall will also be used for speaking engagements by the school's president and other invited speakers.

The acoustical design, including room acoustics, sound isolation and noise and vibration control needs to support the opera house, is a big focus. Situated on an open city block downtown, consideration needs to be taken to the highly trafficked streets that surround the building site.

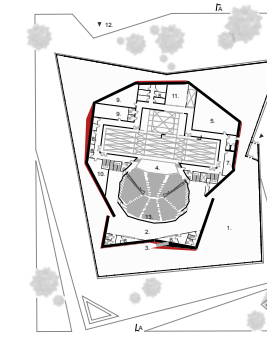
TRI ANGLE



Southwest Perspective



SITEPLAN 1:3000



FIRST FLOOR 1:600

OPEN FOR ALL

Students can explore room acoustics on their performances through adaptable acoustic settings tailored to various activities. Accessible to the public, the venue offers space for all to immerse in music, architecture, and the view from the Red Palace, overlooking New Haven. The building features two distinct components: a glass enclosure shields against external noise and weather, while a red volume houses the opera's functions. This bold red hue defines both the interior and exterior, blending classical tradition with contemporary design.

OPERA OF YALE

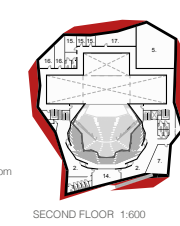
The TriAngle Opera at Yale University is not just a training ground for opera students; it is a purpose-built facility that enhances the acoustic experience for performers and audiences.

Situated on the outskirts of Yale in New Haven, follow the city's main flow from the station to the university, it bridges social divides, engaging students and residents alike in music and architecture. By filling a void in a city without its own opera house, it becomes a cultural hub, fostering unity among diverse audiences and visitors.

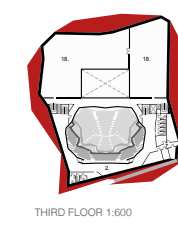
FUNCTIONS & NOISE CRITERIA

- ▲ 1 Public Lounge
- ▲ 2 Inner Lobby
- ▲ 3 Stairs to Red Plaza
- ▲ 4 Opera Hall
- ▲ 5 Rehearsal Hall
- ▲ 6 Warehouse
- ▲ 7 Storage
- ▲ 8 Choir Dressingroom
- ▲ 9 Choral Dressingroom
- ▲ 10 Green Room
- ▲ 11 Scene Shop
- ▲ 12 Loading Dock entrance
- ▲ 13 Audio Mix Position
- ▲ 14 Follow Spot Booth, Light & Stage Manager Control Room
- ▲ 15 Booth Office
- ▲ 16 Rehearsal Office
- ▲ 17 Main MEPPIT

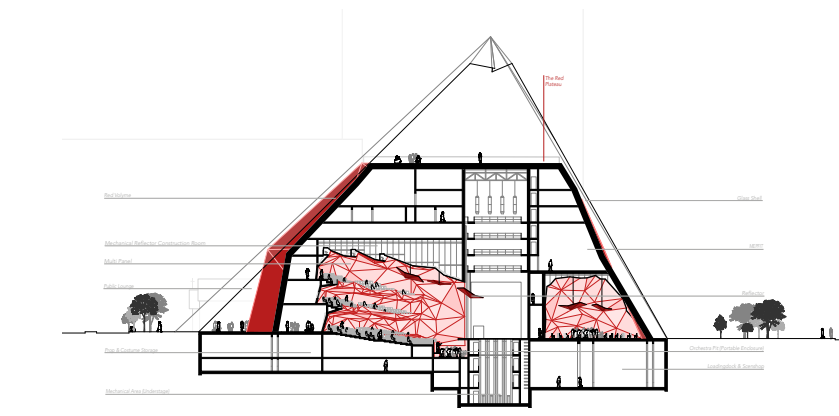
▲ NC 40 ▲ NC 30 ▲ NC 25 ▲ NC 15



SECOND FLOOR 1:600



THIRD FLOOR 1:600

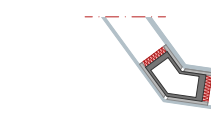


SECTION A-A 1:300

SOUND ISOLATION

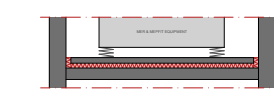
The shell features double glazing with varying glass thicknesses spaced 7cm apart, lined with absorbents to prevent sound and vibration transmission through the frames. Suction cups secure the glass panels to a steel frame.

The red volume's wall is a 1m wide double-layered structure clad with sound-absorbing material and perforated slots for a tranquil lobby/lounge. This heavy design counters structure-borne vibration transmission effectively.



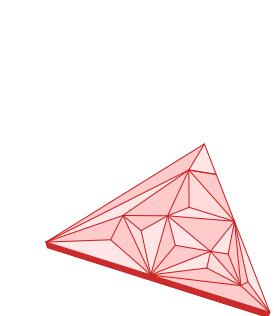
DETAIL GLASS 1:3

Sound and vibrations from MERV MEPPIT are eliminated from penetrating the opera and rehearsal room by steel spring isolators beneath each technical unit and a floating absorption floor.



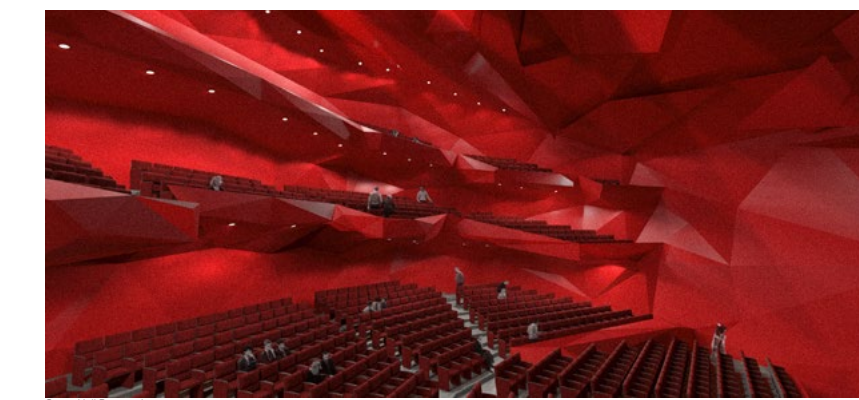
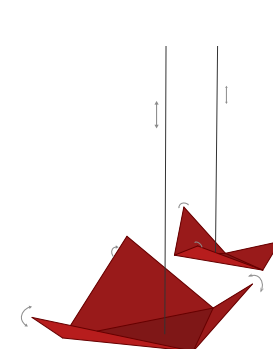
MULTI PANELS

The auditorium will feature wooden diffuse panels on the ceiling and walls, designed in triangular modules and therefore easily angled to direct the sound evenly to every seat. The various-sized surfaces and angles diffuse the sound to ensure consistent acoustics. The students can replace certain panel surfaces with absorbers or resonators as needed to adjust for desired acoustic effects. This adaptability is further enhanced by the use of recycled materials, harmonizing sustainability with exceptional auditory performance.



REFLECTORS

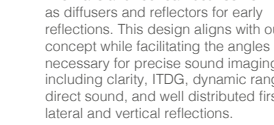
The triangular reflectors, installed in the ceiling, can fold and adjust vertically. This allows for controlling sound reflection: lowering and unfolding more reflective surfaces increases reflection, while folding them in reduces it. As these reflectors form the inner ceiling, adjusting the room volume affects the desired reverberation time.



Opera Hall - Southwest Perspective

GREAT SOUND FOR ALL

In the opera hall, with capacity of 1200 seats and 80 musicians, the triangular theme design extends. The asymmetrical orientation of the walls prevent flutter echo and the straight balconies avert sound focusing. The balconies and parquet, following the triangular theme and with traditional seating, are designed to optimize sightlines and acoustics in all areas. The walls and roof can both serve as diffusers and reflectors for early reflections. This design aligns with our concept while facilitating the angles necessary for precise sound imaging, including clarity, ITDG, dynamic range, direct sound, and well distributed first lateral and vertical reflections.

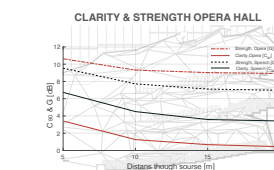


MSQ (dB)

▲ 31.24 ▲ 28.26 ▲ 25.55

ABSORBING

Fabric-covered chairs and absorbing materials behind the multi panels enable a RT₆₀ of 1.6 s for opera performances.



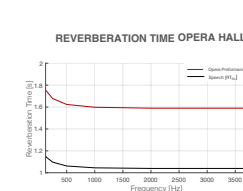
CLARITY & STRENGTH OPERA HALL

VARIABLE ACOUSTICS

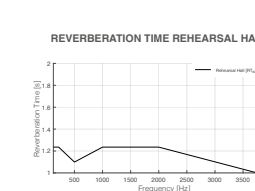
The adjustable ceiling enables optimization of reverberation time and room acoustics for different occasions or to be used for educational exploration by students. By lowering or rising the roof it creates a RT₆₀ spectrum of 1.1 up to 1.7 s, including optimized values for opera 1.6 s and speech 1.1 s.

REHEARSAL HALL

With a volume of approximately 1900 m³ and capacity up to 80 musicians, the rehearsal room incorporates the same panels and reflectors as the opera hall. These features, combined with the smaller volume, enable lower reverberation time, enhanced clarity, and reduced gain, ensuring ideal acoustic conditions for rehearsals. We attain an average RT₆₀ of 1.1 s, a gain (G) ranging from 14 to 15 decibels, and clarity (C₈₀) between 3 to 2 decibels.



REVERBERATION TIME OPERA HALL



REVERBERATION TIME REHEARSAL HALL

[2]

[2] THE THREE POSTERS, HANDED IN AS THE FINAL MATERIAL FOR THE COMPETITION.

DESIGN PROCESS

OPERA HOUSE

SPATIAL ACOUSTIC CONCEPTS

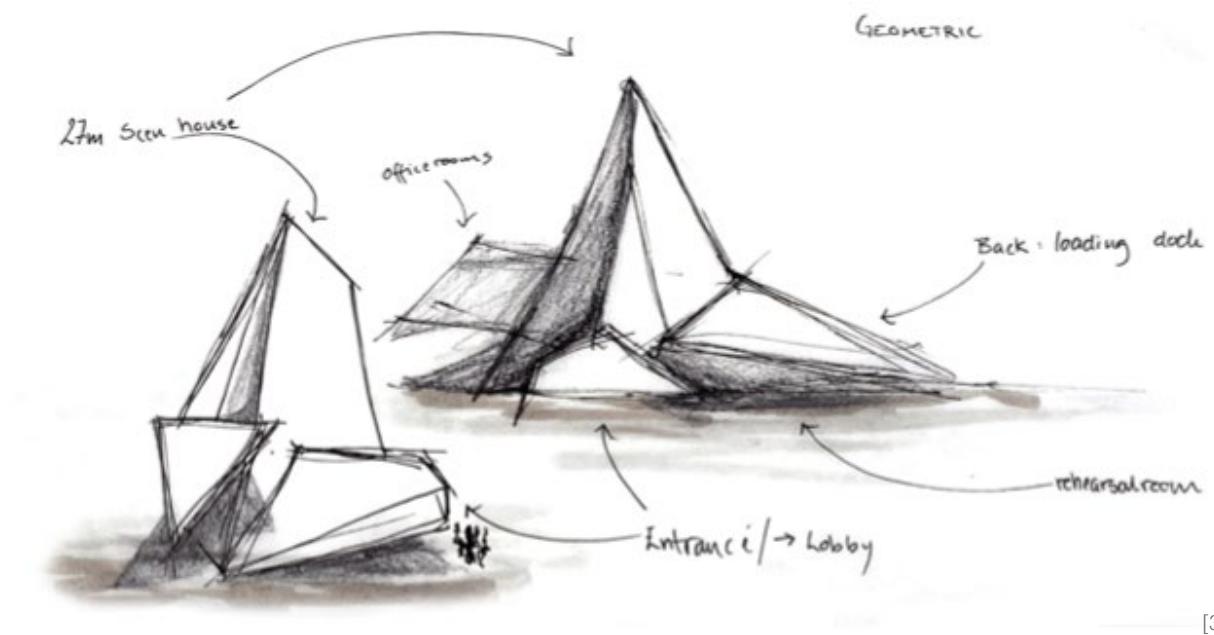
The process began with a pen in hand in front of a sketch paper. The primary objective was to get all thoughts and ideas down on that paper, with an emphasis on quantity rather than quality. Through this, different conceptual ideas began to take shape. After a while, we were able to narrow it down to three: *FLOWING CURVES*, *BALANCE*, and *HAIKU*.

Based on the initial quick sketches, we allowed the conceptual foundation to take precedence above all else as we continued to develop the ideas in alignment with the requirements outlined in the competition program. This was vital for initially exploring the potential offered by the different concepts. Yet, at this stage, it was also easy to prematurely encounter potential obstacles. To avoid getting mired in these challenges too early, we acknowledged them while temporarily setting aside the quest for solutions. Our focus was on exploring how far the core idea could lead us. We

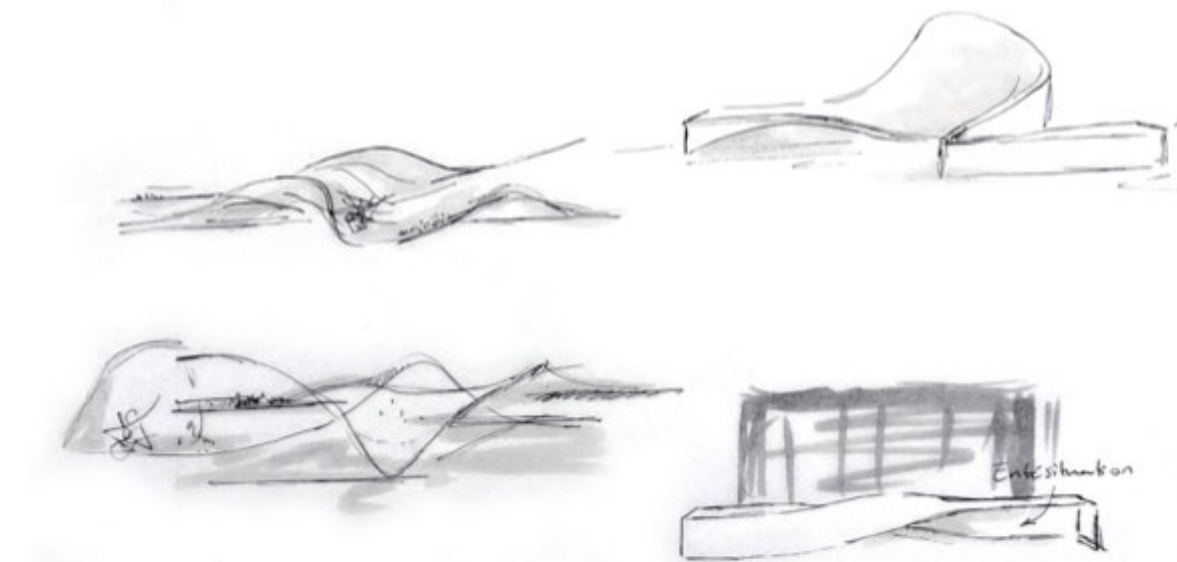
aimed to find a common thread to hold onto and to let problem-solving, which inevitably arises, be an integral part of the creative process.

We chose to continue working with the concept of *HAIKU*, drawing inspiration from the folded paper models we had crafted from haiku poems during a previous course. We were drawn to its aesthetic, and the decision felt intuitive once we conceived the idea of utilizing triangular modules to shape not only the architecture but also the acoustics of the opera house. We also wanted to challenge ourselves and do something completely different from anything either of us had done before.

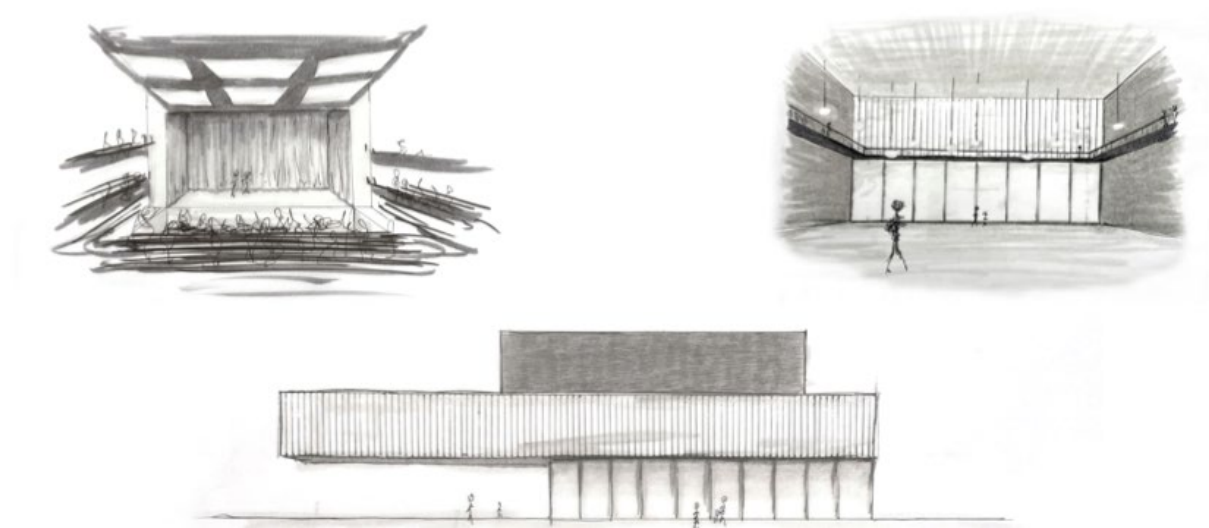
The concept remained a leading force throughout the process. An iterative approach, involving testing, evaluating, and improving, refined both the architectural and acoustic qualities. Exploring what the concept can offer has been an active choice, making it the clear guiding thread.



[3]



[4]



[5]

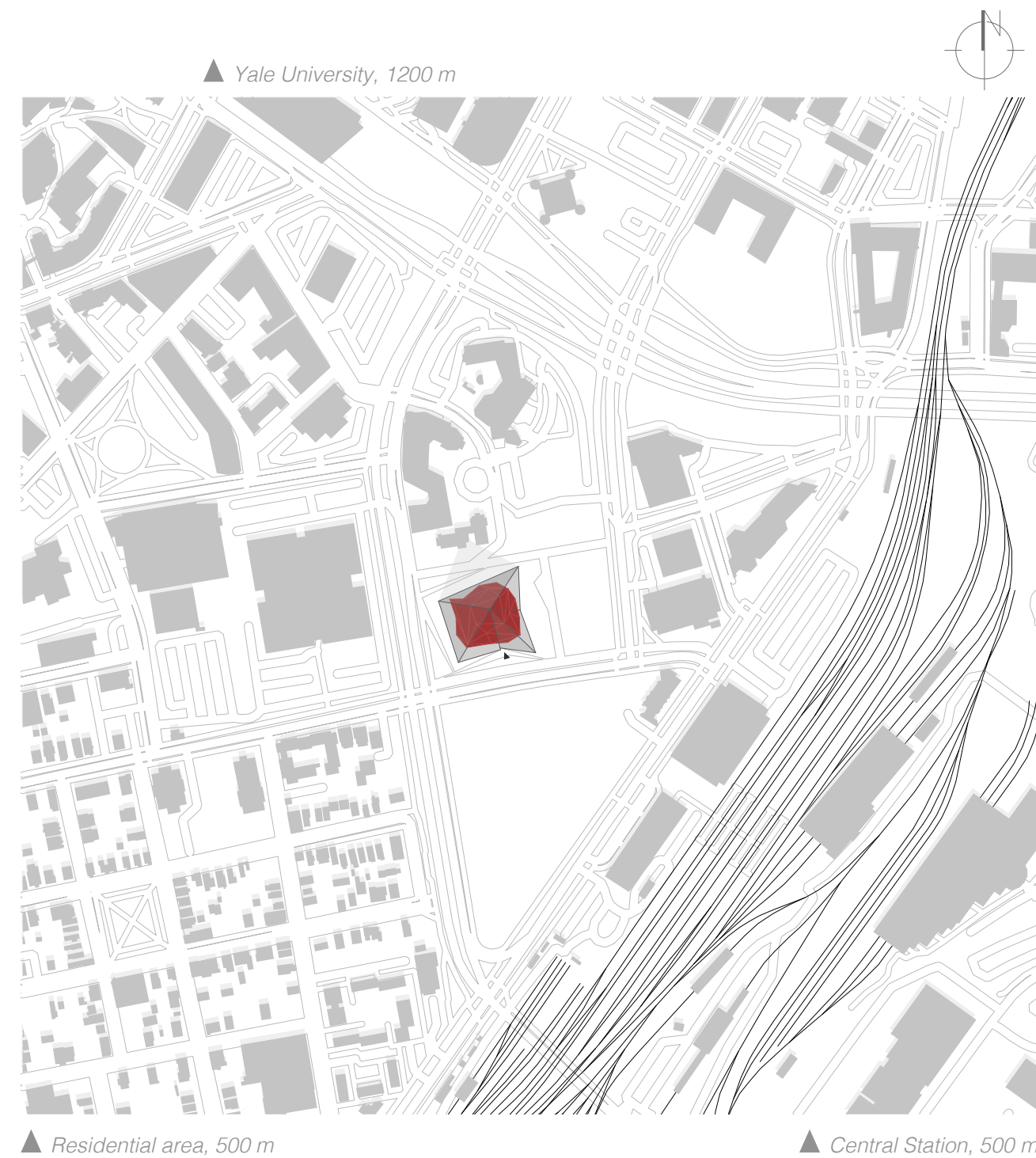
THE CONTEXT

YALE UNIVERSITY, NEW HEAVEN

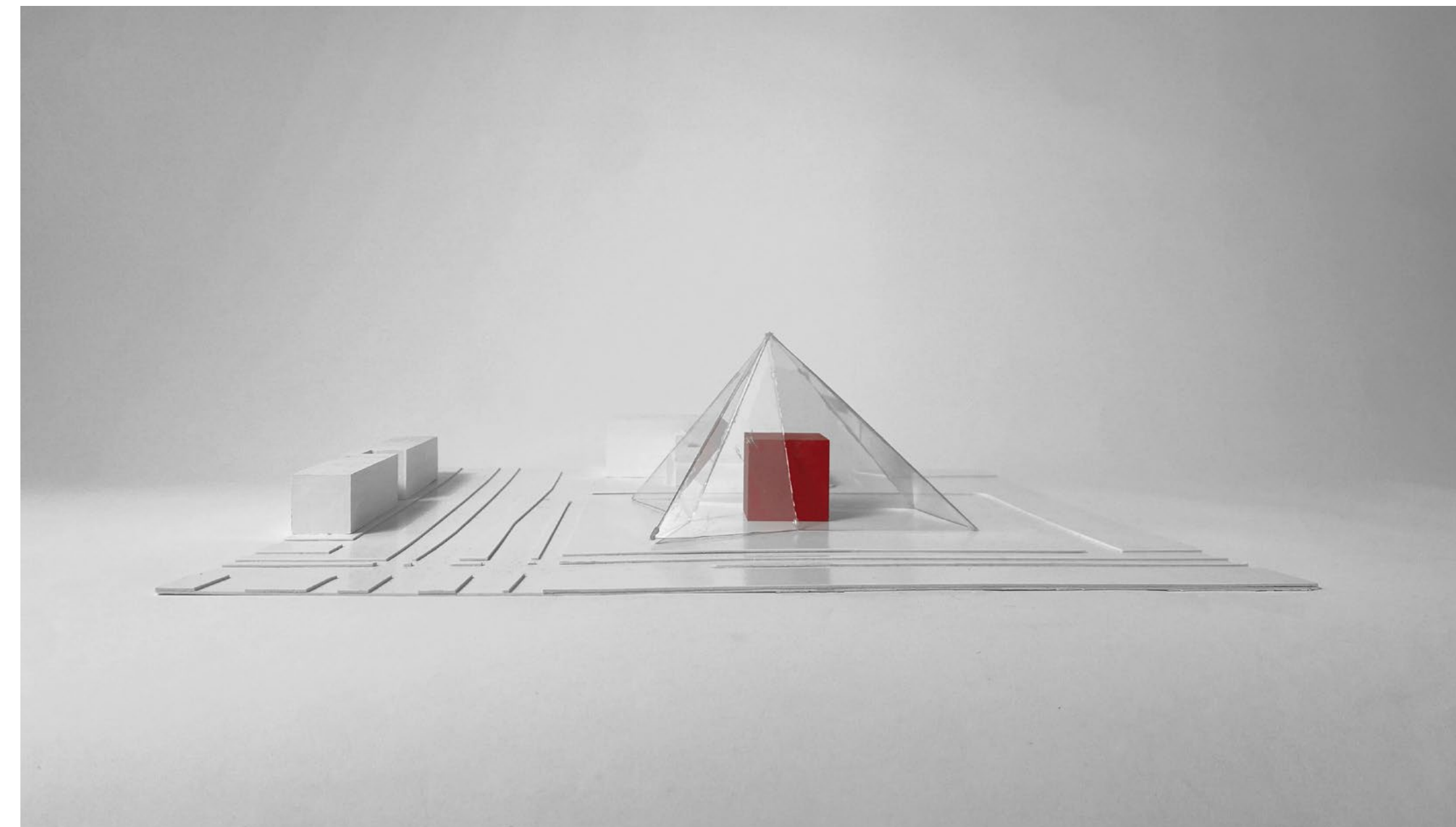
TRI ANGLE

OPERA OF YALE

Located at Yale University, the TriAngle Opera is not just a training ground for opera students; it is a purpose-built facility that enhances the acoustic experience for performers and audiences alike. Situated on the outskirts of Yale in New Haven and following the city's main flow from the station to the university, it bridges social divides, engaging students and residents alike in music and architecture. By filling a void in a city without its own opera house, it becomes a cultural hub, fostering unity among diverse audiences and visitors. Passing by, everyone should feel the urge to go inside and discover their place of interest within the building.



[6]



[1]

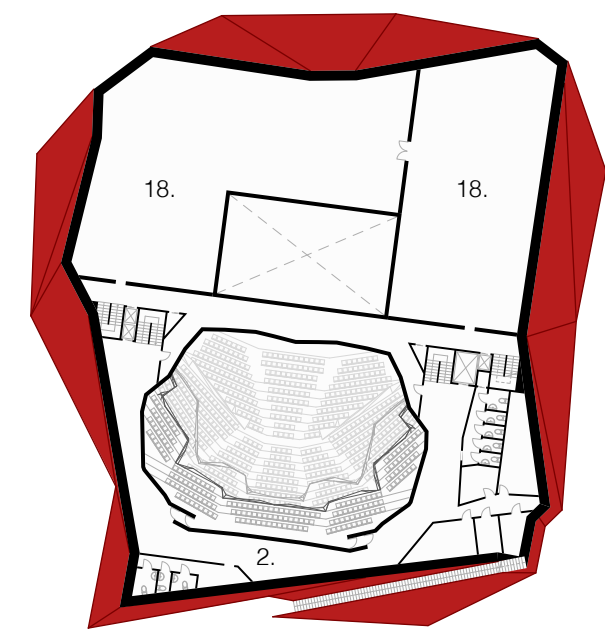
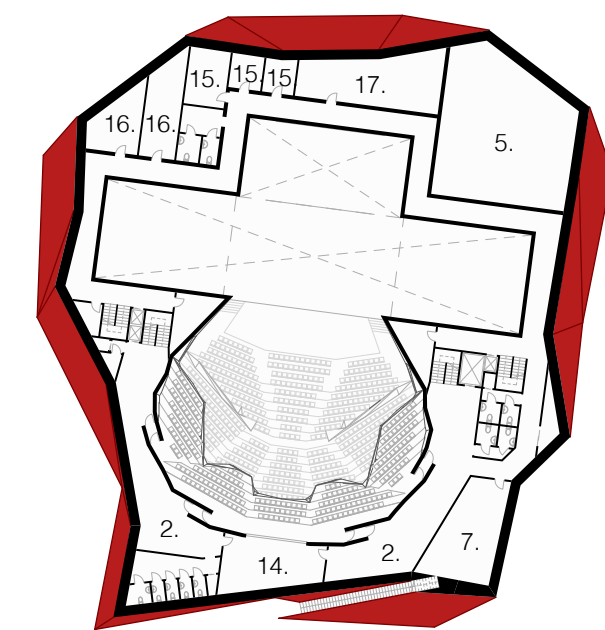
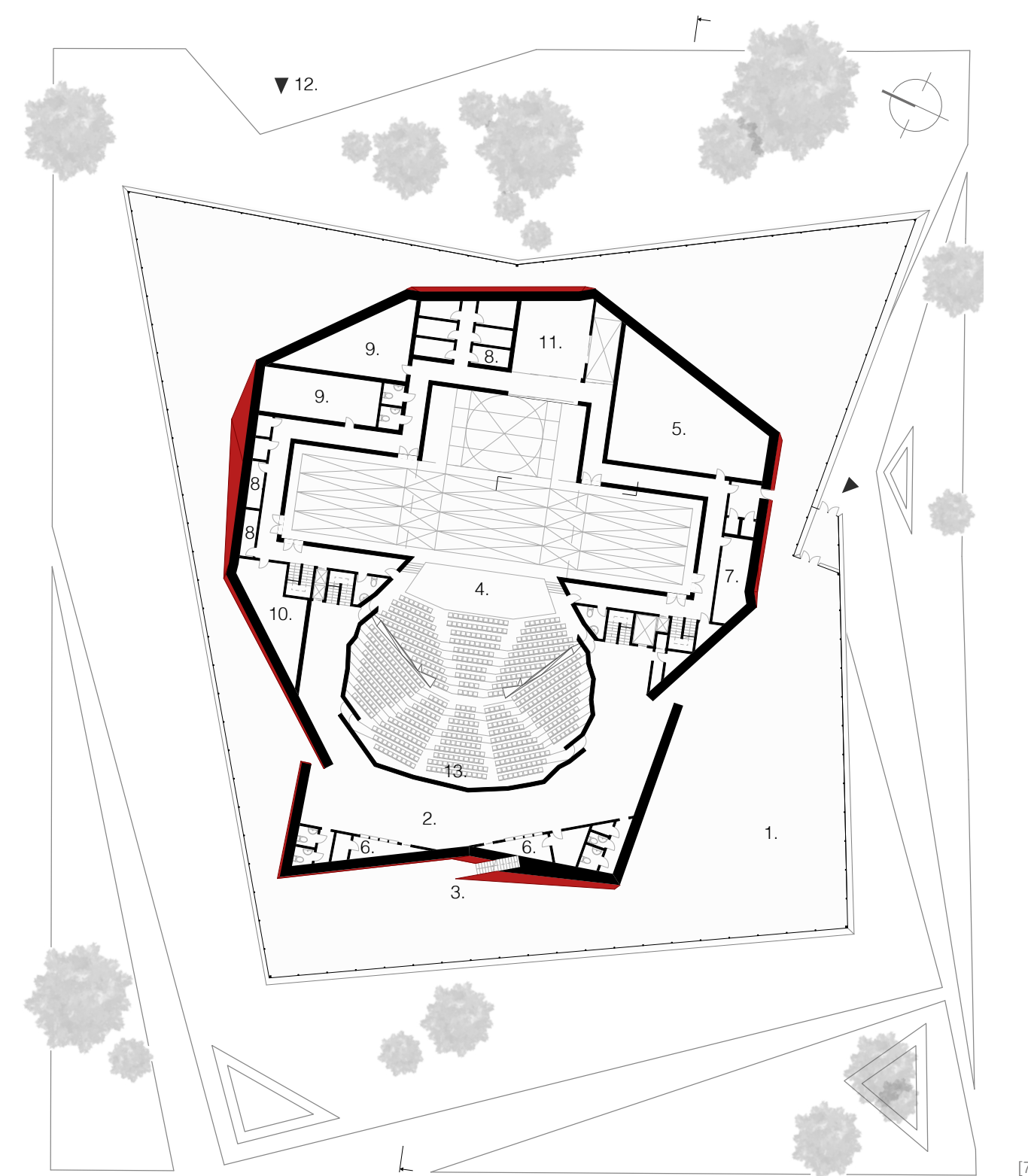
THE BUILDING

FLOOR PLANS

FUNCTIONS & NOISE CRITERIA

- 1. Lobby/Public Lounge
- 2. Inner Lobby
- 3. Stairs to Red Platau
- 4. Opera Hall
- 5. Rehearsal Hall
- 6. Wardrobe
- 7. Storage
- 8. Solo Dressingroom
- 9. Choral Dressingroom
- 10. Green Room
- 11. Scene Shop
- 12. Loading Dock entrancé
- 13. Audio Mix Position
- 14. Follow Spot Both,
- Light & Stage Control Room
- 15. Tech Office
- 16. Resident Office
- 17. MER
- 18. MEPPFIT

▲ NC 40 ▲ NC30 ▲ NC25 ▲ NC15



THE BUILDING

SECTION

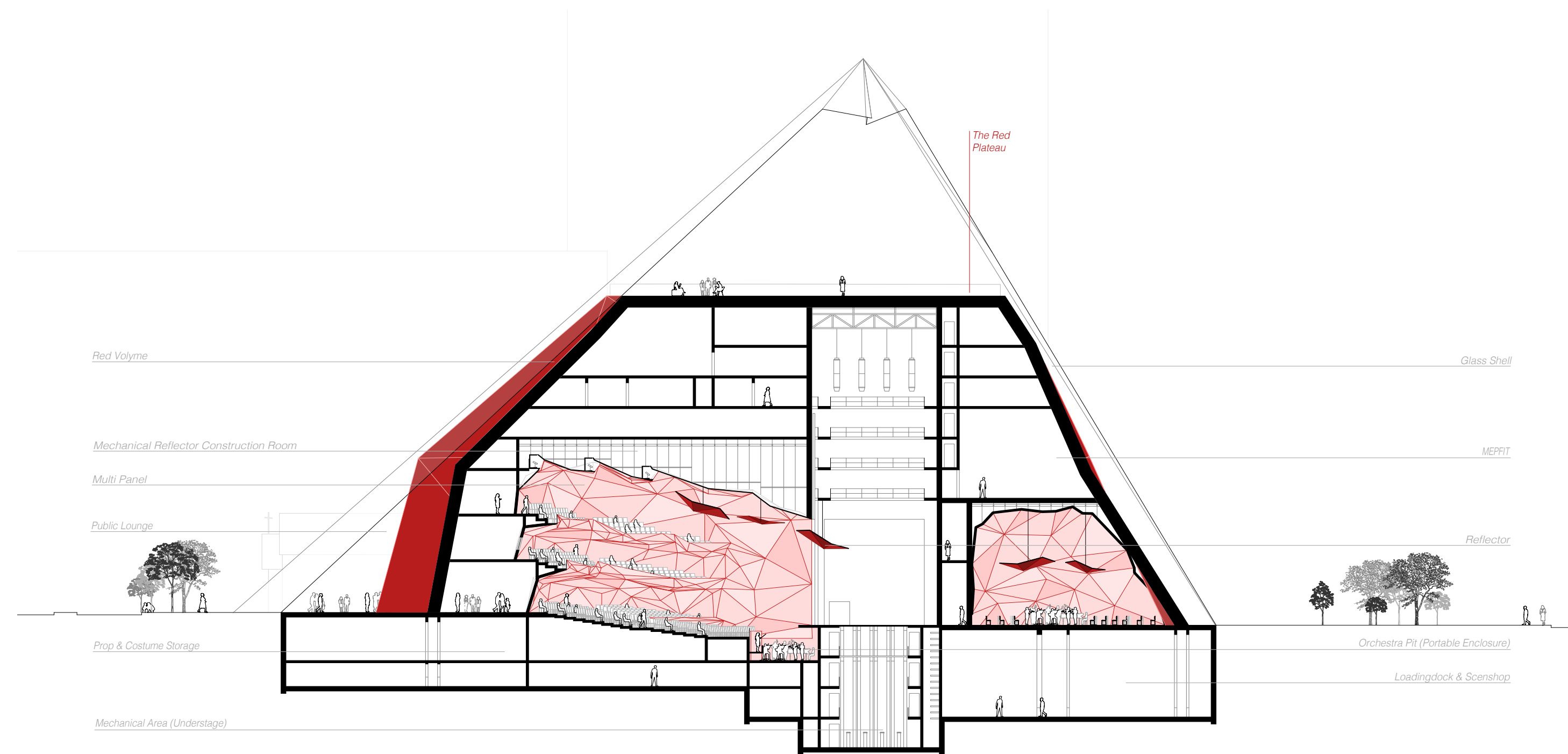
SPACES FOR ALL

The glass enclosure in relation to the red volume creates a space in between, hosting the lobby/lounge. The walls on each side never run parallel to avoid the occurrence of flutter echoes. Simultaneously, the incline of the surfaces generates intriguing spatial qualities, where the space alternately narrows and opens up. During the daytime, it's a perfect spot for students to sit and study between classes or for passersby in the area to grab lunch and appreciate both architecture and music. Here, music enthusiasts should easily find their natural spot, whether they're studying through the university or pursuing their own interests. Before performances, the audience can mingle in the lobby, getting themselves ready to enter the opera hall. The transparent outer shell welcomes everyone to see what's going on inside and be part of the activities.

From the lobby, you can reach the red plateau from which you can overlook the city 30m above ground. Accessible for the public, it's for everyone to enjoy the view. Above the plateau, the top of the glass enclosure rises, creating an airy atmosphere and a spatial effect of having sightlines in all directions at this elevation, as if outdoors.

Outside the building, the surroundings are lush with greenery, inviting visitors to relax on benches that echo the triangular theme in their design.

For performers, the acoustic treatment remains consistent between the opera hall and the rehearsal room, considering that when practicing, the room is smaller and doesn't accommodate an audience. This ensures excellent acoustics for both visitors and performers to enjoy.



[10]

[10] SECTION A-A

ACOUSTIC PROTOTYPES

SOUND & VIBRATION TREATMENT

SOUND ISOLATION [11]

The shell features double glazing with varying glass thicknesses spaced 7 cm apart, lined with absorbents to prevent sound and vibration transmission through the frames. Suction cups secure the glass panels to a steel frame made out of fossil free-steel material from SSAB.

The red volume's wall is a 1 m wide double-layered structure clad with sound-absorbing material and perforated slots for a tranquil lobby/lounge. This heavy design counters structure-borne vibration transmission effectively.

MER & MEPFIT [12]

Sound and vibrations from MER/MEPFIT are eliminated from penetrating the opera and rehearsal room by steel spring isolators beneath each technical unit and a floating absorption floor.

MULTI PANELS [13]

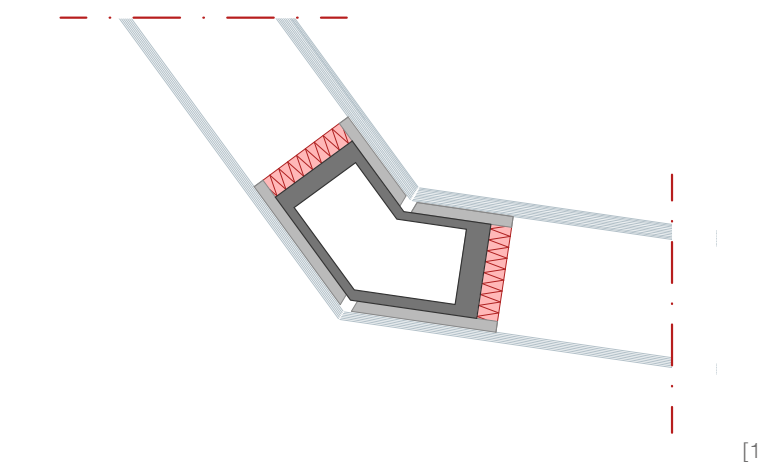
The auditorium will feature wooden diffuse panels on the ceiling and walls, designed in triangular modules and therefore easily angled to direct the sound evenly to every seat. The various-sized surfaces and angles diffuse the soundwaves of different frequencies to ensure consistent acoustics. Incorporating absorbing materials behind the multi panels together with small gaps in the surface enable the panels to also work as absorbers, improving sound quality by reducing echoes and reverberations as well as preventing excessive noise levels.

The students can replace certain panel surfaces with more absorbers or resonators as needed to adjust for desired acoustic effects. This adaptability is further enhanced by the use of recycled materials, harmonizing sustainability with exceptional auditory performance.

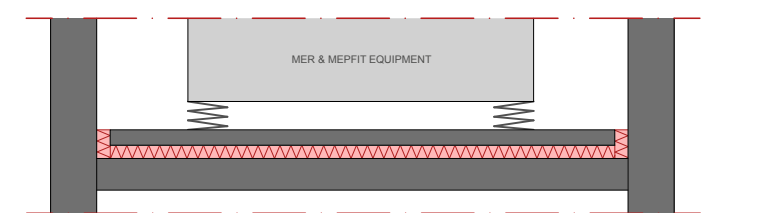
REFLECTORS [14]

The triangular reflectors, installed in the ceiling, can fold and adjust vertically. This allows for precise control of sound reflection: lowering and unfolding more reflective surfaces increases reflection, while folding them in reduces it. They can be placed and angled to direct the sound reflections towards desired audience sections, ensuring that good sound quality is delivered uniformly throughout the room.

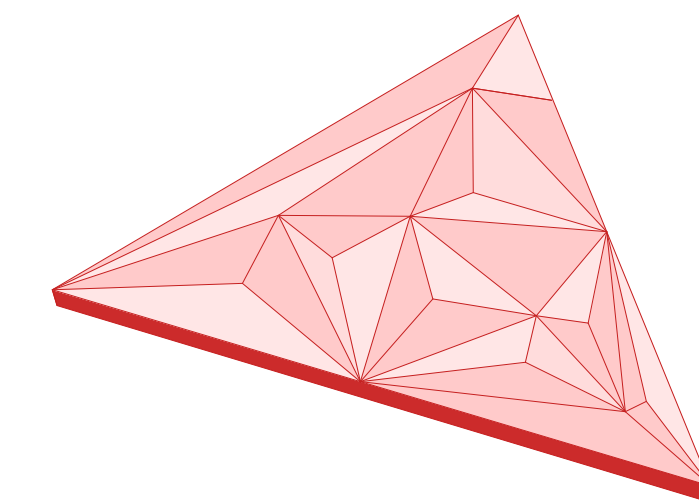
As these reflectors form the inner ceiling, their height adjustment capability allows for the modification of the room's volume. Consequently, the reverberation time is changeable and can be tailored to suit different types of performances, such as opera or speech. Students can also for educational research change the room's volume, adding the dynamic dimension of experimenting with and exploring different acoustic effects.



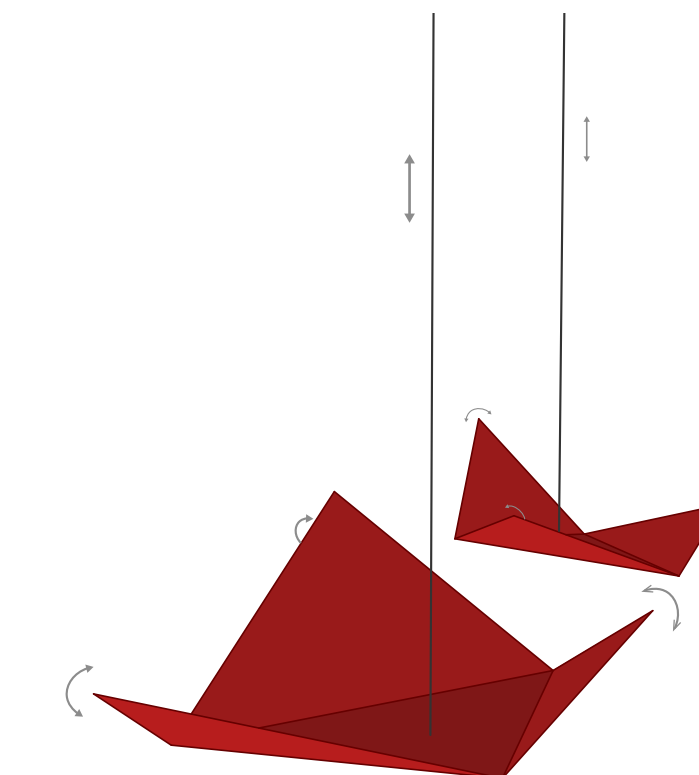
[11]



[12]



[13]

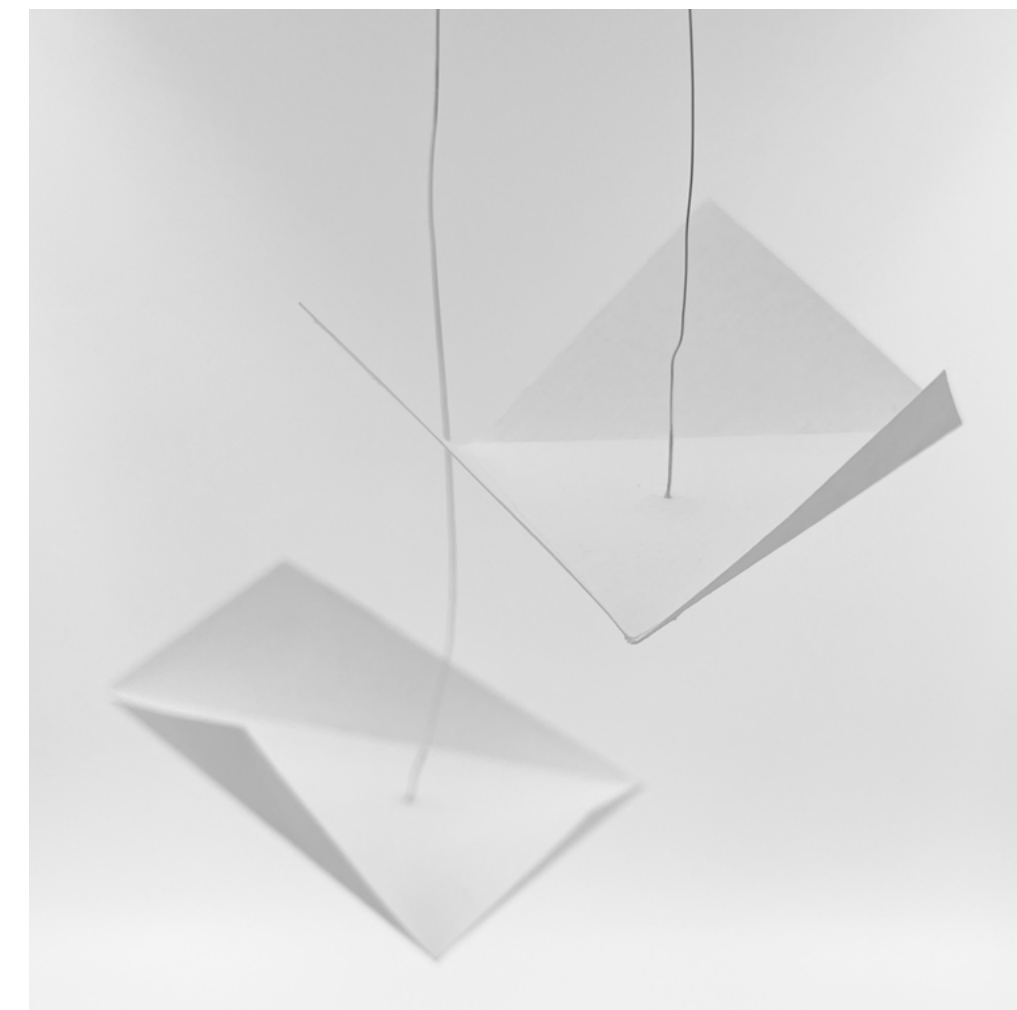
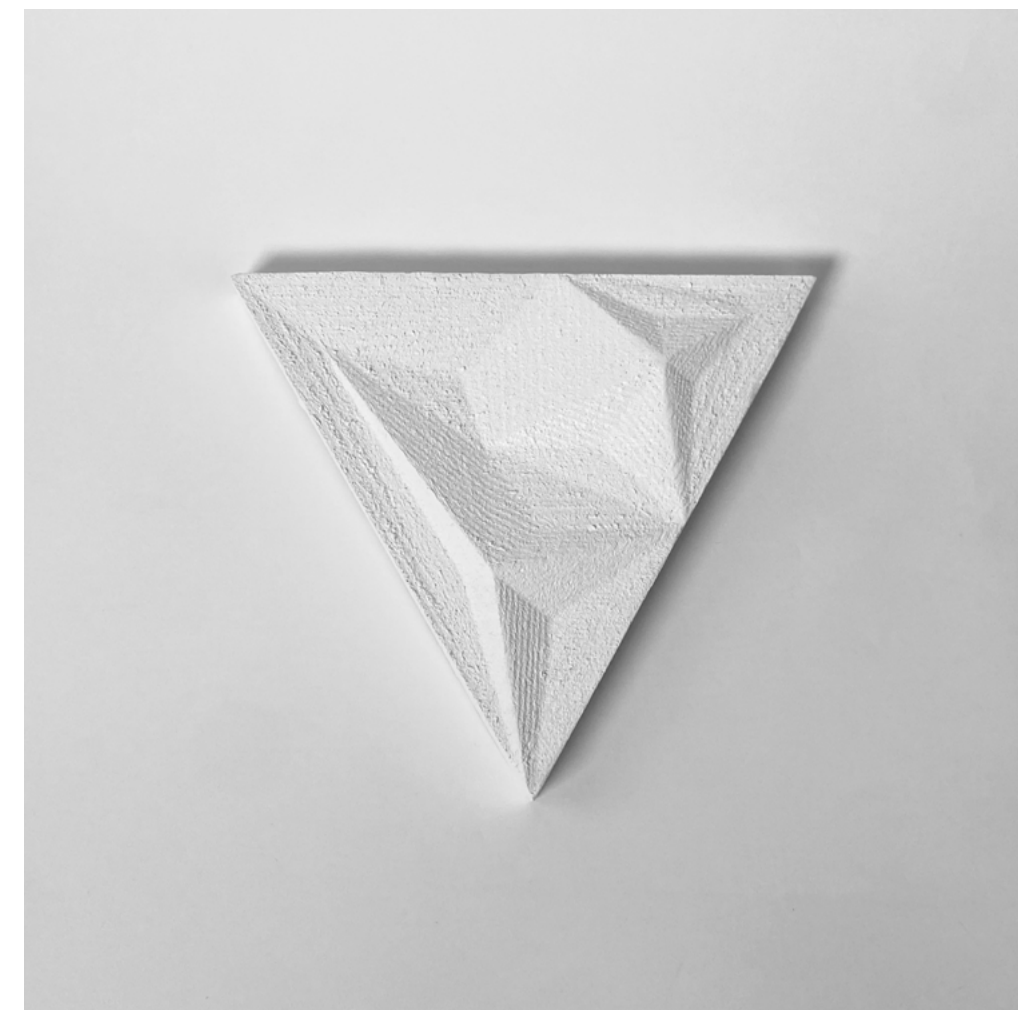
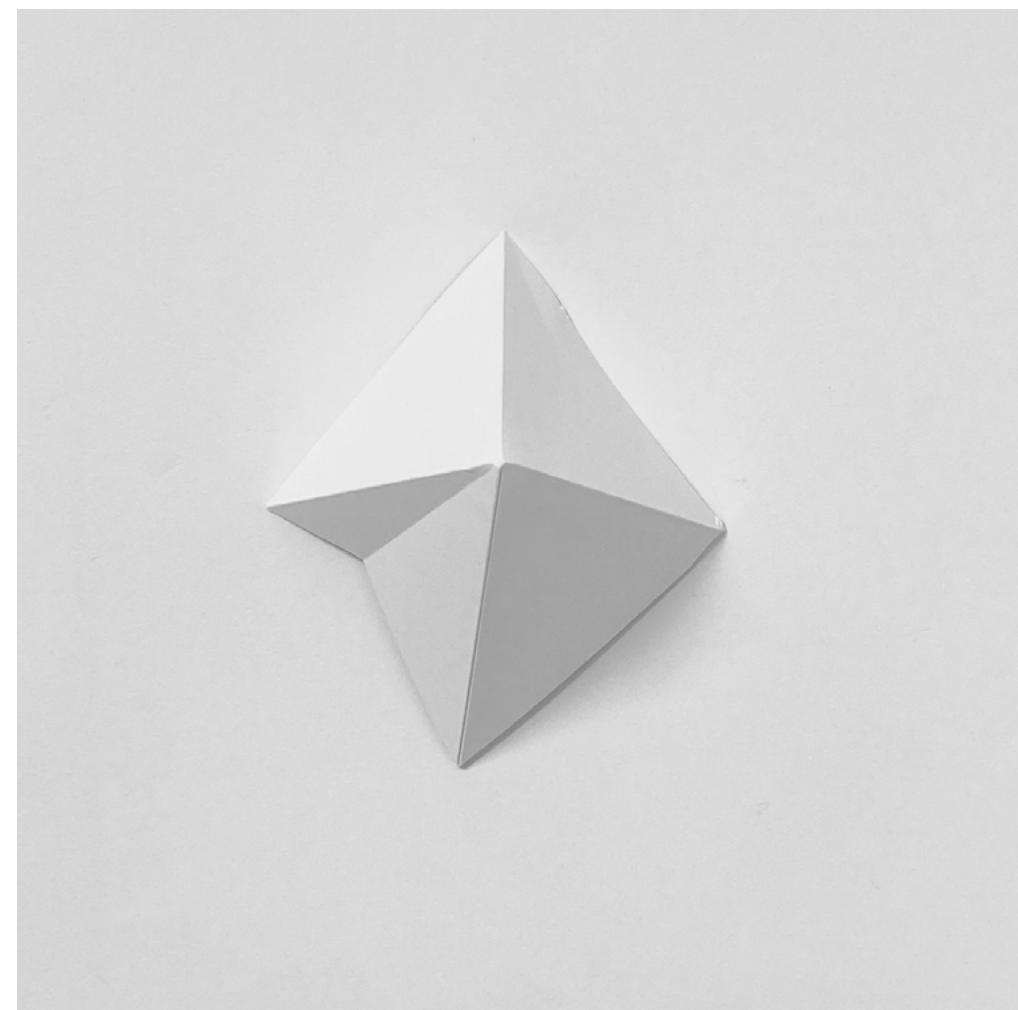
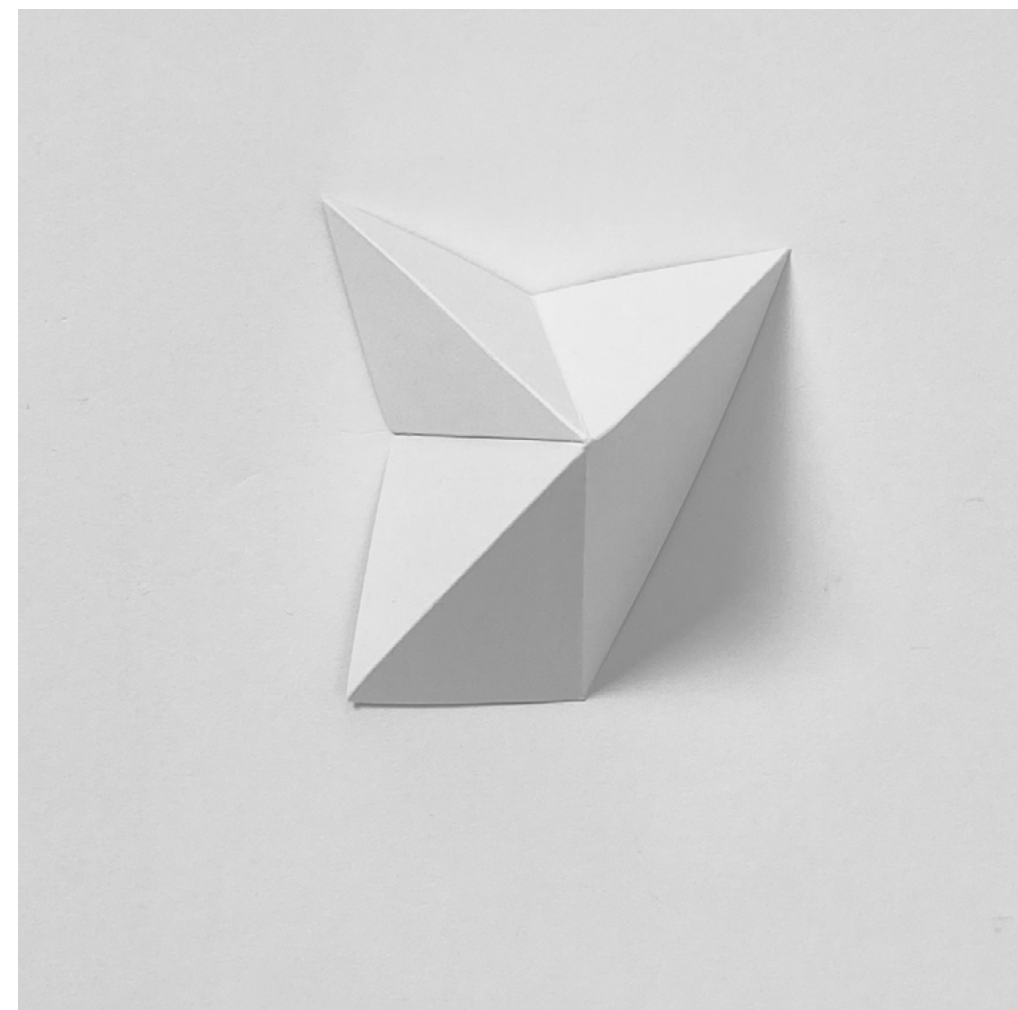


[14]

PHYSICAL MODELS

FROM THE PROCESS

TRI ANGLE



BACHELOR PORTFOLIO 2024

THE OPERA HALL

INSIDE THE AUDITORIUM

GREAT SOUND FOR ALL

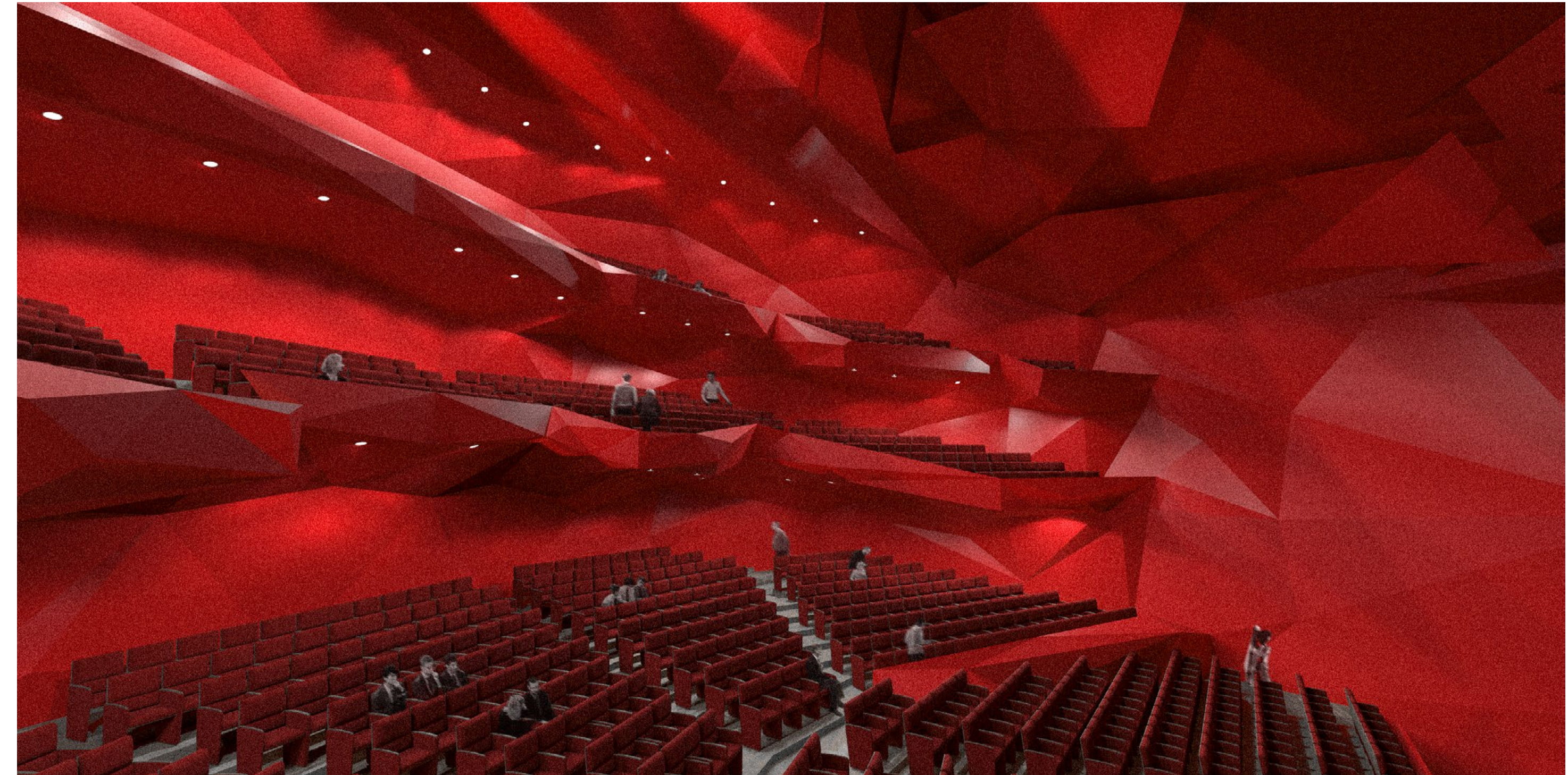
In the opera hall, with capacity of 1200 seats and 80 musicians, the triangular design extends. The asymmetrical orientation of the walls prevent flutter echo and the straight surfaces avert sound focusing. The balconies and parquet, following the triangular theme and with traditional seating, are designed to optimize sightlines and acoustics in all areas. Fabric-covered chairs and absorbing materials behind the multi panels improve sound quality by reducing echoes and reverberations, as well as preventing too loud noise levels inside the auditorium and for the orchestra performing.

The walls and roof can both serve as diffusers and reflectors for early reflections. This design aligns with our concept while facilitating the angles necessary for precise sound imaging, including

clarity, ITDG, dynamic range, direct sound, and well distributed first lateral and vertical reflections.

The reflectors, following the triangular design of the room, are visible when unfolded but can seamlessly fit into the surface structure of the ceiling and blend together to be visually concealed if desired.

The interior is also defined by the red tone, infusing the room with warmth and creating a vibrant and inviting atmosphere. This striking color choice not only emphasizes the dynamic lines and geometric shapes of the space but also evokes a sense of passion and intensity, perfect for the performances hosted within. The rich, bold tone envelops the audience, drawing them into the powerful performances that define the opera tradition.



[15]

ROOM ACOUSTICS

REVERBERATION TIME

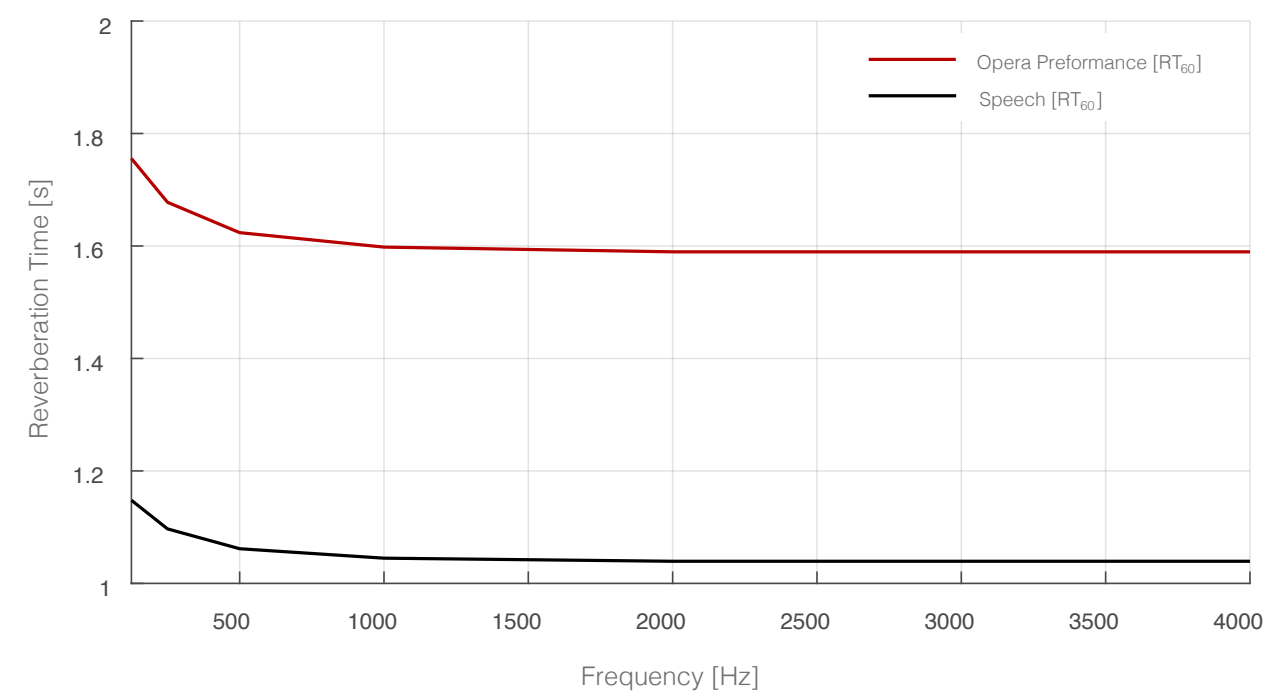
OPERA HALL

RT60 1.1-1.7 s

VARIABLE ACOUSTIC

The adjustable ceiling enables optimization of reverberation time and room acoustics for different occasions or to be used for educational exploration by students. By lowering or rising the roof it creates a RT60 spectrum of 1.1 up to 1.7 s, including optimized values for opera 1.6 s and speech 1.1 s.

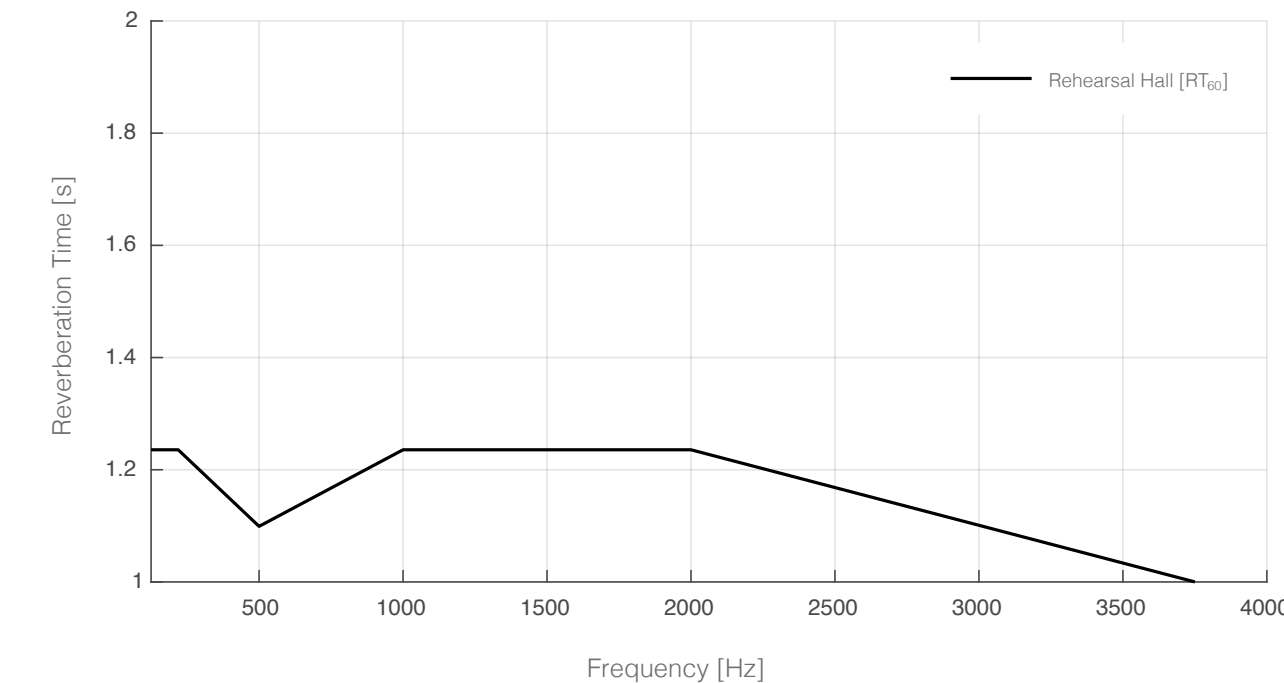
REVERBERATION TIME OPERA HALL



REHERSAL ROOM

With a volume of approximately 1800 m2 and capacity up to 80 musicians, the rehearsal room incorporates the same panels and reflectors as the opera hall. These features, combined with the smaller volume, enable lower reverberation time, enhanced clarity, and reduced gain, ensuring ideal acoustic conditions for rehearsals. We attain an average RT60 of 1.1 s, a gain (G) ranging from 13 to 14 decibels, and clarity (C80) between 2 to 3 decibels. (See next page)

REVERBERATION TIME REHEARSAL HALL



ROOM ACOUSTICS

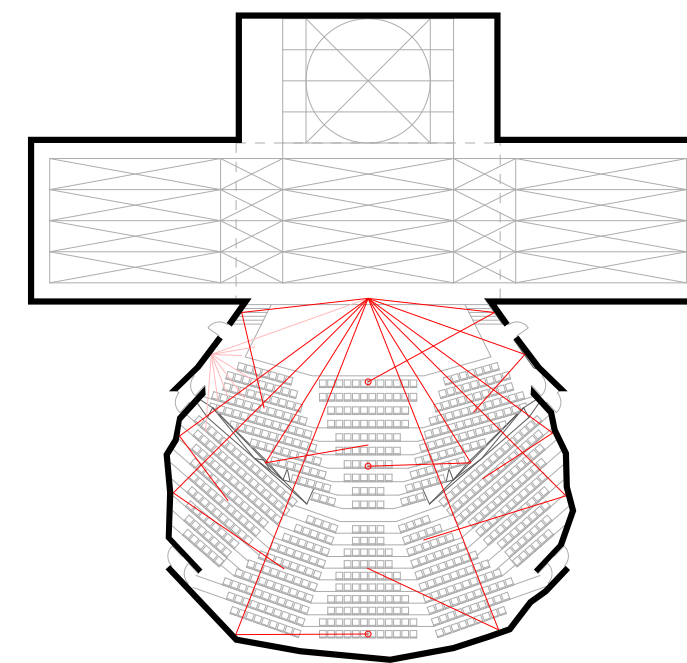
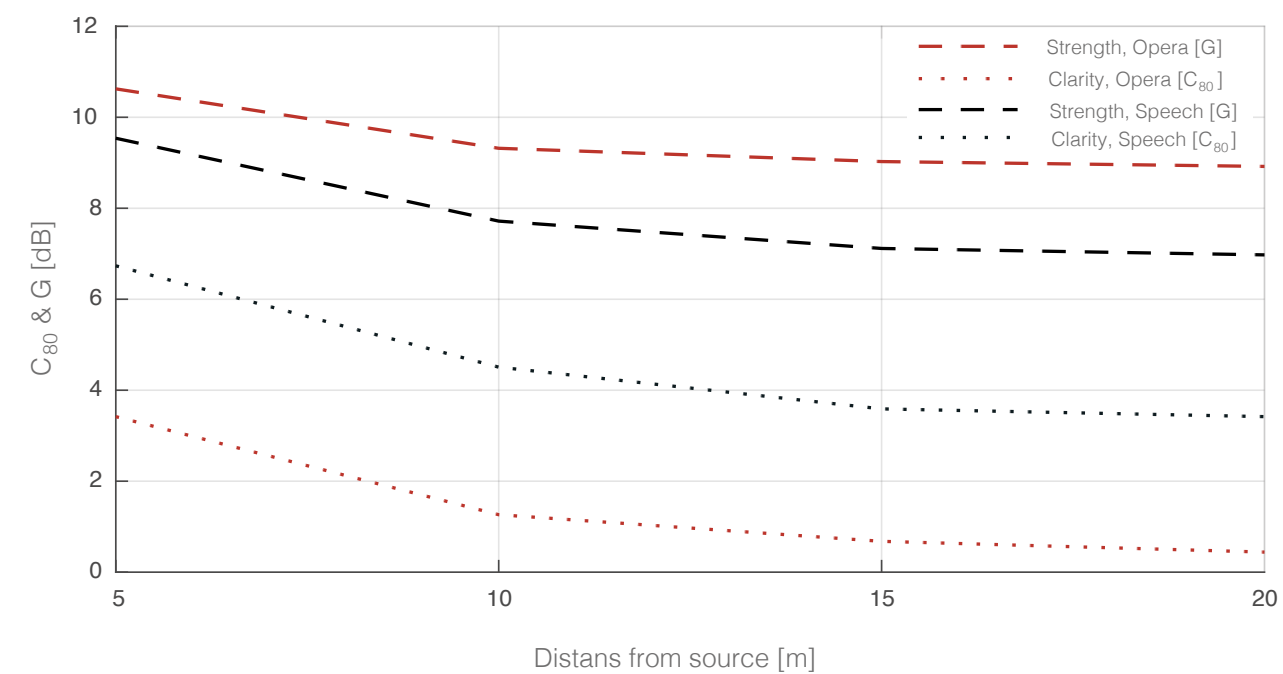
CLARITY & STRENGTH

OPERA HALL

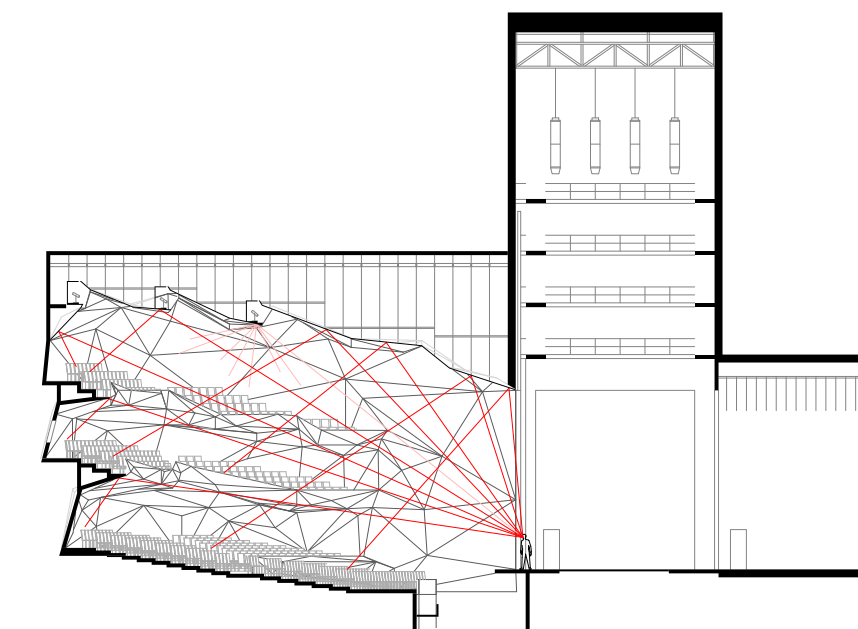
G 13-14 dB
C80 2-3 dB

The asymmetrical orientation of the walls prevent flutter echo and the straight surfaces avert sound focusing. This design facilitates the angles necessary for precise sound imaging, including clarity, ITDG, dynamic range, direct sound, and well distributed first lateral and vertical reflections.

CLARITY & STRENGTH OPERA HALL



[20]



[21]

TRI ANGLE

BACHELOR PORTFOLIO 2024

REFLECTION

PROCESS & RESULT

DESIGN PROCESS

From the outset, we decided that we wanted to create a building that would spark interest and curiosity, also in those who might otherwise just pass by on the street — a building that invites people to enter and explore.

One of the most intriguing aspects of the project was the design process. Working with triangles provided us an unprecedented level of freedom and flexibility. Architecturally, this was the project's greatest strength, but also its greatest challenge.

A crucial step in the process was settling on a final form. We didn't know much more than that we wanted to base our design on triangles, and experimented through form finding, using both physical and digital models. Aesthetically, we were drawn to a clear geometric shape with a unique twist. It was before lunch during a session in the computer labs that inspiration struck, and we settled on a pyramid-shaped configuration, featuring at least one side interrupted by a fold that ascends to the apex. Through iterations with paper models, we explored the placement and number of folded surfaces and refined the silhouette until it embodied our vision.

Designing the interior volume was the next challenge. We struggled with the need for two disparate building masses to harmonize. It was a transformative moment when our advisor, Peter, replaced our symbolic representation of the interior volume — a red cube — with a simple stone. This shift in perspective unlocked a world of new possibilities, allowing us to create dynamic spatial interplays between the angled walls of two volumes that contrast with each other.

The architectural approach of using triangular modules and flexible design has also proven to be justified acoustically. Whenever we encountered challenges or had to tackle inquiries from the acoustician, our core concept consistently served as our guiding light, providing us with the answers and solutions we needed.

DESIGN METHODOLOGY

Sketching has been crucial to our way of working. We allowed ourselves to remain in a sketching phase for a long time, producing hand-drawn materials and making quick, simple models to physically test our ideas. This hands-on approach not only clarified our vision but, amidst the complex geometries, also vital for the dialog, both with myself and between me and my partner Linnea Brose. It has been a valuable tool in order to understand and discuss both with myself and my partner. Additionally, it underscored the importance of sensory engagement in architecture—of being able to feel, observe, and interact with spatial elements.

One thing that has particularly stood out in this project has been the conversations about architecture. Through these discussions, we have made several significant advances in the process. First and foremost, the many conversations shared between me and my partner. We have worked together at every stage, together navigating through decisions, testing new ideas and re-evaluating the project, all while maintaining an ongoing dialog. Added to this, I think of the input we received from our peers, in addition to that from our supervisors. The discussions we had within the study group during both the supervision sessions and during our own meetings have been incredibly rewarding and always provided new perspectives that we have incorporated. The interactive presentation sessions after each iteration similarly led to conversations that raised questions, which Linnea and I then discussed further. In retrospect, these conversations have become a significant part of our project, and I am grateful to carry this experience with me.

The conversations with the acoustician, however, were more challenging. My partner and I felt that we had to drive the conversation and the creative process, whether it involved architecture or acoustics. It would have been beneficial and fun to incorporate more of the acoustician's expertise. Poor communication made it difficult to establish a good collaboration. I would have preferred

if all three of us could have sat together in the drawing room, using the sketch materials as a basis for discussions about acoustics in relation to architecture. Moving forward, I will remember how important face-to-face meetings and working together are for mutual understanding.

That was something Linnea and I prioritized and it facilitate for us to be present and on the same page in every step of the project. We didn't divide the work based on what we were most comfortable doing. Instead, we both wanted to take the opportunity to try new things and develop existing skills. As a result, it is impossible to say who completed what in this project, as we were both involved in all the materials created. This approach made the work especially enjoyable, as we both acquired new skills to carry forward.

Reflecting on our iterative workflow, the benefits of breaking down a big project into smaller parts is something I'll also bring with me. The task was divided into five iterations, and in a project of a larger scale like this one, these smaller sub-tasks structured the timeline and the interim presentations fostered as regular checkpoints for reflection and refinement. We often considered multiple parallel approaches and questioned ourselves, "Can this be done in another way?" This self-critical search helped to maintain a distance to the project. We weren't afraid to rethink, explore alternative approaches and remain open to feedback. Sometimes we tested new ideas that proved better, other times worse. Regardless, this approach empowered us to make informed decisions based on what we genuinely believed in.

Last but not least, I've reflected on how to present a project effectively. This was our first experience working with a competition. All the materials and work had to fit into the concise narrative of three posters, capable of independently encapsulate the essence of acoustical and architectural innovation. This challenge was intensified by the fact that we wouldn't present the proposal to the jury in person. Learning to communicate concisely through a balance between images and words was valuable.



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