Nam, optio cum sam ende rehenda velisquam, tem aut enit et quo bla ventis eatia derferiam, soluptur simpos ant.

Spiraling Cosmos The Astronomical Museum in Yabuli

Set within the snow-covered landscape of Yabuli, Heilongjiang—a region known for its alpine terrain and long, crystalline winters—the Astronomical Museum emerges as both an extension of the earth and a vessel for the cosmos. Its architecture draws inspiration from the natural morphology of snow mounds, whose fluid contours echo the surrounding mountains. The building settles gently into the terrain, merging with its environment rather than standing apart, evoking a seamless dialogue between nature and the universe.The spatial narrative of the museum transforms the act of exploration into at cosmic journey. Visitors begin at a vast entrance hall, ascend by elevator to the highest interior point, and then follow a long, spiraling ramp that descends through a sequence of immersive environments. Each segment of the descent embodies a different concept of the universe—from the primordial explosion of the Big Bang, to the curvature of spacetime, the birth and death of stars, the enigma of black holes, and the invisible forces of dark matter and dark energy.

The building itself becomes the medium of exhibition. Instead of relying on display cases or digital installations, the architecture gives physical form to abstract astronomical ideas. Light, scale, materiality, and spatial tension together construct a sensorial cosmology—an experience that is not simply about observing the universe, but about being inside its unfolding.Through its

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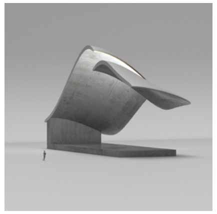
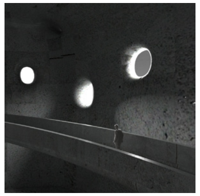
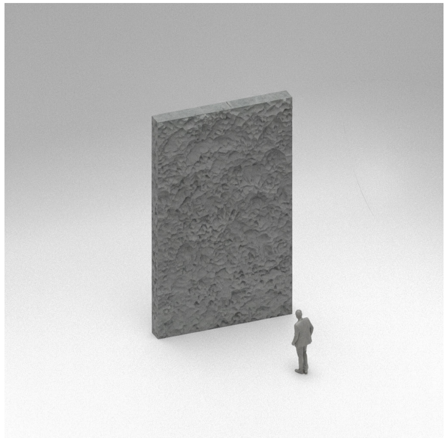
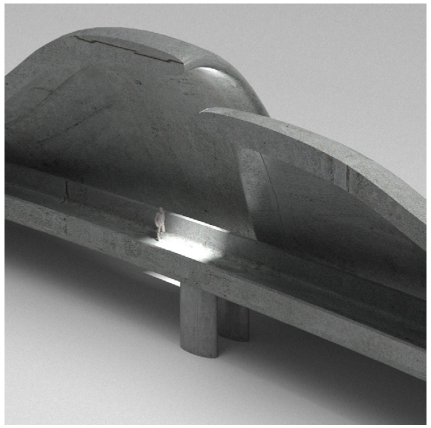
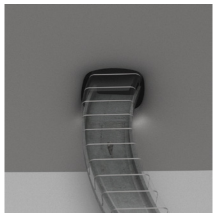
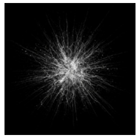






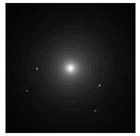






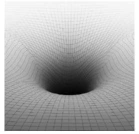
Cosmic Origin and Expansion

The universe began from an



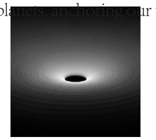
The Solar System and the Sun

The Solar System illustrates the dynamic relationship between a star and its planets, anchoring our understanding of the cosmos.



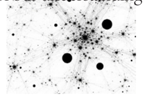
Spacetime and Gravity

Matter curves spacetime, and curved spacetime guides matter's motion, forming the foundation of our understanding of gravity.



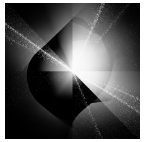
Black Holes and the Event Horizon

vExtremely dense objects warp spacetime so strongly that not even light



Large-Scale Structure of the Universe

Galaxies form a filamentary network that shapes the large-scale structure of the universe.

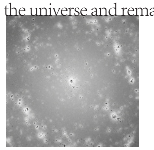


Dark Matter and Dark Energy

Invisible yet dominant, dark matter and dark energy make up most of the universe and remain profound mysteries.

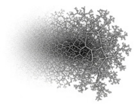
Stellar Birth and Death

Stars are born from molecular clouds and die in explosions that forge new elements.



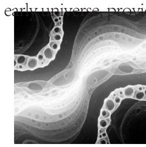
Cosmic Microwave Background and Observational Cosmology

The cosmic microwave background is the relic radiation of the early universe, providing evidence of its origin.



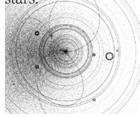
Element Formation

From hydrogen and helium to heavy elements, all matter in the universe is produced inside stars.



Exoplanets and the Search for Life

The discovery of planets beyond our Solar System expands the search for possible

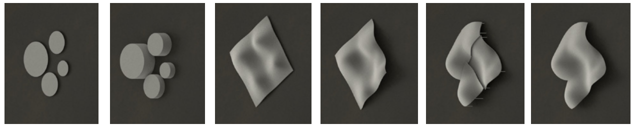


Formation of Planets and Planetary Systems

Planets condense from disks of gas and dust around stars, creating diverse planetary systems.

Scale and Time

Grasping the immense scales and times of the universe helps us

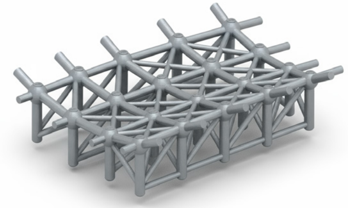


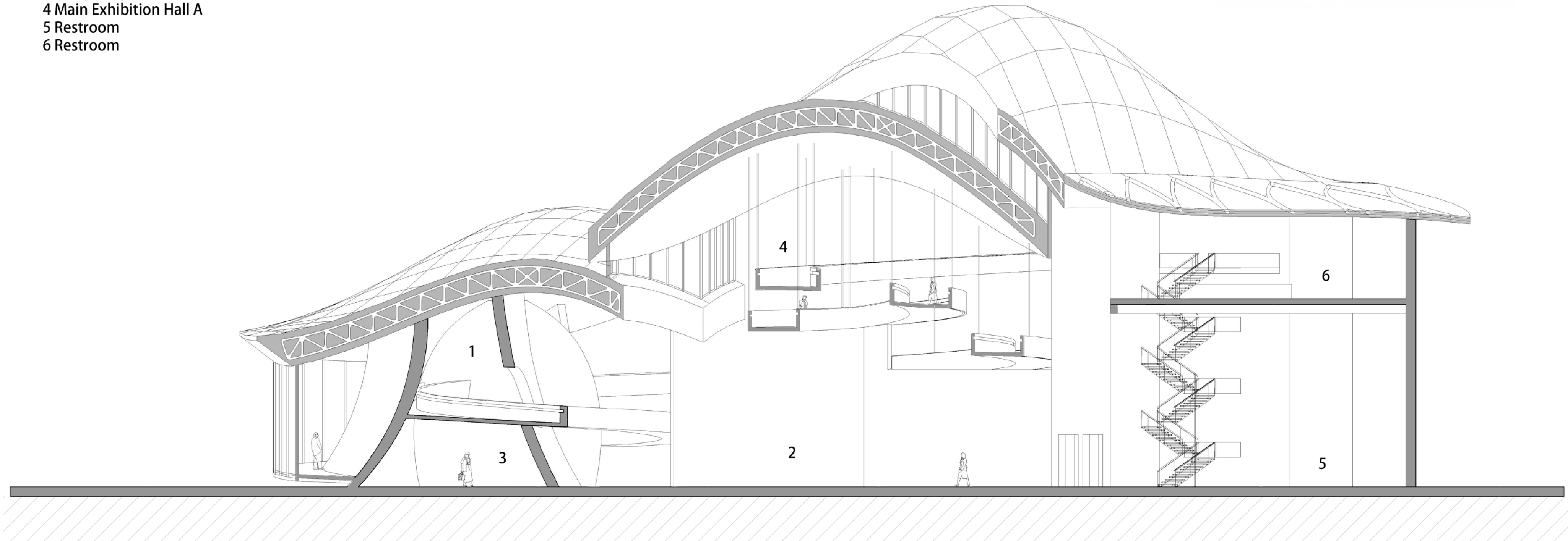
The Astronomical Museum in Yabuli, Heilongjiang, draws its form from the region's snowy landscape and alpine character. Yabuli is defined by its cold climate, long winters, and reputation as one of China's most renowned ski destinations. The architecture takes inspiration from naturally formed snow mounds, whose gentle, fluid contours echo the surrounding mountains covered in snow. This morphological approach allows the building to integrate seamlessly with its site, minimizing visual intrusion while enhancing the dialogue between architecture and nature. The snow-like forms also evoke a sense of purity and stillness—qualities that resonate with the celestial themes of astronomy, creating an environment where visitors can contemplate both the earth and the cosmos.

Section A-A′

0 2,5 5 7,5 10m

1 Main Exhibition Hall B
2 Temporary Exhibition Hall A
3 Temporary Exhibition Hall C
4 Main Exhibition Hall A
5 Restroom
6 Restroom

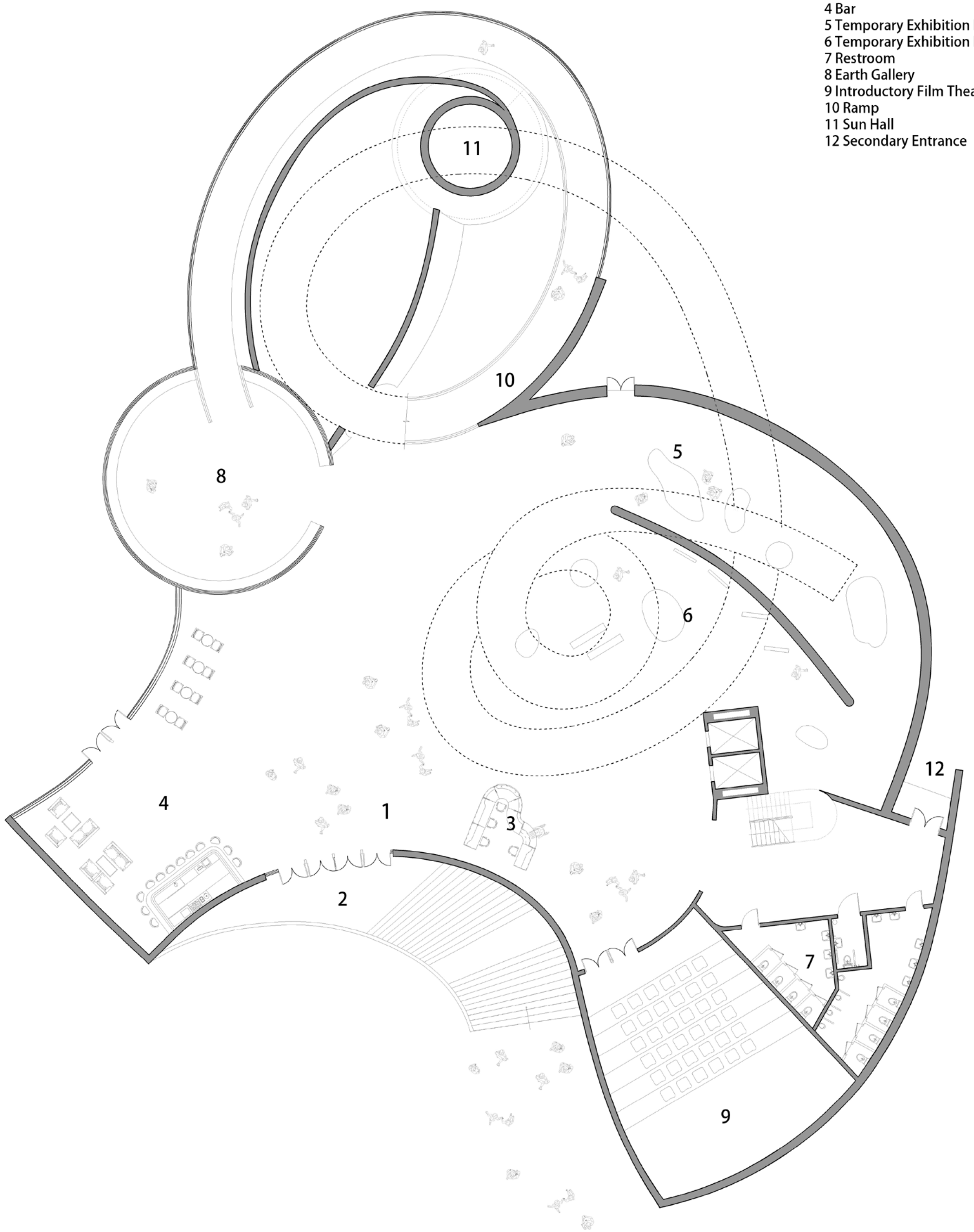


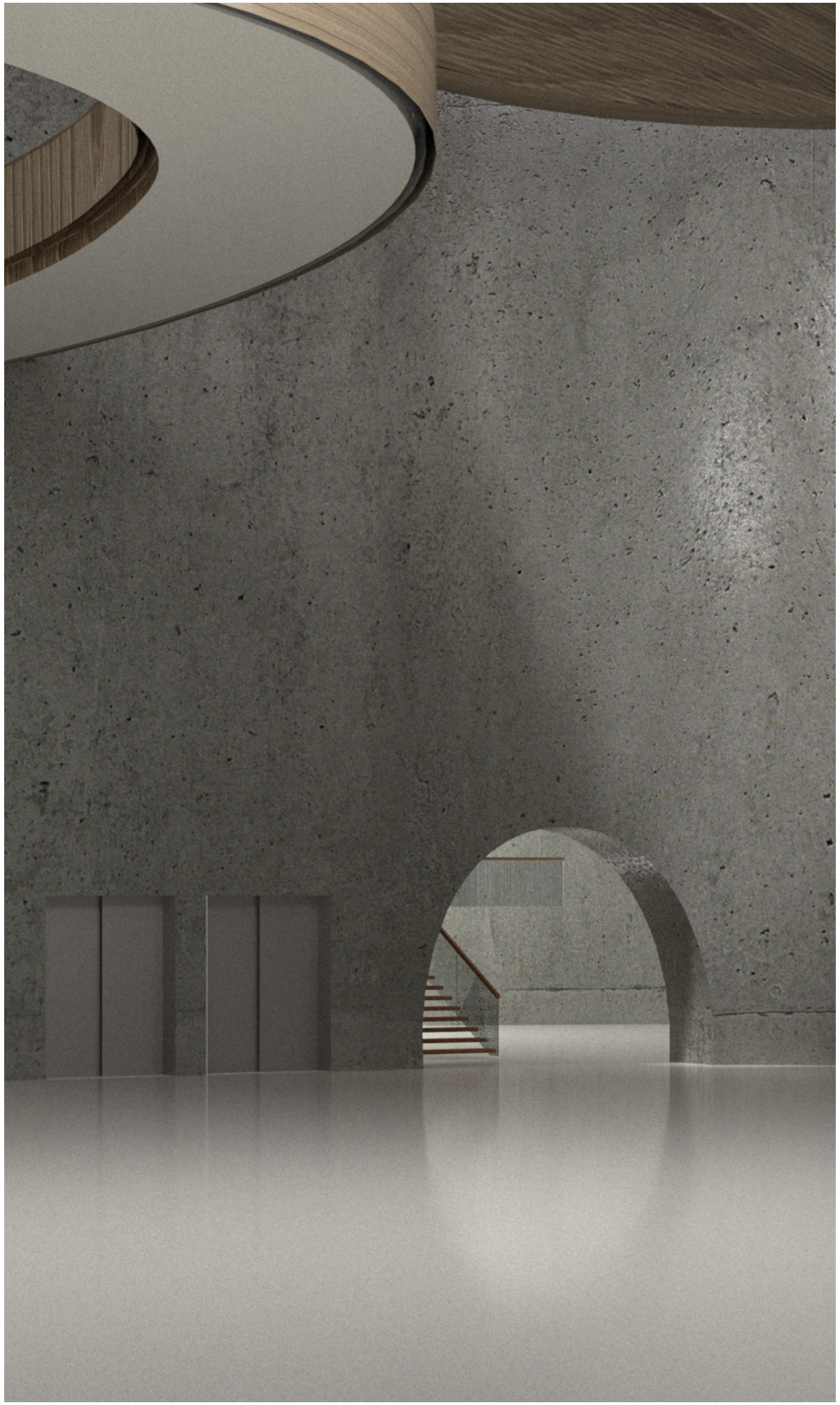


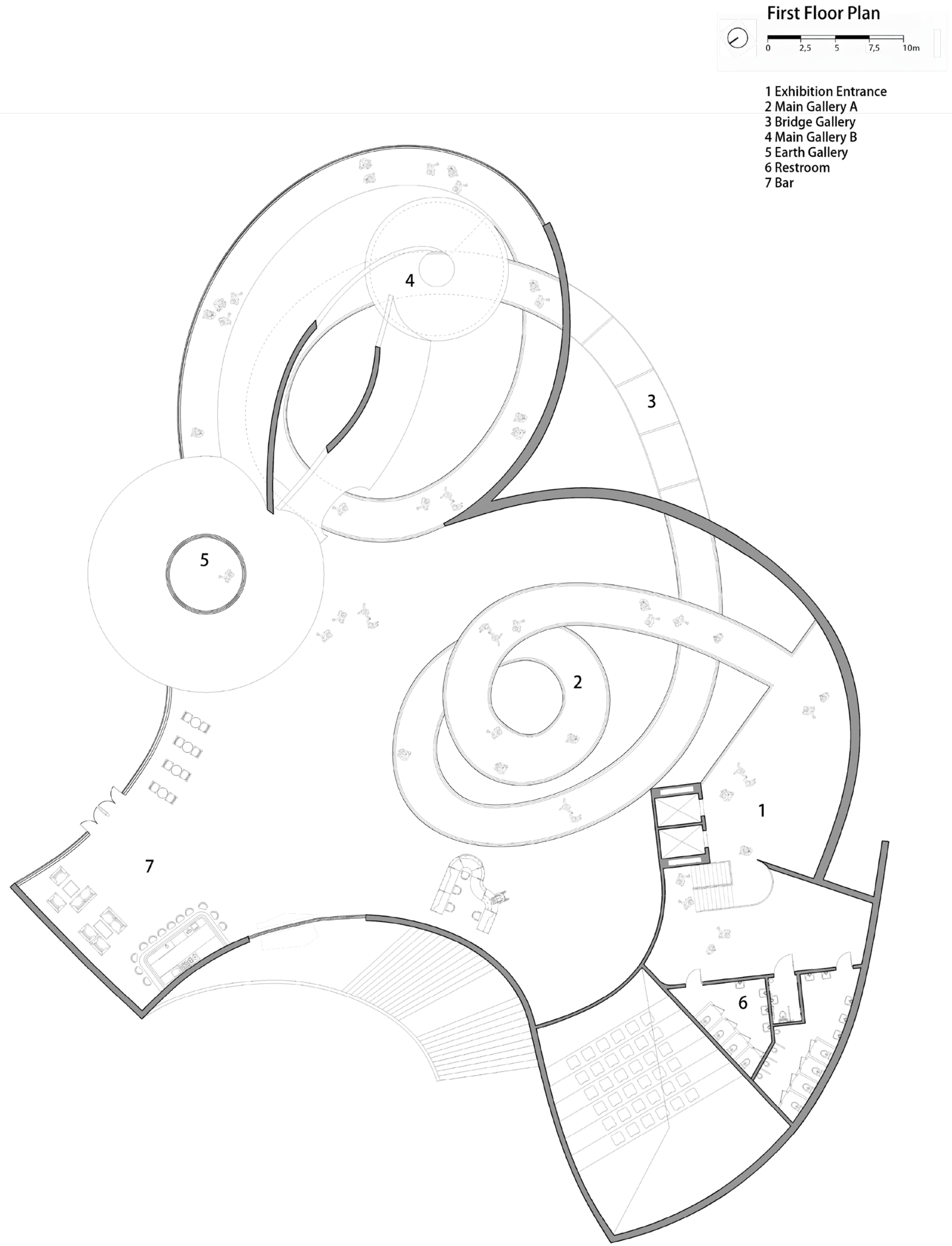
Ground Floor Plan

0 2,5 5 7,5 10m

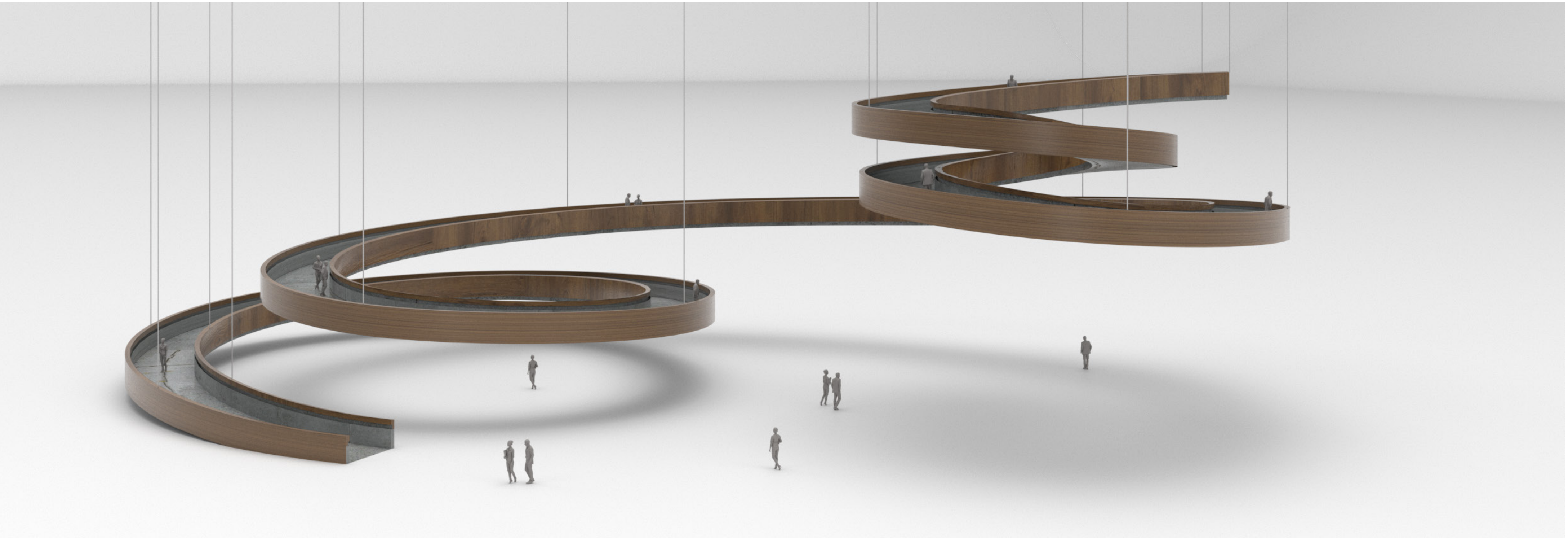
1 Lobby
2 Main Entrance
3 Service Counter
4 Bar
5 Temporary Exhibition Hall A
6 Temporary Exhibition Hall B
7 Restroom
8 Earth Gallery
9 Introductory Film Theater
10 Ramp
11 Sun Hall
12 Secondary Entrance

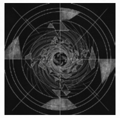
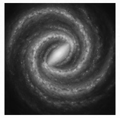
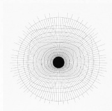
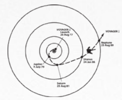






First Floor Plan
0
2,5
5
7,5
10m
1 Exhibition Entrance
2 Main Gallery A
3 Bridge Gallery
4 Main Gallery B
5 Earth Gallery
6 Restroom
7 Bar
1
2
3
4
5
6
7



Angular Momentum & Cosmic Rotationv

The form of the spiral ramp originates from the universal phenomenon of rotation and the conservation of angular momentum during the formation of celestial bodies. From the collapse of nebulae to the birth of stars, planets, and galaxies, rotation represents one of the most fundamental logics of cosmic order.

The building’s spiral form responds to this primal dynamic law of the universe.

Spiral Galaxies

The spiral is one of the most iconic geometries in the cosmos.

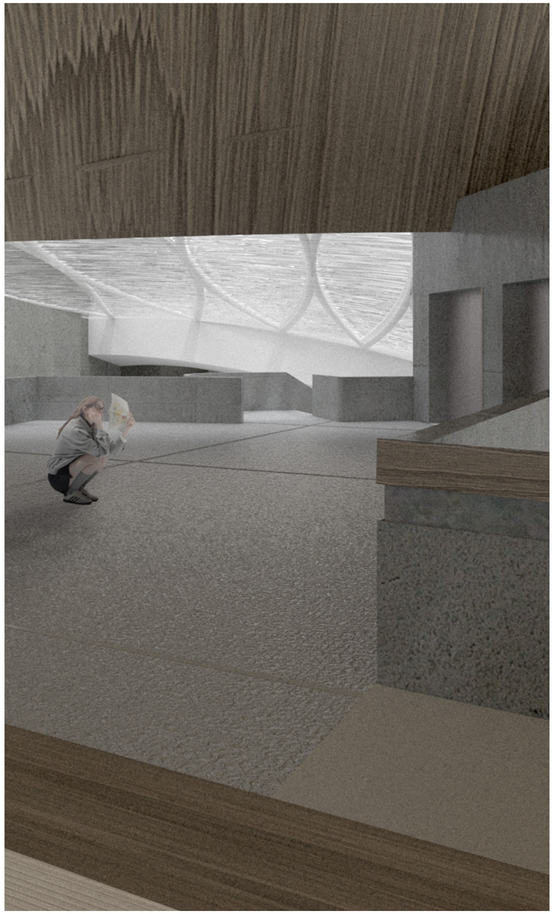
The spiral arms of galaxies such as the Milky Way and Andromeda embody the balance between gravity and motion. Within the museum, the spiral ramp recreates this macrostructure at the scale of the human body, allowing visitors to "enter" the galactic arms through movement.

Gravitational Wells & Curved Spacetime

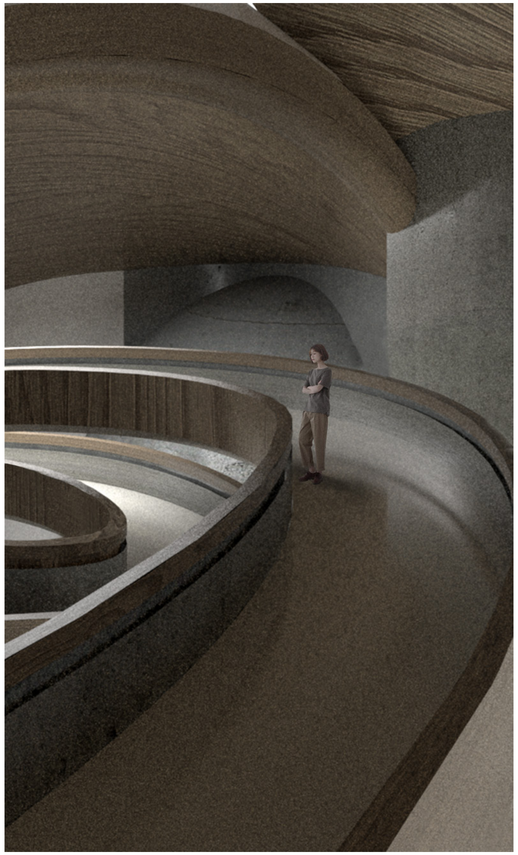
Massive celestial bodies bend spacetime, forming gravitational wells along which all matter follows curved trajectories. The descending spiral path symbolizes the experience of "falling into a gravitational field", inviting visitors to physically sense the curvature of spacetime through their own movement and orientation.

Relativity & the Dissolution of Orientation

In the universe, there is no absolute up or down—only relative frames of reference. Along the spiral circulation, direction constantly shifts and perspectives continuously twist, immersing visitors in a relative spatial system, as if they were drifting within the fluid continuum of the cosmos.



Exhibition Entrance



Down Ramp

The Bioreactor Canopy _ Mine Site Remediation and Ecological Production

Project from EVOLO compitation 2022

The Big Canyon Copper Mine in Arizona represents a critical challenge inherited from industrial legacies: a vast open pit and extensive toxic tailings contributing to persistent soil and water contamination. Moving beyond traditional containment, this project proposes a performance-driven architectural intervention to establish a self-sustaining Ecological Production Hub.

The core innovation lies in integrating architectural design with biochemical engineering. The design converts the mine pit floor into a large-scale Bioreactor, utilizing Anaerobic Fermentation to process local organic waste. This strategic convergence achieves dual sustainability: efficient waste disposal and the generation of high-quality Bio-Fertilizer essential for soil remediation.

A cluster of Adaptive Tensile Membrane Structures is deployed above the Bioreactor. This architecture is not arbitrary; its fixed morphology is the direct, quantifiable output of advanced optimization. We employed a Genetic Algorithm (GA) for Multi-Objective Optimization, ensuring the membrane's geometry precisely regulates temperature, radiation, and airflow. The design is optimized for the most climatically challenging moments (e.g., summer solstice peak hours), guaranteeing maximum microbial efficiency throughout the year.

The final phase involves backfilling the bioreactor with the nutrient-rich digestate, actively initiating ecological succession. By transforming a severely contaminated site into a productive landscape—an Ecological Production Hub—this project establishes a replicable, high-performance model for remediating industrial scars globally and converting environmental liabilities into ecological assets.

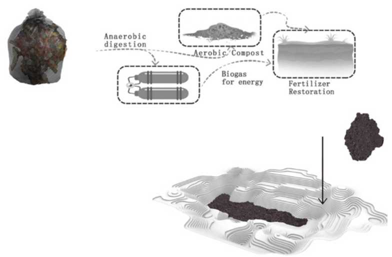
MINE SITE REMEDIATION_ CONTEXT / OBJECTIVES

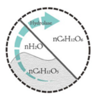
Open-pit mining leaves behind heavily contaminated soil, disrupted hydrology, and damaged ecological systems, and conventional remediation approaches often remain passive and containment-driven. This project proposes a shift toward an active, performance-based restoration method that transforms abandoned mine pits into controlled ecological production systems capable of accelerating soil renewal while simultaneously generating renewable bioproducts.

WASTE-TO-RESOURCE TECHNOLOGY _ ANAEROBIC FERMENTATION

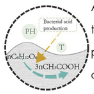
At the center of this strategy is a large-scale anaerobic fermentation bioreactor constructed on the pit floor, where local organic waste undergoes a four-phase transformation involving drying, anaerobic decomposition, aerobic composting, and solar-assisted exposure. Through these coordinated phases, organic matter is gradually converted into biogas that sustains the facility's energy demand and a nutrient-rich digestate that becomes the primary amendment for rebuilding degraded soil. The result is a continuous circular system in which waste management and ecological restoration reinforce one another.

DISPOSAL PROCESS

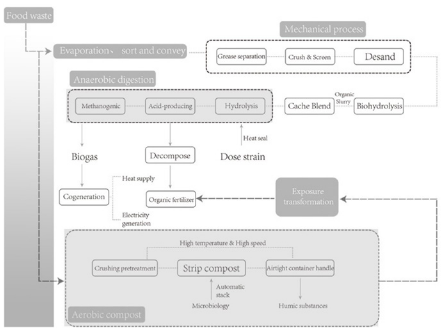


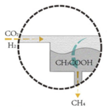


Biohydrolysis process: Depending on the type of reaction catalyzed by the hydrolytic microorganisms, these hydrolysates can be esterases, glycosidases or peptidases.

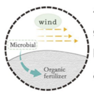


Acidification reaction : which leads to the further conversion of hydrolysis products into volatile fatty acids, alcohols, aldehydes and gases such as CO_2, H_2 and NH_3.





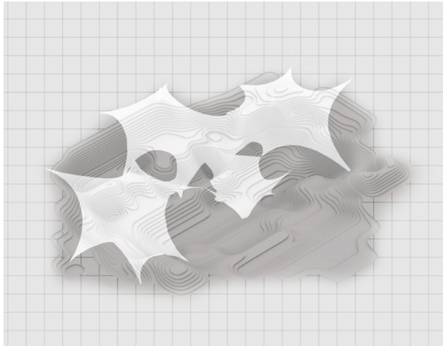
The final stage: he substrate acidification products are converted to CO_2 and CH_4 by methanogenic bacteria.

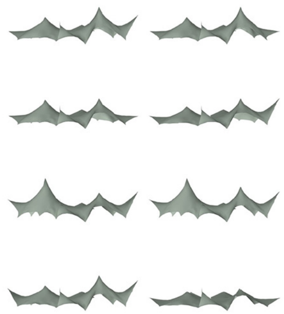


Aerobic composting: the use of microorganisms and waste to carry out different biochemical reactions to ultimately convert food waste into humus and organic fertilizer

ARCHITECTURAL SYSTEM_ ADAPTIVE MEMBRANE STRUCTURE

Suspended above the bioreactor, the adaptive tensile membrane structure acts as an environmental interface that stabilizes the conditions required for efficient fermentation. Its continuously adjustable geometry provides shading during periods of excessive radiation, retains heat when temperatures drop, and subtly redirects airflow to create wind environments suitable for aerobic phases. By responding to hourly climatic fluctuations, the membrane ensures that microbial processes remain in their optimal thermal and atmospheric ranges.





Provide Shading

Hear Resercation

Change The Wind Environment

MATERIAL STRATEGY_ MYCELIUM-BASED COMPONENTS

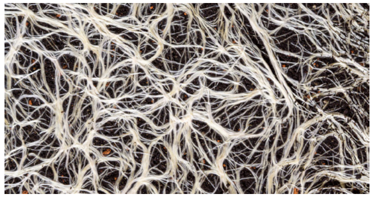
The interior secondary components are constructed with mycelium-based bio-materials chosen for their biodegradability and their compatibility with the project's regenerative goals. As the material naturally breaks down over time, it leaves no detrimental residue and gradually integrates into the soil as an organic supplement, reinforcing the long-term ecological renewal initiated by the fermentation process. This integration allows the building to participate directly in the landscape's recovery rather than exist apart from it.

Applications of Mycelium in Construction

The Growing Pavilion in the Netherlands

MycoTree in Seoul

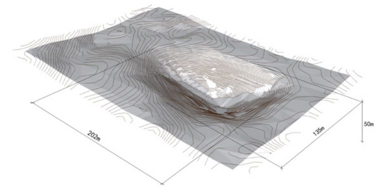
The Hy-Fi Pavilion in New York

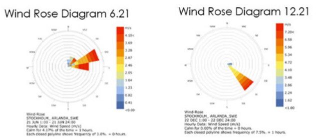


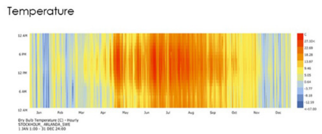
Mycelium

DEMONSTRATION SITE_ FALUN MINE, SWEDEN

The Falun Copper Mine in Sweden, a UNESCO World Heritage site, was selected as a representative case due to its steep pit geometry, heavy-metal contamination, and sub-arctic climate. Analyses of annual solar exposure, thermal cycles, and wind rose data revealed a highly variable environment where drastic seasonal shifts and irregular wind corridors created by the pit's terrain demand precise architectural and thermal control.

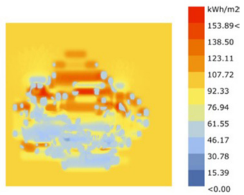


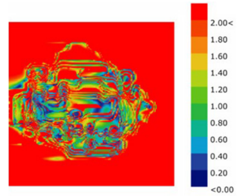


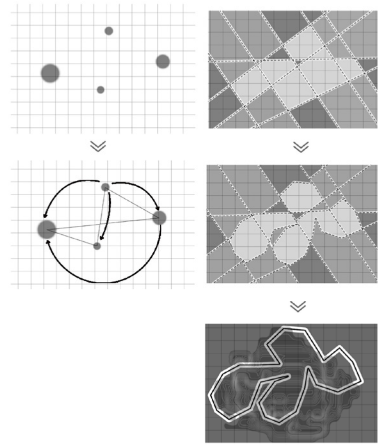


ENVIRONMENTAL SIMULATION / SPATIAL STRATEGY

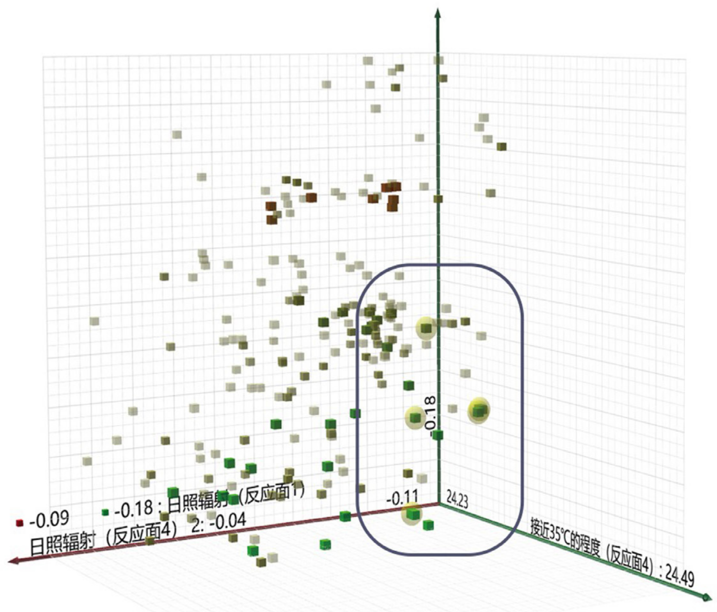
Through microclimatic modeling conducted with Ladybug, Honeybee, and CFD simulations, the pit's hourly behavior in terms of radiation, temperature, and airflow was reconstructed. The simulations disclosed strong summer radiation concentrated on the pit floor, significant winter heat loss, and complex airflow patterns shaped by the surrounding mineral walls. These findings, combined with the physical requirements of the four fermentation phases described on Page 1, guided the positioning of the bioreactor pits and the arrangement of membrane structures within the site.







PERFORMANCE-DRIVEN OPTIMIZATION OF MEMBRANE GEOMETRY

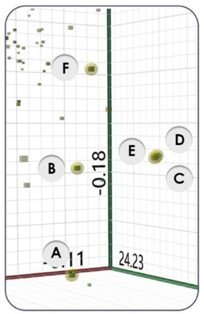


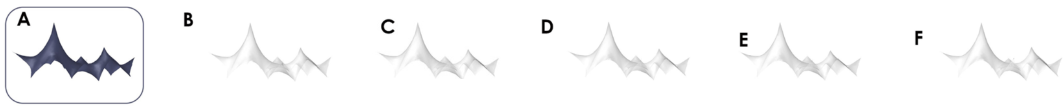
The membrane geometry was optimized in Grasshopper by linking its anchor-point coordinates to the specific physical requirements of the four fermentation stages. Each stage demands a distinct microclimatic condition:

The evaporation and delivery phase benefits from stronger short-term solar radiation;
The anaerobic fermentation phase requires temperature stability around 35 °C;
The aerobic composting phase performs best under higher wind speeds;
The exposure conversion phase again relies on accumulated sunlight to accelerate biochemical reactions.

These environmental needs were translated into performance metrics that the membrane must regulate—solar admission, shading response, thermal retention, and wind-field modulation.

Using Octopus for multi-objective genetic optimization, thousands of membrane configurations were evaluated simultaneously against these stage-based criteria, together with structural stability and radiation mitigation of the pit environment. The algorithm produced a Pareto front of non-dominant solutions, from which the final geometry was selected for its ability to maintain ideal conditions even during the most extreme climatic hour—peak solar intensity at noon on the summer solstice—ensuring that all four fermentation stages can operate efficiently throughout the year.





As the soil returns and the membranes settle into the terrain, the former mine shifts from a landscape of extraction to one of renewal. Architecture and ecology merge, allowing the pit to evolve into a living ground once again.

SITE TRANSFORMATION

Snowflake Crystal Formation

Set within the snow-covered landscape of Yabuli, Heilongjiang—a region known for its alpine terrain and long, crystalline winters—the Astronomical Museum emerges as both an extension of the earth and a vessel for the cosmos. Its architecture draws inspiration from the natural morphology of snow mounds, whose fluid contours echo the surrounding mountains. The building settles gently into the terrain, merging with its environment rather than standing apart, evoking a seamless dialogue between nature and the universe.The spatial narrative of the museum transforms the act of exploration into a cosmic journey. Visitors begin at a vast entrance hall, ascend by elevator to the highest interior point, and then follow a long, spiraling ramp that descends through a sequence of immersive environments. Each segment of the descent embodies a different concept of the universe—from the primordial explosion of the Big Bang, to the curvature of spacetime, the birth and death of stars, the enigma of black holes, and the invisible forces of dark matter and dark energy.

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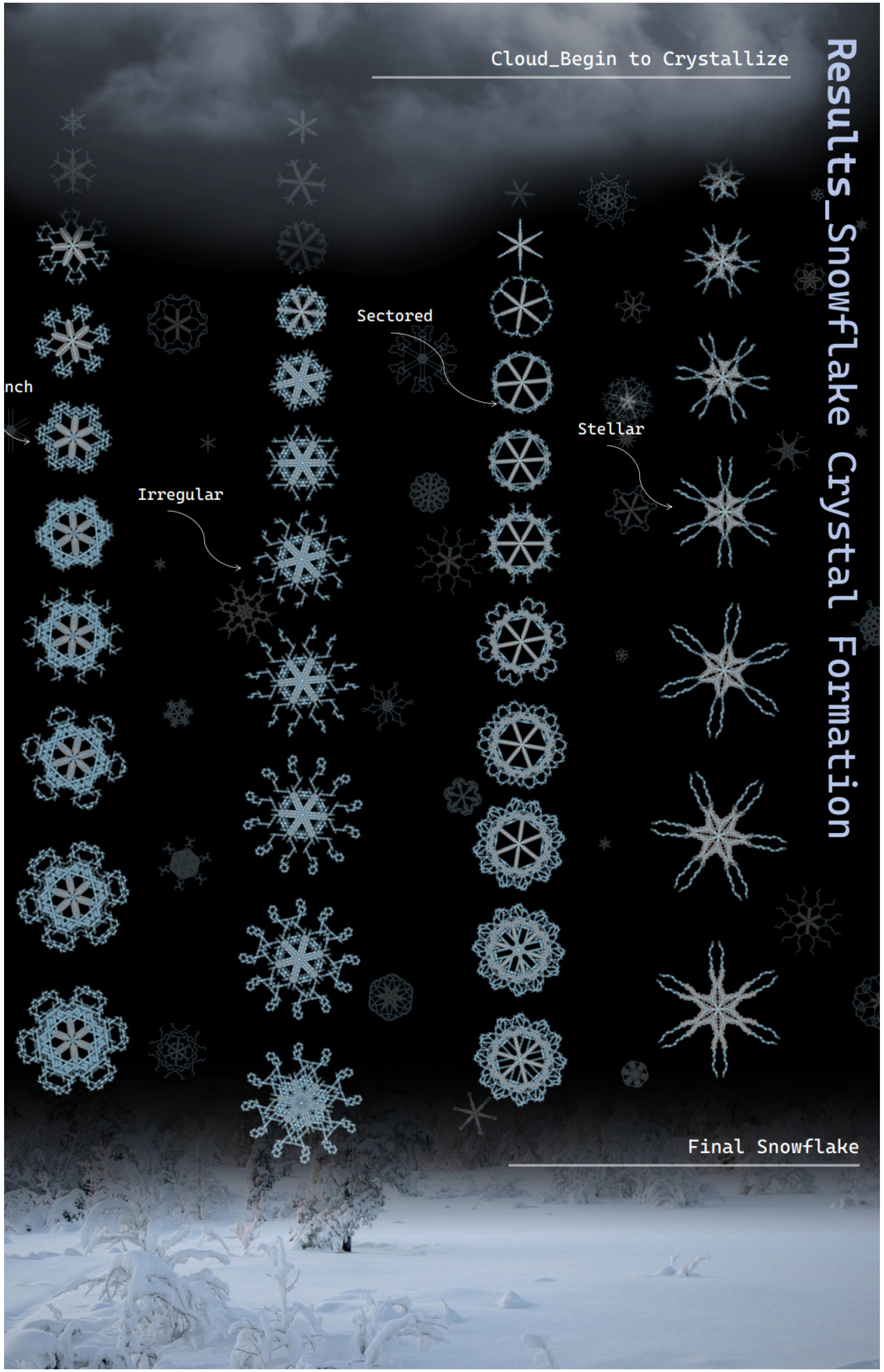

Pseudocode_Snowflake Crystal Formation

Initialize System

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Set grid size = 100
Set triangle size = 1.0
Set maximum simulation steps = 70
```

Select Snowflake Type

```
    Select snowflake type:
        Randomly choose from available types (Stellar, Broad Branch, Sectored,
Irregular)
        Add random factor to all parameters (±5-20%)
```

Set Environmental Parameters

```
Create grid points array
Create all triangles list (from input mesh)
Initialize spatial query structure

For each point (x,y) in grid:
    Calculate distance to origin
    Set initial vapor value based on snowflake type
    Add random factor to vapor value
    Initialize temperature value to 0

Create initial vertical line segment from origin (seed)
Update vapor and temperature field around seed
```

One step in the growth process___Main loop (while simulation step < 70)

ONE STEP OF GROWTH

```
Increment step counter
Update vapor and temperature fields

If step >= 65 or approaching maximum size:
    Execute late-stage growth mode
    (primarily face crystal growth)

Else:
    If main branch hasn't exceeded
    maximum length:
```

GrowLineCrystal()

```
Get tip position and direction from current last segment

Calculate new growth direction:
    Small probability to deflect original direction
    Apply rotation transformation

Calculate growth step size:
    Base step size = lineStepX × random factor
    Reduce step size when approaching maximum radius

Create new line segment:
    New point = current point + direction × step size
    Add to line crystal list

Update environmental fields

Branch generation:
    If random value < branch probability × distance factor:
        Determine branch angle based on type
        Create branch segment
        Update environmental fields
```

GrowFaceCrystal()

```
Find candidate triangles:
    Check triangles adjacent to occupied triangles
    Check triangles adjacent to line segments

Calculate growth weights:
    Base weight = 1
    Adjust based on type and position
    Adjust based on vapor and temperature

Randomly select triangles based on weights

Occupy selected triangles:
    Add to occupied list
    Update environmental fields
```

Vapor and Temperature Control

```
UpdateVaporAndTemperature(point, intensity):
    Calculate influence radius:
        Base radius = 3 × (1 + scale × 7)

    For each grid point within radius:
        Calculate distance to center
        If within radius:
            Calculate effect factor = 1 - (distance / radius)
            Add random variation (±20%)
            Decrease vapor concentration at point
            Increase temperature at point
```

```
OperateVaporAndTemperature
    Add vapor near line tips:
        For each line segment:
            Get tip position
            Within surrounding radius:
                Adjust vapor addition based on type
                    If Stellar: adjust based on direction similarity
                    If Plate Columns: adjust based on perpendicularity
                Apply random factor
                Add vapor to grid point (max value 10)
                Reduce temperature (×0.7)

    Perform global cooling:
        For entire grid:
            Temperature ×= 0.7 × (1 ± random factor)
```

Methods Review_Snowflake Crystal Formation

Simulated Physical Principles

Diffusion-Limited Aggregation
Simulates the diffusion of supersaturated water vapor toward the growing crystal surface. In the algorithm, the vapor field is represented by a two-dimensional grid, with vapor concentration values ranging from 0 (saturated) to 10 (highly supersaturated). The crystallization process consumes local vapor, creating concentration gradients that further guide growth direction.

Anisotropic Growth
Ice crystals have a hexagonal structure at the molecular level, causing growth rates to differ in different directions. The algorithm utilizes symmetry simplification, simulating only 1/12 sector (30° angle), then reconstructing the complete form through mirroring and rotation.

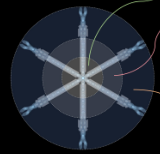
Thermodynamic Effects
The crystallization process releases latent heat, raising local temperature. In the algorithm, the temperature field shares the grid structure with the vapor field. Crystal growth increases local temperature, and high-temperature areas inhibit subsequent growth, forming a natural feedback mechanism.

Adaptation Mechanisms

Vapor Field Adaptation
Crystal growth consumes surrounding vapor, reducing local concentration. Vapor diffuses from high concentration areas to low concentration areas, with the rate affected by the vapor gradient. This diffusion process simulates the material migration in nature, ensuring reasonable distribution of vapor resources.

Temperature Field Adaptation
The crystallization process releases latent heat, raising surrounding temperature. The temperature field gradually equalizes over time, simulating heat diffusion. The inhibitory effect of temperature on growth (lower growth probability in high-temperature areas) creates a natural regulation mechanism.

Distance-Based Growth Adjustment



0-30% of maximum radius
Low branching probability, high growth density, forms the crystalline core. Vapor consumption is concentrated, temperature is higher, and face crystals develop preferentially.

30-70% of maximum radius
Gradually increasing branching probability, optimal growth conditions, main morphological development area. Vapor is abundant, temperature is moderate, line and face crystals develop in balance.

70-100% of maximum radius
Highest branching probability, decreasing step size, formation of fine structures. Vapor resource competition intensifies, growth speed slows, forming delicate terminal structures.

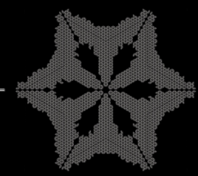
Snowflake Types

Snowflake Type	Branching Probability	Face Density	Vapor Distribution Pattern	Structural Features
Stellar	0.1-0.3	0.3-0.5	Concentrated along main axis	Thin line crystals, few branches
Broad Branch	0.3-0.7	0.6-0.9	Uniform distribution	Robust line crystals, many branches
Sectored	0.4-0.8	0.5-0.9	Angular sector distribution	Clear sector boundaries
Irregular	0.3-0.8	0.4-1.0	Random distribution	Irregular structure, low symmetry

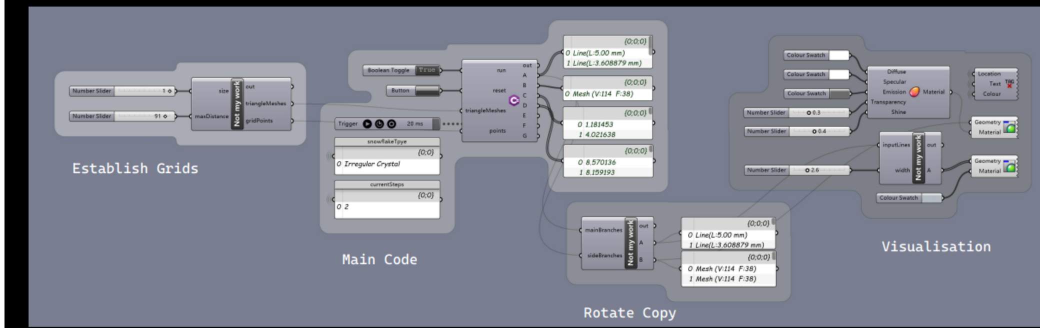
Growth Structure

Line Crystals
Uses line segments to represent the main trunk structure of the snowflake. Grows in areas with high vapor concentration (7-10), follows directional continuity but introduces small probability deflections. Line crystals can produce branches based on probability and distance, simulating tree-like growth patterns. Each step of line crystal growth updates the surrounding environmental field, forming dynamic feedback.

Face Crystals
Uses equilateral triangle mesh to represent the plate-like filling parts of the snowflake. Grows in areas with medium-low vapor concentration (1-6), gradually expanding by weighted selection of adjacent triangles. Face crystal growth is influenced by local environmental conditions (vapor, temperature) and snowflake type parameters, ensuring morphological consistency.



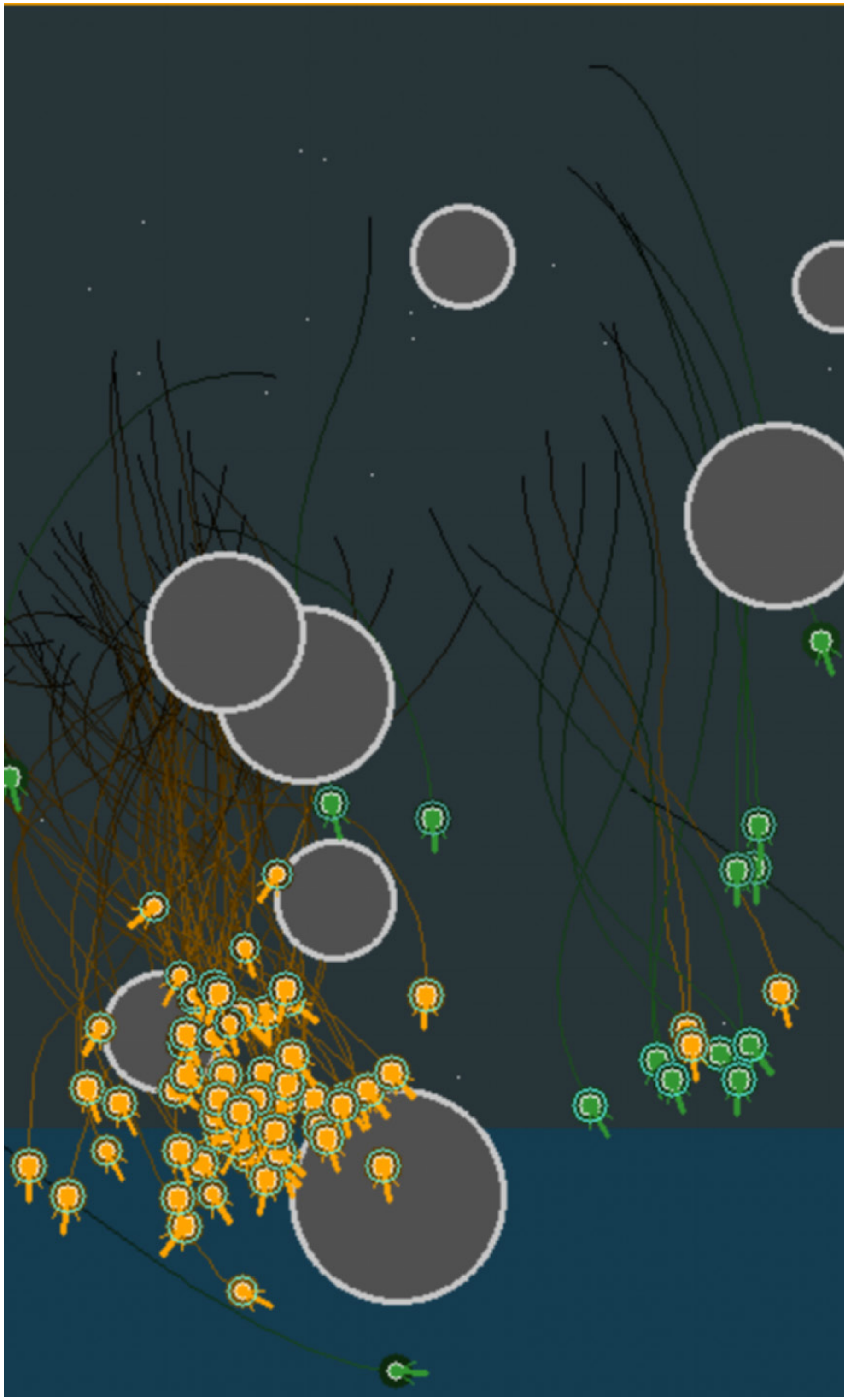
Interface Setup



Future Work

- Extension to 3D crystal growth simulation
- Integration of more complex environmental factors_airflow, humidity changes

Boids Simulation

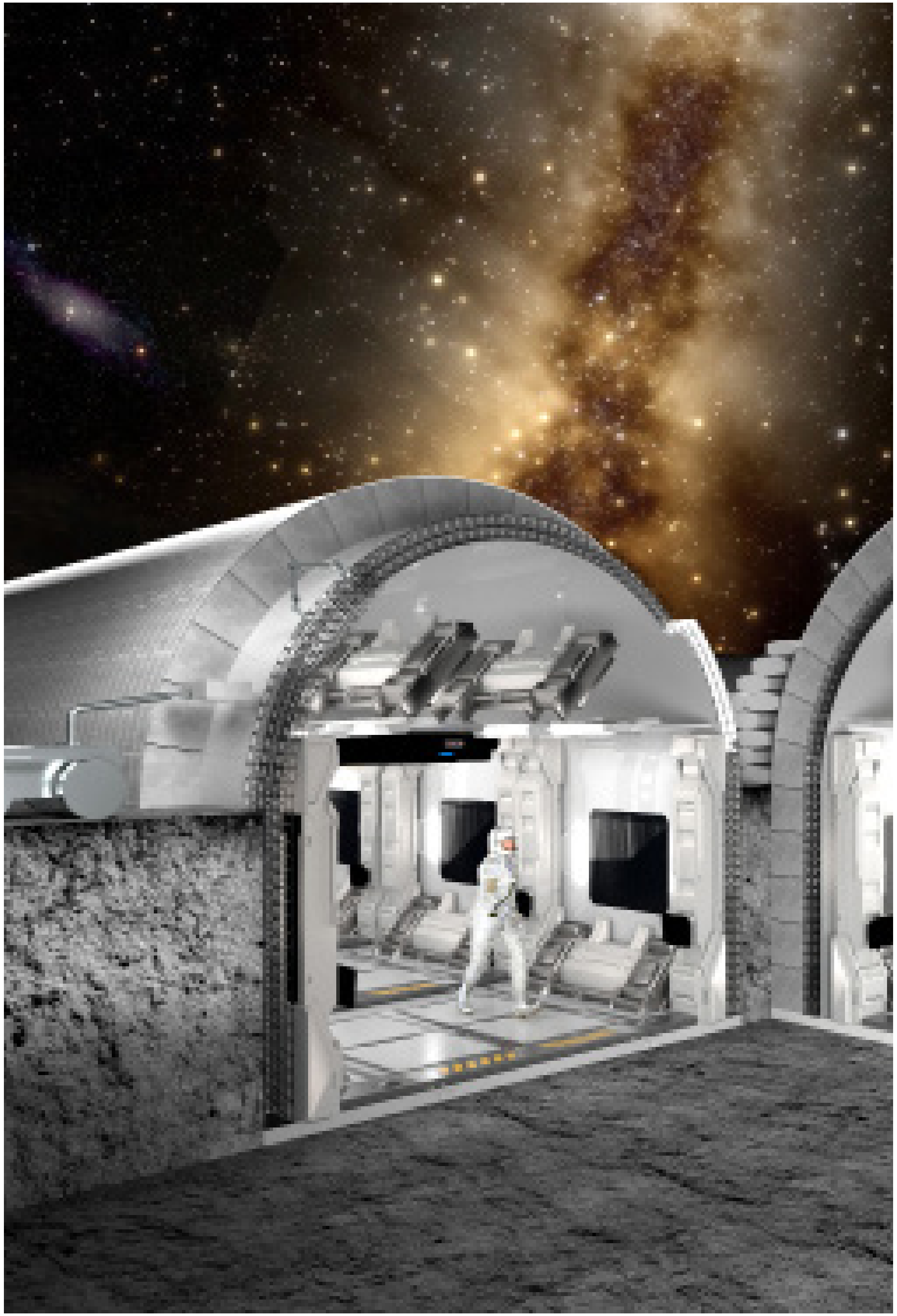


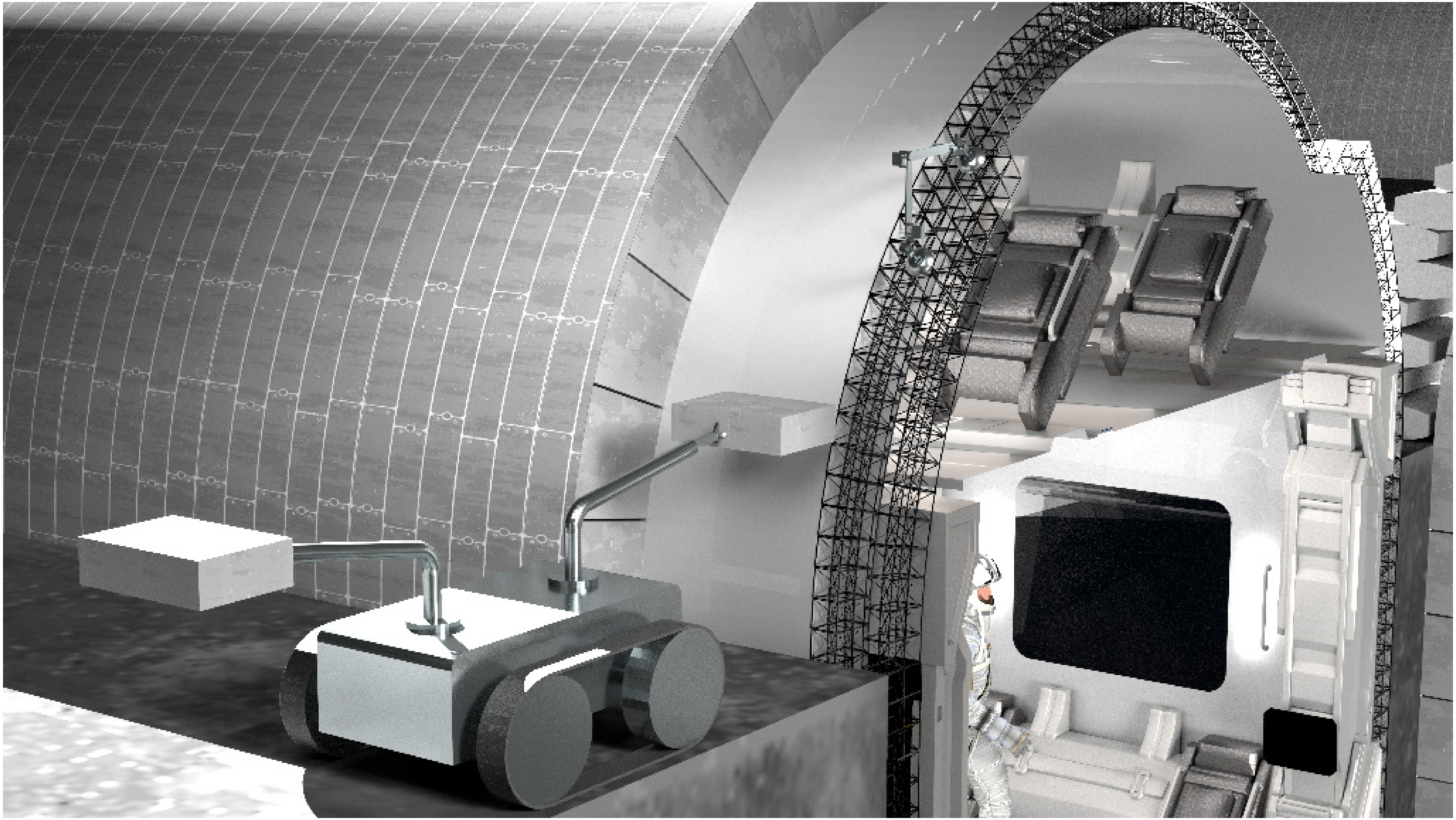
Buildings on the Moon

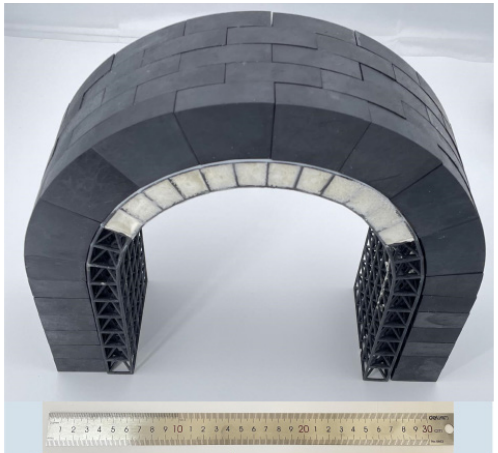
-

Set within the snow-covered landscape of Yabuli, Heilongjiang—a region known for its alpine terrain and long, crystalline winters—the Astronomical Museum emerges as both an extension of the earth and a vessel for the cosmos. Its architecture draws inspiration from the natural morphology of snow mounds, whose fluid contours echo the surrounding mountains. The building settles gently into the terrain, merging with its environment rather than standing apart, evoking a seamless dialogue between nature and the universe.The spatial narrative of the museum transforms the act of exploration into a cosmic journey. Visitors begin at a vast entrance hall, ascend by elevator to the highest interior point, and then follow a long, spiraling ramp that descends through a sequence of immersive environments. Each segment of the descent embodies a different concept of the universe—from the primordial explosion of the Big Bang, to the curvature of spacetime, the birth and death of stars, the enigma of black holes, and the invisible forces of dark matter and dark energy.

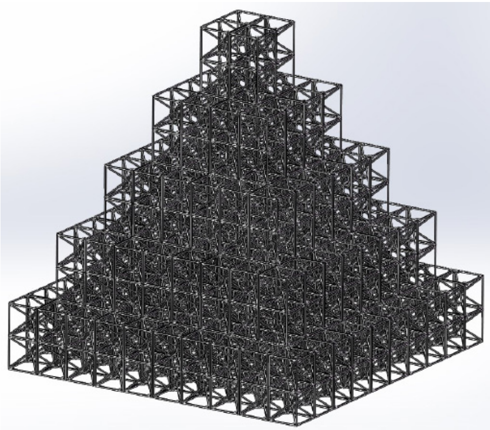
The building itself becomes the medium of exhibition. Instead of relying on display cases or digital installations, the architecture gives physical form to abstract astronomical ideas. Light, scale, materiality, and spatial tension together construct a sensorial cosmology—an experience that is not simply about observing the universe, but about being inside its unfolding.Through its sinuous, snow-formed geometry and its narrative descent through space and time, the Astronomical Museum invites visitors to perceive the unity between earthly landscape and cosmic order, between architecture and infinity.

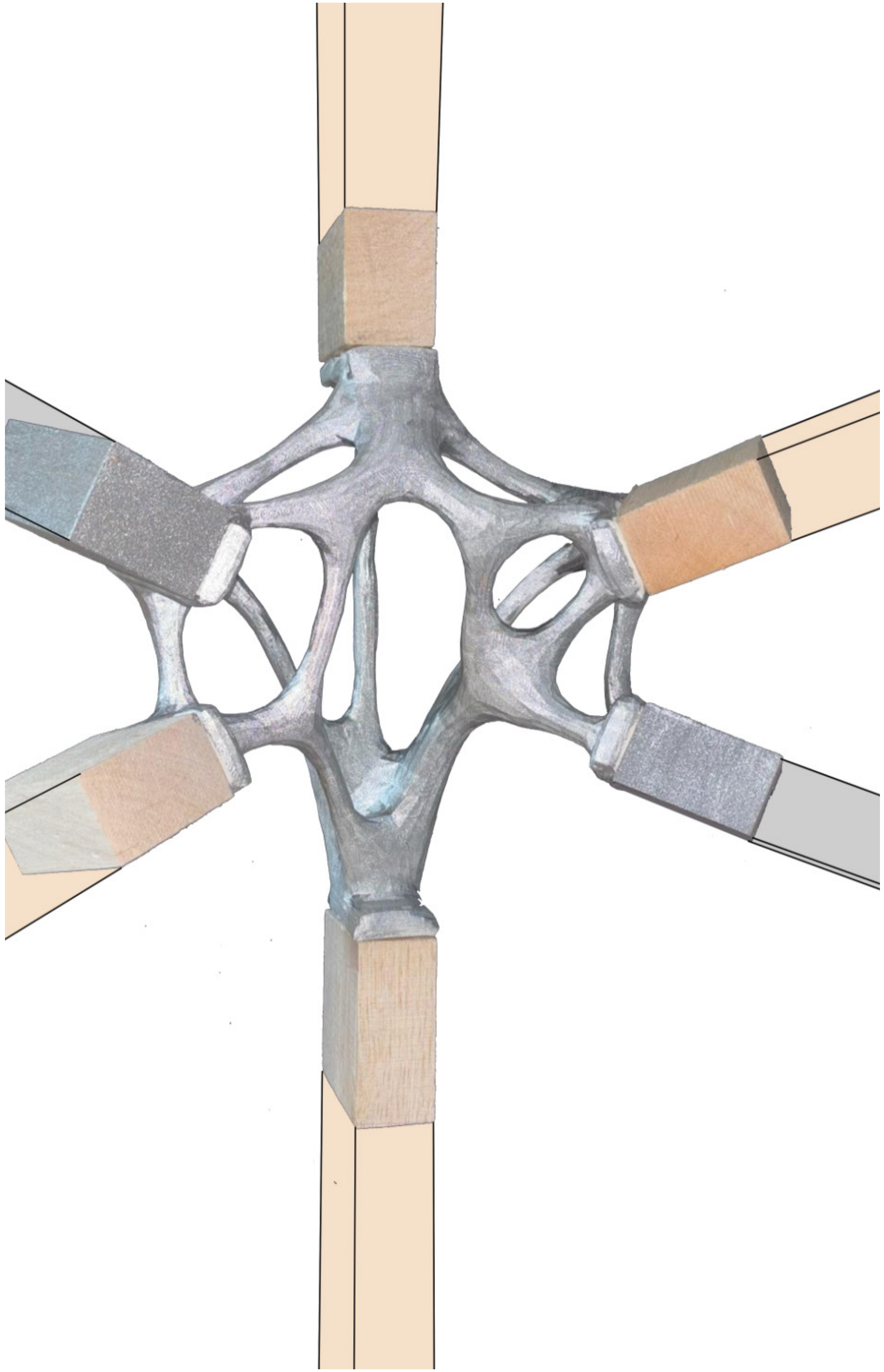






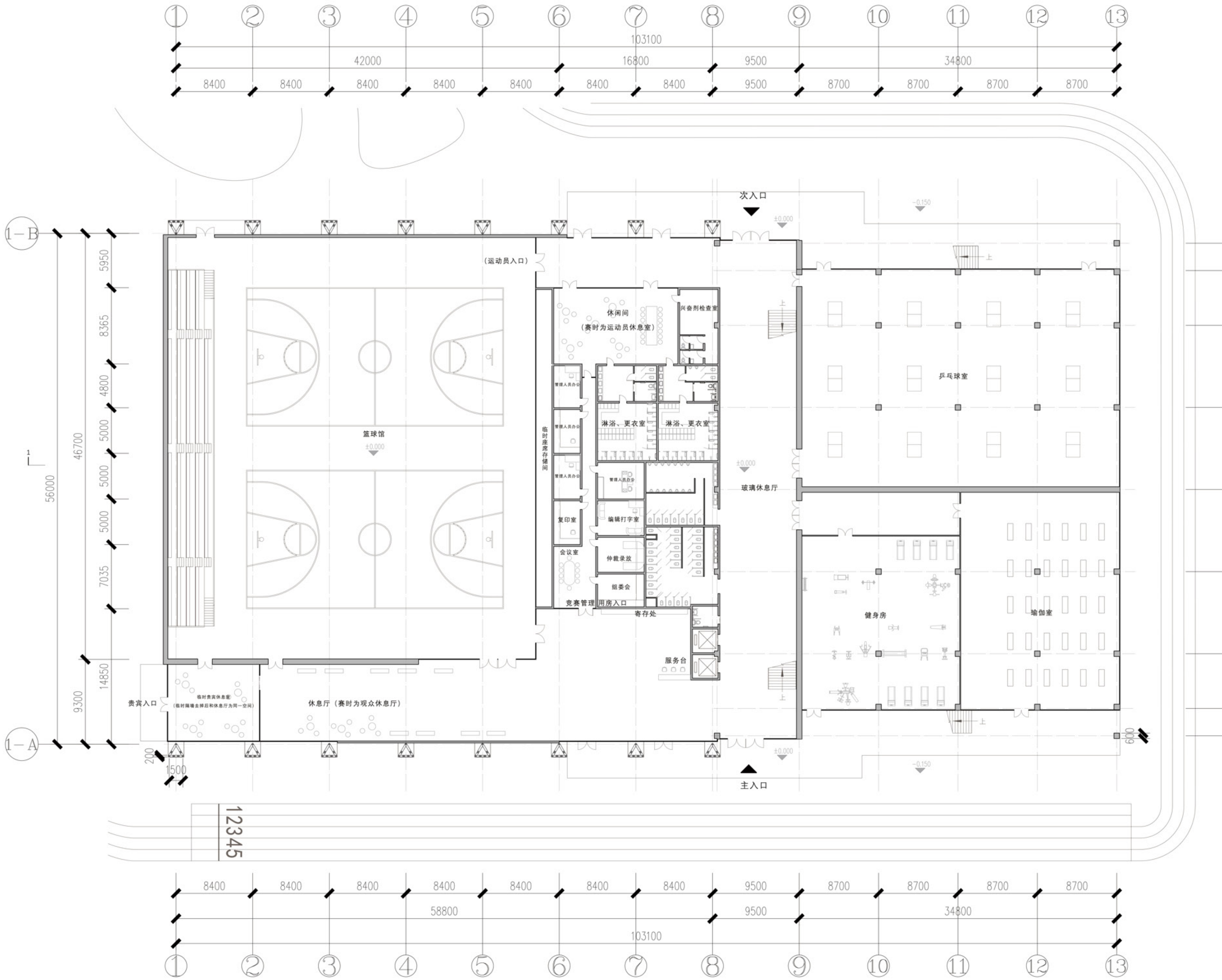
哈爾濱工業大學
HARBIN INSTITUTE OF TECHNOLOGY
轻质材料与结构实验室
Lightweight Materials and Structures Laboratory

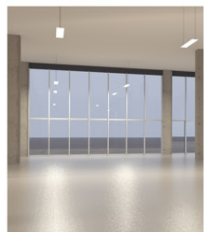




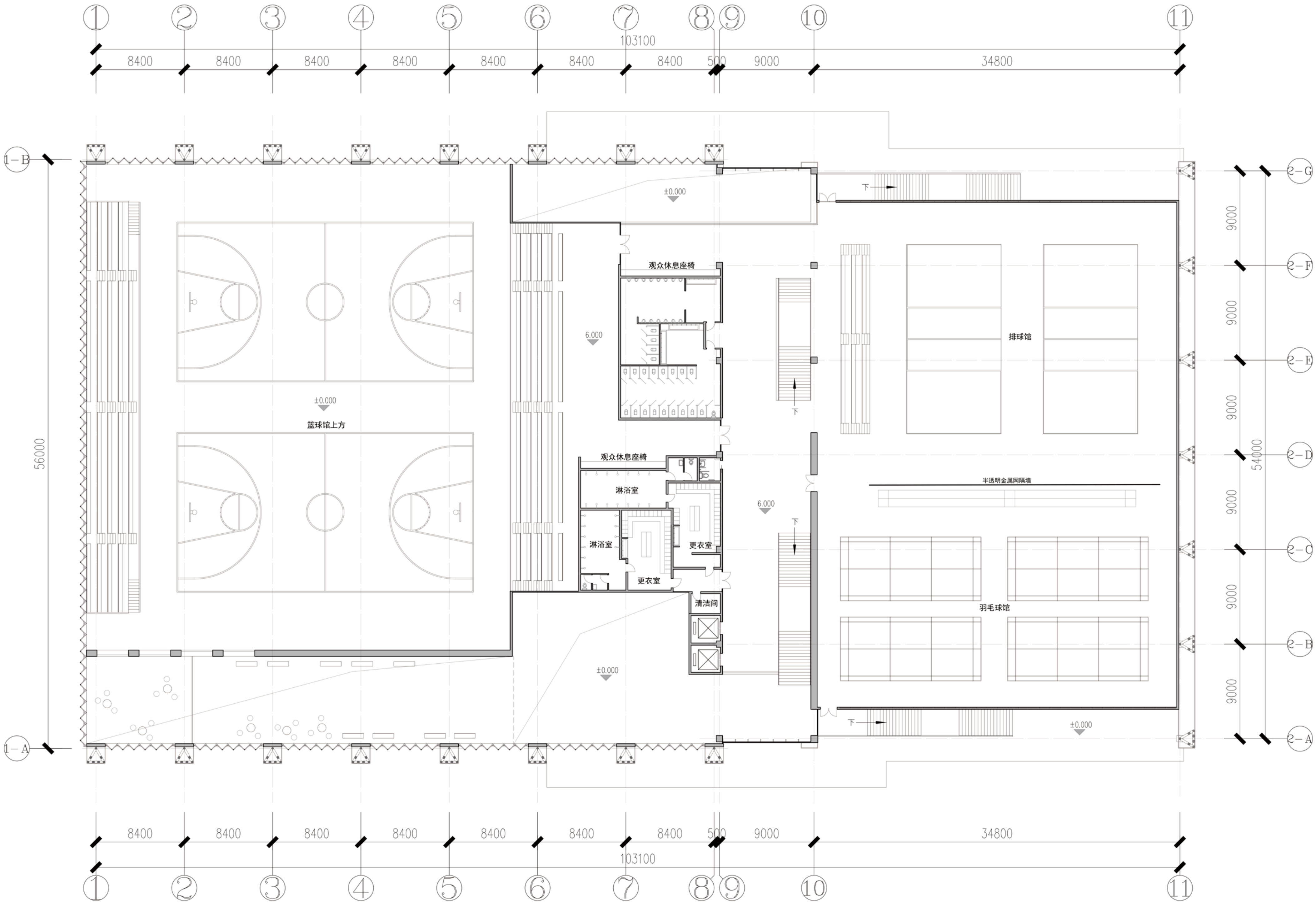
建筑主入口

首层平面图1：150


次入口
主入口
篮球馆
休闲间
（赛时为运动员休息室）
兴奋剂检查室
淋浴、更衣室
淋浴、更衣室
玻璃休息厅
乒乓球室
健身房
瑜伽室
编辑打字室
仲裁录放
组委会
会议室
复印室
竞赛管理用房入口
寄存处
服务台
贵宾入口
临时贵宾休息室
休息厅（赛时为观众休息厅）
（运动员入口）
临时座席存储间



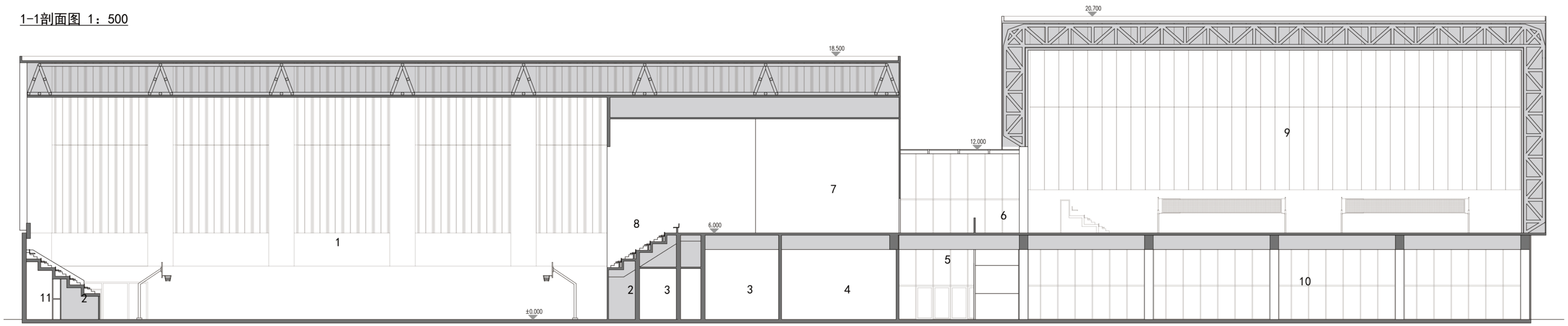
二层平面图 1：100

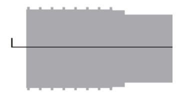


103100
8400
8400
8400
8400
8400
8400
8400
500
9000
34800
±0.000
观众休息座椅
6.000
±0.000
篮球馆上方
观众休息座椅
淋浴室
淋浴室
更衣室
更衣室
清洁间
6.000
±0.000
排球馆
半透明金属网隔墙
羽毛球馆
±0.000
56000
54000
9000
9000
9000
9000
9000
9000

东南立面图 1：500

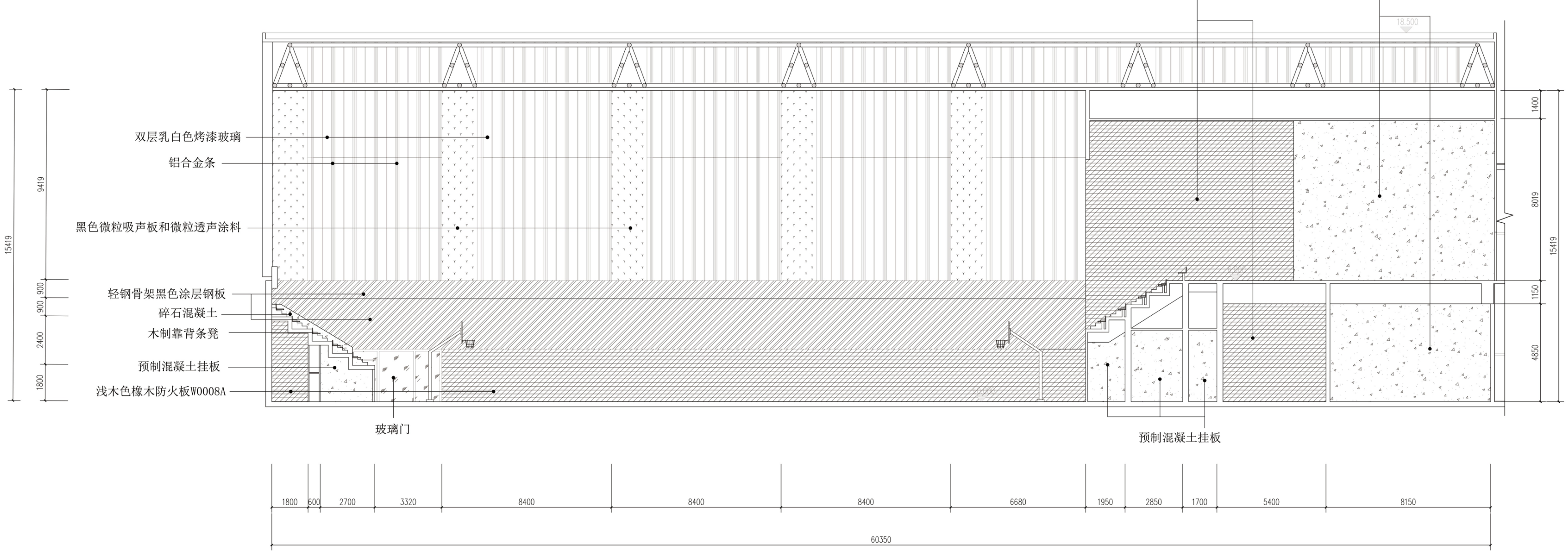
1-1剖面图 1：500



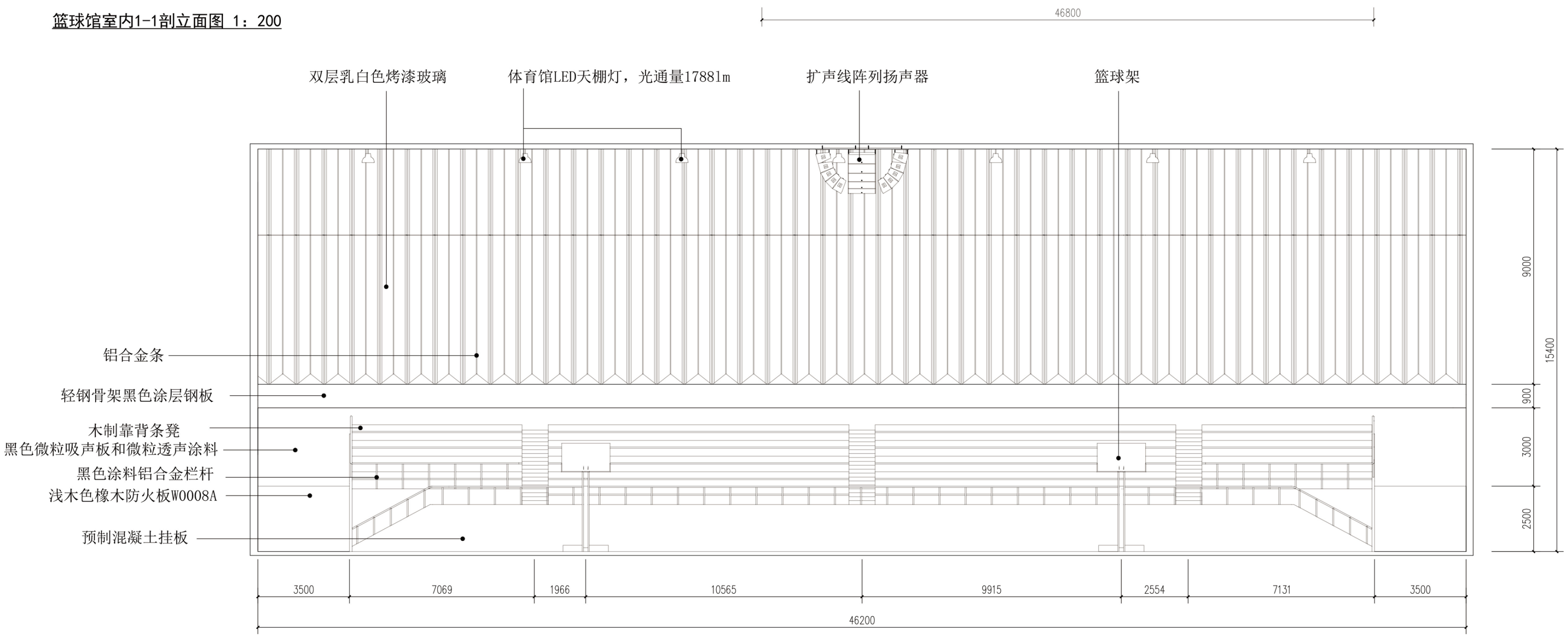


1 篮球馆
2 临时看台储存间
3 竞赛管理用房
4 卫生间
5 玻璃中厅
6 楼梯
7 观众休息区、走廊
8 看台
9 排球馆
10 乒乓球馆
11 寄存间

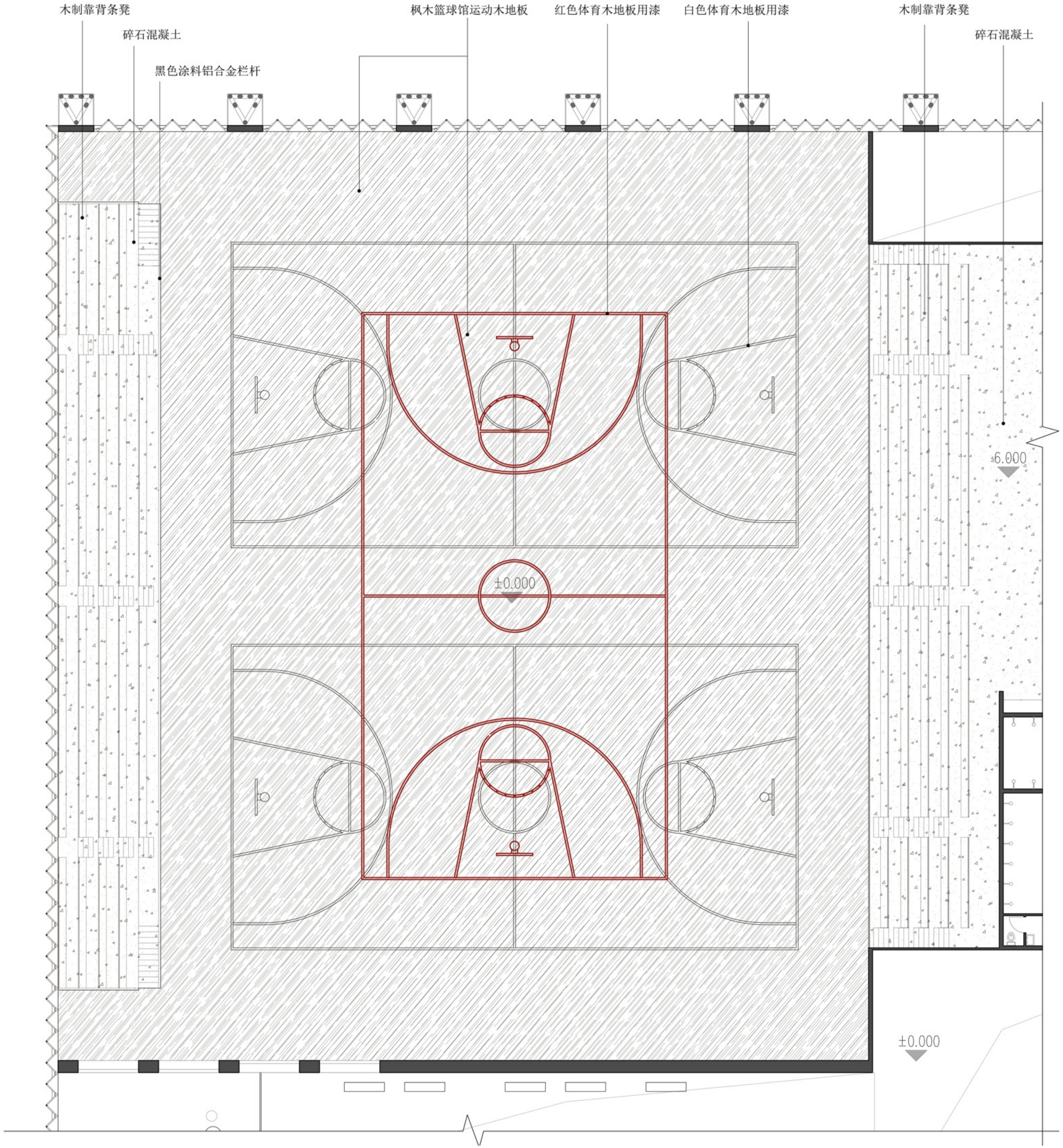
篮球馆室内1-1剖立面图 1：100



篮球馆室内1-1剖立面图 1：200

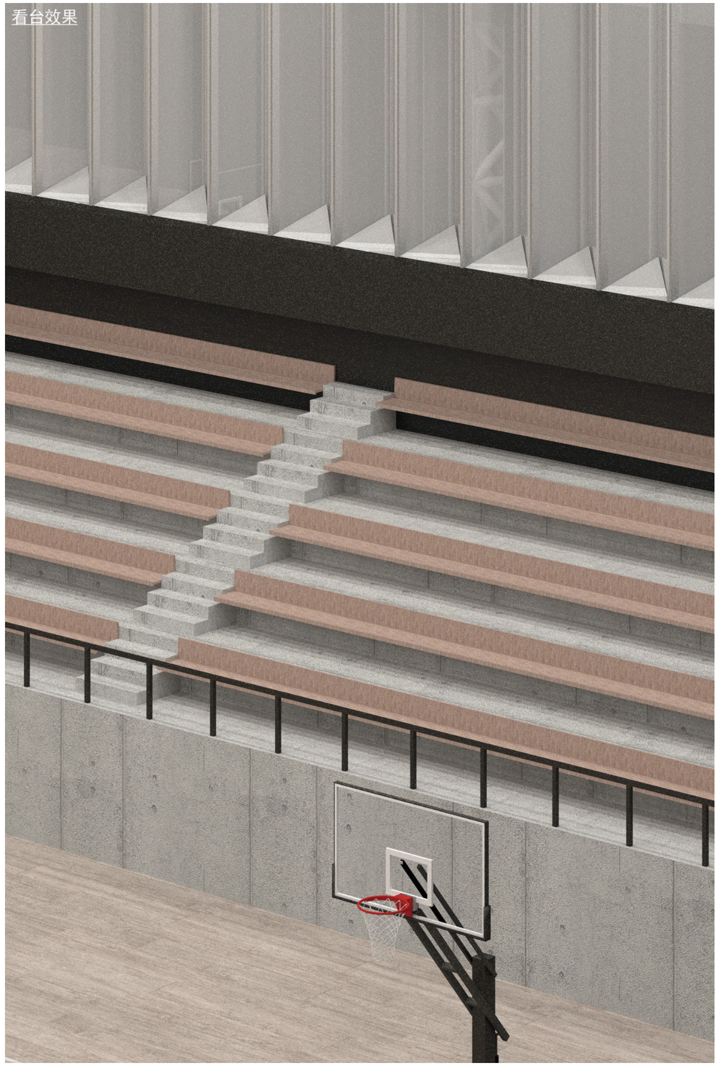


篮球馆地面布置平面图 1：100

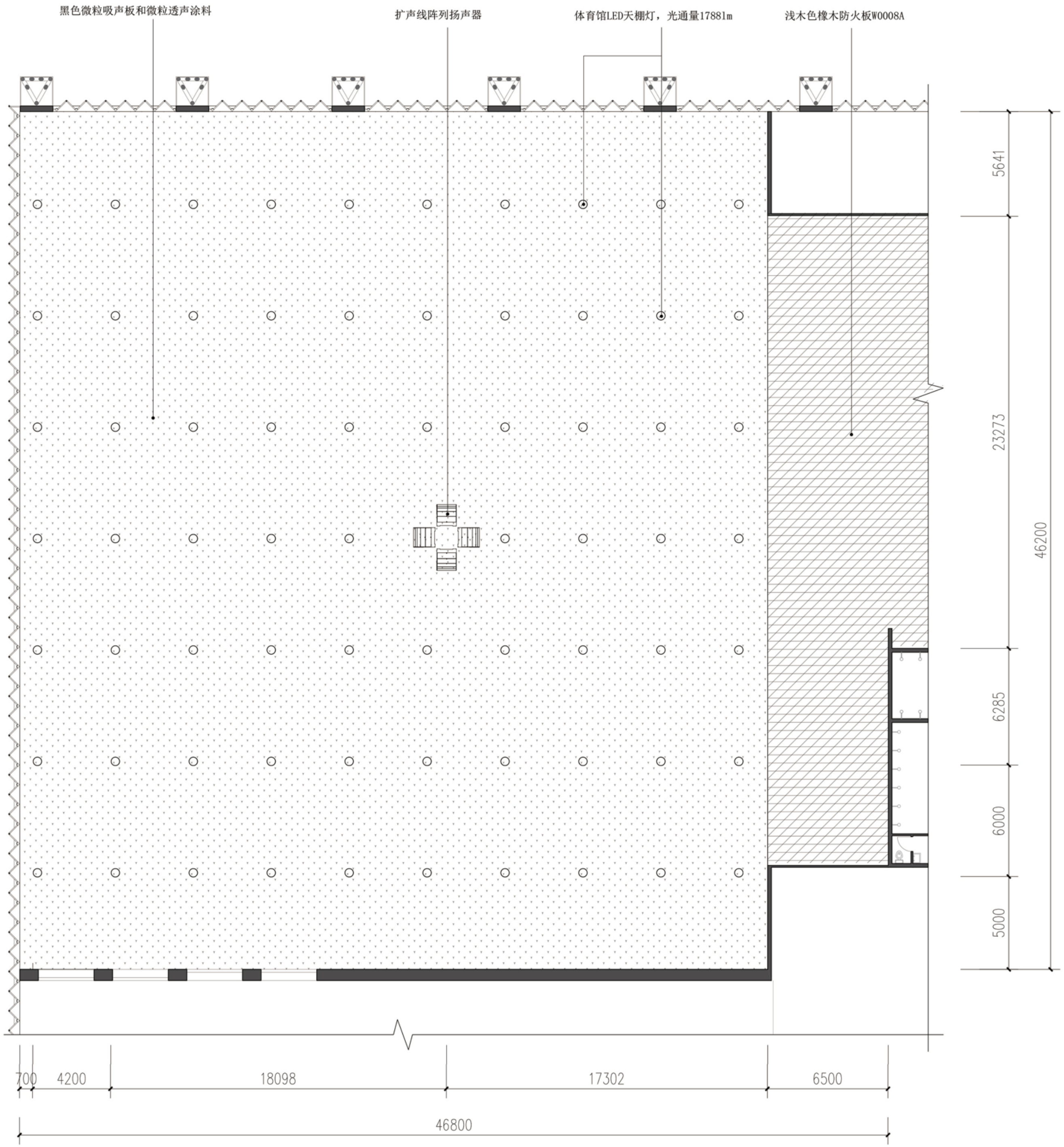


篮球场两侧看台

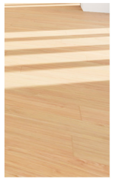
看台效果




门厅效果图

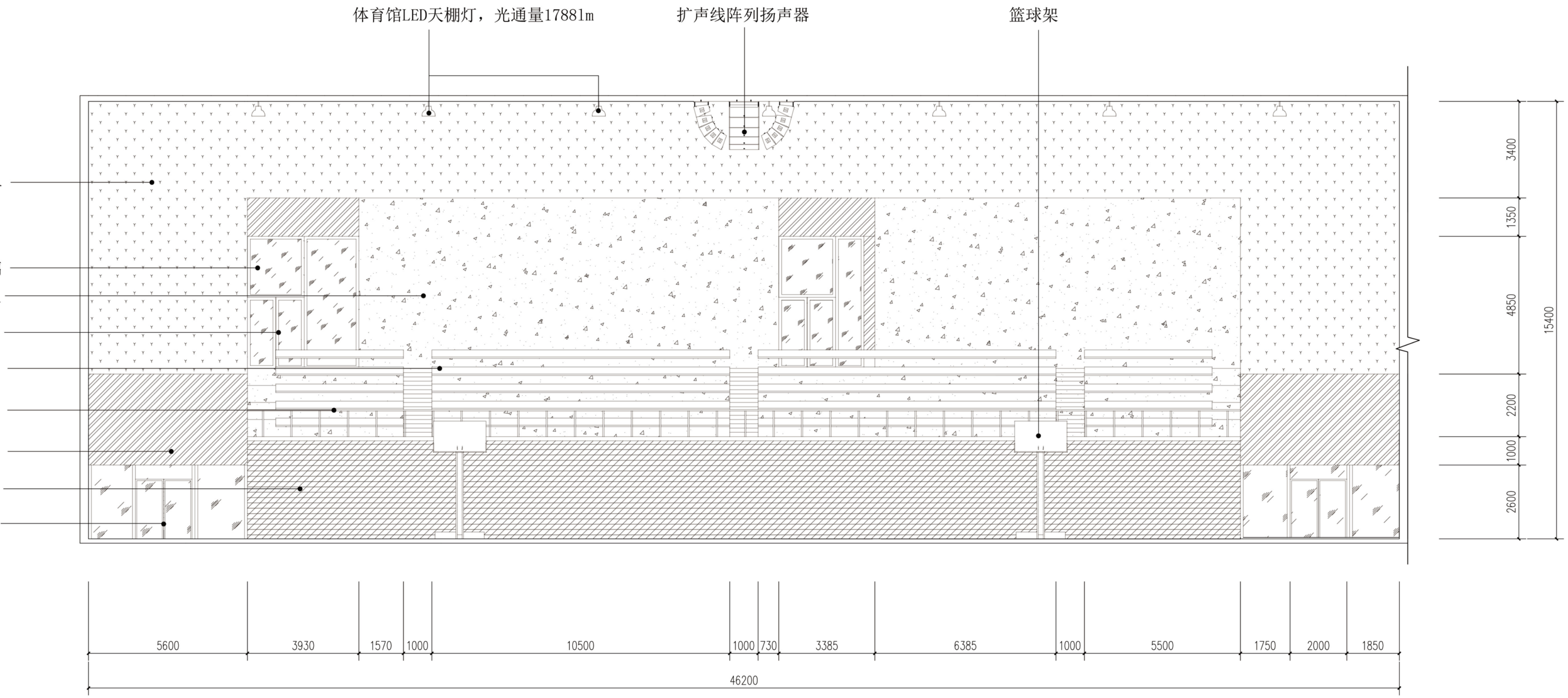


黑色微粒吸声板和微粒透声涂料
扩声线阵列扬声器
体育馆LED天棚灯，光通量17881m
浅木色橡木防火板W0008A
5641
23273
46200
6285
6000
5000
700
4200
18098
17302
6500
46800



台、寄存处

篮球馆室内2-2剖立面图 1：200

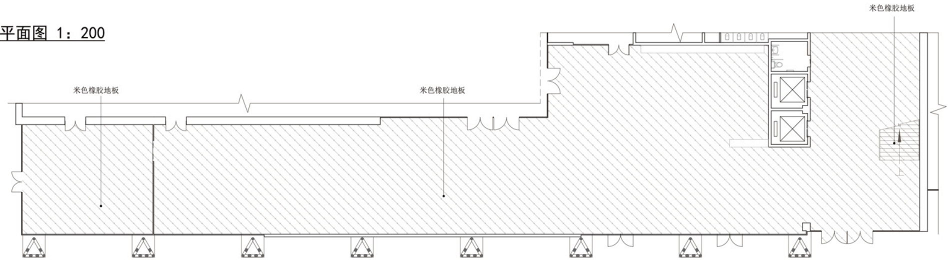


0450)

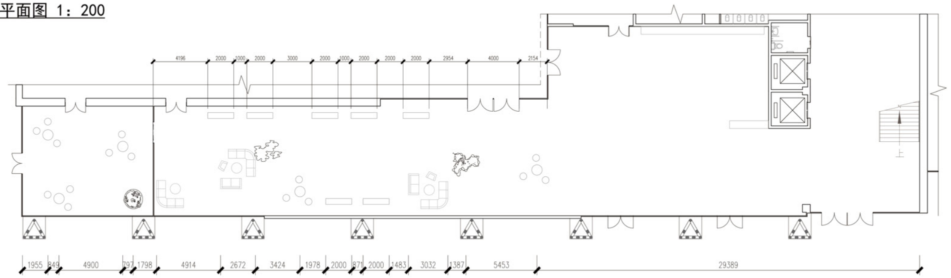
0450)

0450)

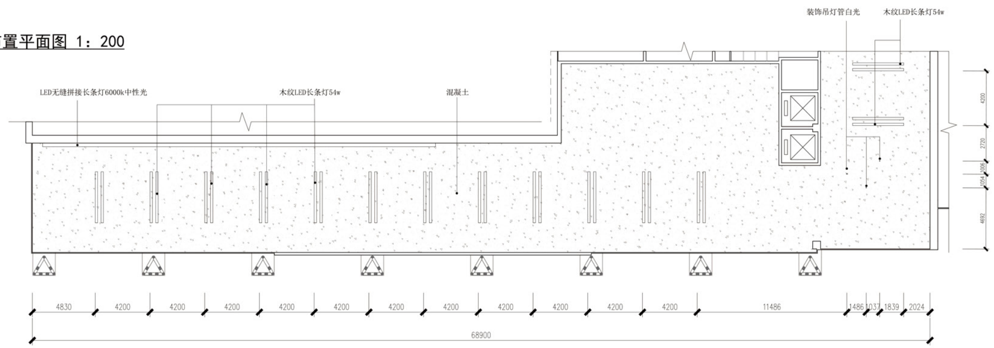
门厅地面布置平面图 1：200



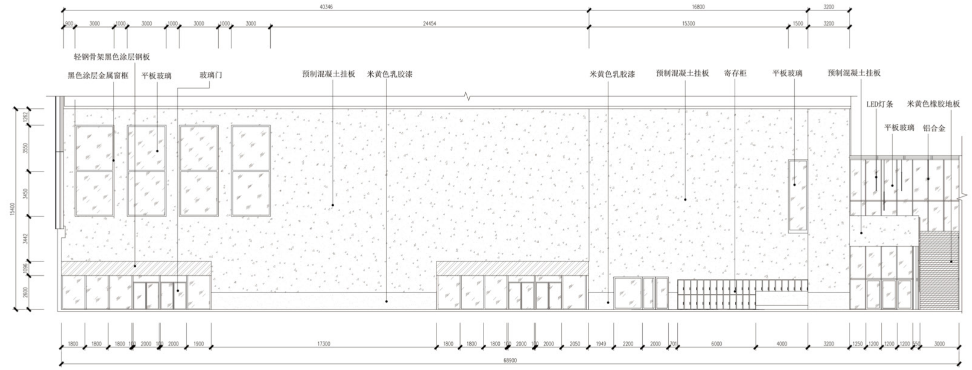
门厅家具布置平面图 1：200



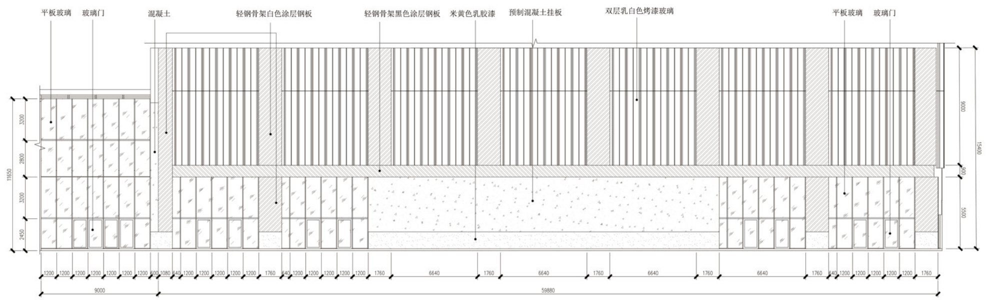
门厅天棚布置平面图 1：200



门厅室内1-1剖立面图 1：200

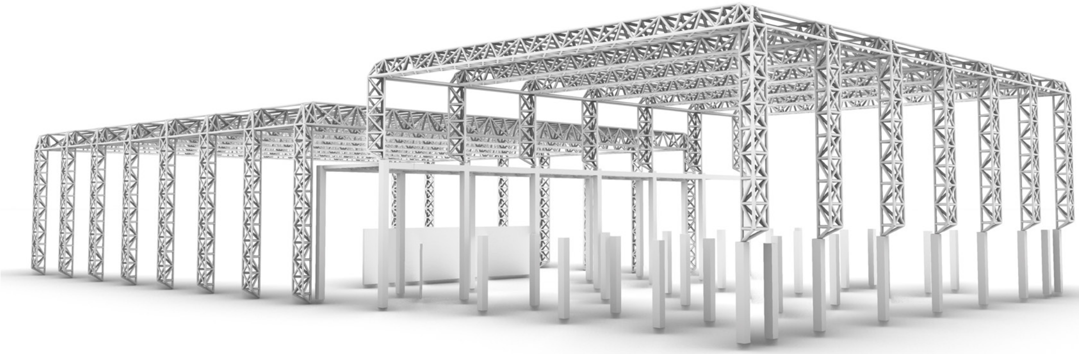


门厅室内2-2剖立面图 1：200



门厅效果图

竖向支撑结构体系——门式刚架



篮球比赛场地声学设计

在顶棚中央设置四个扬声器，分别面对四周的观众席。在该位置设置扬声器可使直达声分布均匀，并对观众达到声影一致的感受效果，根据声线分析得出，由于体育馆较大，导致反射声与直达声传播距离差大部分都大于 17m，易产生回声，从避免产生音质缺陷的角度考虑，该体育馆的侧墙应大面积使用吸声材料，为避免顶棚与地面间产生多重回声，应在顶棚大量使用吸声材料。

对于体育馆的功能需求来说，对音质条件的要求有：能够听清语言广播，运动员能及时听到发令声，所有人能听清伴奏音乐，还要防止顶棚与场地之间的多重反射，控制混响时间，并设置强指向性的扩声系统，以上为主观评价标准。客观指标中的响度值的确定是根据选取的扬声器的参数和扬声器距观众耳朵的距离计算到达人耳的声压级所确定；混响时间根据设计规范中的标准值和频率特性进行设计。经过声学设计的改造，篮球馆的音质满足响度、清晰度、丰满度的需求，且基本无音质缺陷，混响时间几乎贴近设计值。计算过程如下：

混响计算

（1）根据设计完成的体型，求出厅的容积 V 和内表面积 S。

V=43957. 2m³；S=10399. 4 ㎡.

（2）根据体育场馆声学设计及测量规程[附条文说明] JGJ/T 131-2012，各频率混响时间相对于 500Hz～1000Hz 混响时间的比值宜符合表 2. 2. 1-2 的规定。根据体育馆的使用要求，按照体育场馆声学设计规范确定混响时间及其频率特性的设计值，按照本体育馆的容积，取 500Hz 的最佳混响时间为 1. 4s。

表2.2.1-1 不同容积比赛大厅500Hz～1000Hz满场混响时间

容积（m³）	＜40000	40000～80000	80000～160000	＞160000
混响时间（s）	1. 3～1. 4	1. 4～1. 6	1. 6～1. 8	1. 9～2. 1

表2.2.1-2 各频率混响时间相对于500Hz～1000Hz混响时间的比值

频率（Hz）	125	250	2000	4000
比值	1. 0～1. 3	1. 0～1. 2	0. 9～1. 0	0. 8～1. 0

根据规范，选取设计混响时间为 1. 4s.

（3）根据混响时间计算公式求出大厅的平均吸声系数α 。

α=0. 385

（4）计算大厅总吸声量，A=Sα。

A=Sα=10399. 4×0. 385=4003. 77

观众厅混响时间计算表（V=43957. 2m³）

	项目	材料	面积（㎡）	吸声系数和吸声单位（㎡）											
				125Hz		250Hz		500Hz		1kHz		2kHz		4kHz	
				α	S・α	α	S・α	α	S・α	α	S・α	α	S・α	α	S・α
1	观众	1500人（满场）	681. 6	0. 1	150	0. 19	285	0. 32	480	0. 38	570	0. 38	570	0. 36	540
	座椅	1500人（空场）	681. 6	0. 02	30	0. 02	30	0. 02	30	0. 04	60	0. 04	60	0. 03	45
2	运动员和教练	24人		0. 1	2. 4	0. 19	4. 56	0. 32	7. 68	0. 38	9. 12	0. 38	9. 12	0. 36	8. 64
3	地面	木地板（有龙骨架空）	2023. 2	0. 15	303. 48	0. 12	242. 784	0. 1	202. 32	0. 08	161. 856	0. 08	161. 856	0. 08	161. 856
4	墙面	岩棉（板状）（40-180kg/m³、50mm厚、后空100）	2703	0. 55	1486. 65	0. 9	2432. 7	0. 95	2567. 85	0. 90	2432. 7	0. 85	2297. 55	0. 85	2297. 55
5	顶棚1	吊顶（27mm木板）	1780	0. 16	284. 8	0. 15	267	0. 1	178	0. 10	178	0. 10	178	0. 1	178
6	顶棚2	岩棉装饰吸声板、12mm厚（浮雕花纹表面、无后空）	1888. 6	0. 14	264. 404	0. 22	415. 492	0. 36	973. 08	0. 32	604. 352	0. 28	528. 808	0. 22	415. 492
7	顶棚3	平板玻璃	1323	0. 18	238. 14	0. 06	79. 38	0. 04	52. 92	0. 03	39. 69	0. 02	26. 46	0. 02	26. 46
8	门	16个	29. 44	0. 10	1. 6	0. 15	2. 4	0. 2	3. 2	0. 25	4	0. 30	4. 8	0. 3	4. 8
9	4mV											395. 61		976. 06	
	空场	ΣS・α（只有座椅）		2611. 5		3474. 3		4015		3489. 7		3266. 6		3137. 8	
	满场	ΣS・α		2731. 5		3729. 3		4465		3999. 7		3776. 6		3632. 8	
	S		10399. 4												

六个倍频程混响时间

V=43957. 2m³		125Hz	250Hz	500Hz	1kHz	2kHz	4kHz
满场	ΣS・α	2731. 5	3729. 3	4465	3999. 7	3776. 6	3632. 8
	$\bar{\alpha}$	0. 263	0. 359	0. 429	0. 385	0. 363	0. 349
	$-\ln(1-\bar{\alpha})$	0. 305	0. 445	0. 56	0. 486	0. 451	0. 492
	T60 /s	2. 2	1. 5	1. 2	1. 4	1. 4	1. 3

	125Hz	250Hz	500Hz	1000Hz	2000Hz	4000Hz
设计混响时间	1. 82	1. 5	1. 4	1. 4	1. 4	1. 3
实际混响时间（满场）	2. 2	1. 5	1. 2	1. 4	1. 4	1. 3
实际混响时间（空场）	2. 4	1. 7	1. 4	1. 7	1. 6	1. 5