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Biomimicry: Architecture that Imitates Nature's Functions, Forms and Parts

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Biomimicry

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Dean: Stephen White ______________________ ____________

To my father, Theodhor Spaho and to my mother, Meropi Spaho

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Personal Manifesto

At the beginning of every project, we investigate other architectural designs in order to create our own. This is a good starting point, but is it good enough to generate a thesis? Does one formulate a thesis from precedents, or is it simply an extension of those precedents' original ideas? If that is the case, then what is the purest source one might encounter in order to bite a piece of the fruit from the original tree? In search for an answer, I turn to the word "Architecture", and ask myself; what does it mean? According to a book titled Evolutionary Architecture, by Eugene Tsui, "architecture is the art that goes back to the origins – to nature itself. The root meaning of the word is derived from the Greek, archi, meaning "first," or "original"; and tect, meaning the ability to put things together. Thus, architecture implies creation from the origins of nature" (Tsui, 9). Every design that I have produced thus far involves a middleman. There is always a precedent between the site and my design. We must all begin somewhere. However, as students, when do we get the opportunity to design through the following of nature, instead of by following other people? Architecture and society have been interrelated for thousands of years. Culture, symbolism, religion and other human systems make their imprint on architecture and therefore control a great part of it. Although these man-made rules may provide guidance and order, they overlook the relationship between architecture and nature.

Architecture should follow nature's way, in order to solve its problems. It should seek out the endless examples that surround us, extracting their secrets of strength, efficiency, durability, sustainability, and other factors that would yield harmonious coexistence.

Personal Manifesto

For guidance I will refer to the following:

Biomimicry Guild: Website

Worldwide company that investigates biological systems in order to provide solutions for sustainability challenges.

Provides expert information for questions related to nature and design through their affiliates.

Contains a large library of biomimic examples (text, images, videos and external links)

Capable of answering specific questions regarding natural solutions to design challenges

Eugine Tsui: Website and Textbook ”Evolutionary Architecture”

Eugine Tsui: world-renowned architect, contractor, city and regional planer, industrial designer, Investigative scientist, inventor, and competitive athlete. The recipient of numerous grant and design awards, with works profiled on television programs, in documentaries, and in major news papers and magazines worldwide.

Website: Primary focus of design, nature inspired design principles, way of design, evolutionary archi tecture, economic and social benefits, projects, biomimicry, research, videos and more…

Evolutionary Architecture: nature-inspired ideas of conserving space, energy and materials without offending aesthetics; drawings, models, buildings

Janine Benyus

Janine Benyus: American natural sciences writer, innovation consultant, and author

Documentaries: Nature’s design, biomimicry, sustainable design ideas and examples

For full bibliography please see bibliography page

Abstract

This proposal highlights concepts that will implement the strategies used for the design of this project. Such concepts derive from a hypothesis that depicts nature as the ultimate designer of all things. “Architecture implies creation from the origins of nature; putting things together in a way that express an understanding of nature,” states Eugine Tsui in his book, *Evolutionary Architecture* (Tsui, 9). Imagine how our world will look if all architecture follows nature’s way of creating. Would we not live healthier by reducing pollution and waste? Would we not optimize our energy consumption without draining our limited resources? Would we not create architecture that fits and performs harmoniously with its site?

Nature has designed on earth for around “3.8 billion years”. All of her creations are carefully articulated to fit in their existing context and to optimize their energy and material needs. Therefore, the answers to most of our design questions are displayed through the organisms that surround us. We just have to understand these examples and apply them to our design methods. We just have to perform biomimicry (Biomimicry Guild).

Biomimicry “from bios, meaning life, and mimesis to imitate” underlines the process of studying nature’s design resolution strategies and applying them to solve our own challenges, which in this case are architectural. Nature demonstrates her solutions through the nonhuman architects and engineers which are: animals, plants, microorganisms and more. During their existence, which surpasses our own, these organisms “have found what works”.

All the living things that surround us today, hold the “secret to survival”, and all fossils depict failure. “Like the viceroy butterfly imitating the monarch, we humans are imitating the best adapted organisms in our habitat. We are learning, for instance, how to harness energy like a leaf, grow food like a prairie, build ceramics like an abalone, self-medicate like a chimp, create color like a peacock, compute like a cell, and run a business like a hickory forest. The conscious emulation of life’s genius is a survival strategy for the human race, a path to a sustainable future. The more our world functions like the natural world, the more likely we are to endure on this home that is ours, but not ours alone” (Biomimicry Guild). In order to apply biomimicry to my design, I will use three biomimietic processes, which underline: biomimicry of function, biomimicry of form and biomimicry of parts.

Biomimicry

Architecture that Imitates Nature's Functions, Forms and Parts

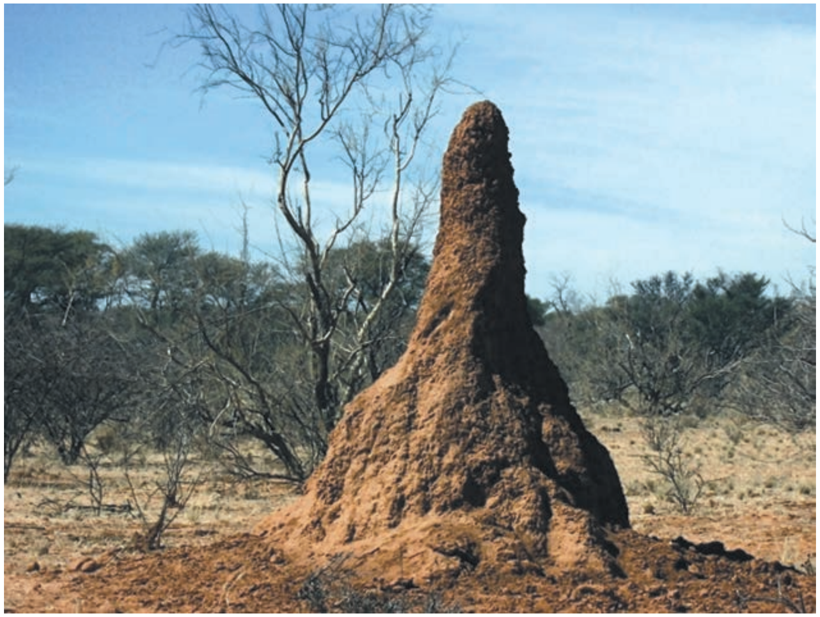
Architecture imitates nature's functions, forms, and parts in order to solve the problems of sustainability, efficiency, strength, durability and more. Nature displays its solutions to these problems through endless examples, which appear everywhere on this planet. Such designs represent nature's work, which has evolved over a "3.8 billion year period." Nature's creations are carefully articulated in order to fit in with their context, and to optimize their need for energy and material. It is likely that the answers to most of our design questions lie amid the surrounding organic fabric.

Architecture that Imitates Nature's Functions

Architecture that imitates nature's functions highlights the process of extracting one or many functions from nature's examples and applying them to architecture. These examples utilize these functions in order to respond to site, climate, energy consumption and other factors, without harming or polluting the surrounding environment. Functional biomimicry begins to dictate some design decisions when it comes to form, orientation and material selection.

Architecture that Imitates Nature's Functions

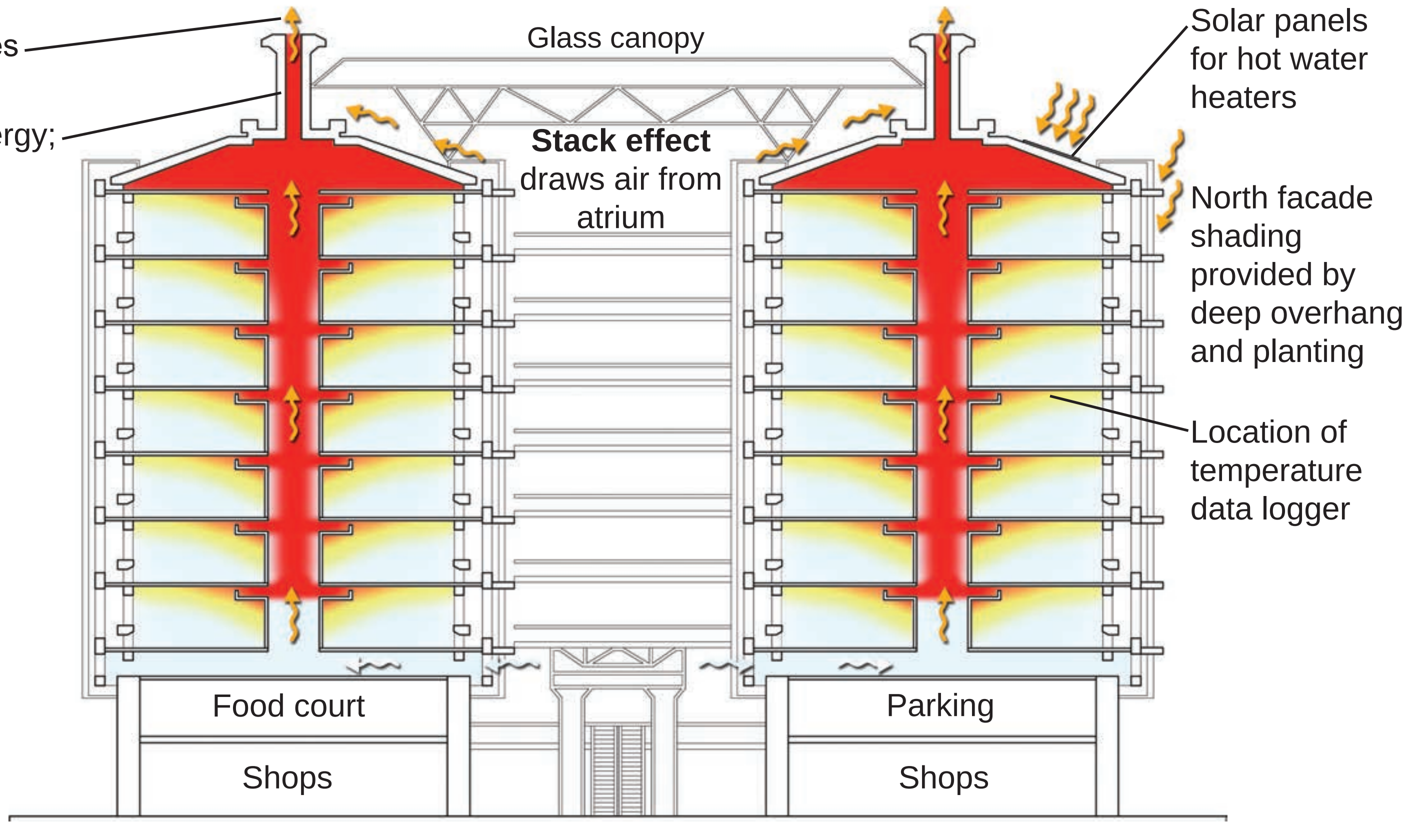
Eastgate Center, Harare, Zimbabwe 1996
Architect: Michael Pearce



Termite Mound, Zimbabwe (since some million years ago)
Architect: Macrotermes Michaelseni (African Termites)

Architect Michael Pearce, along with the engineers of Arup Associates designed the Eastgate Centre in Harare, Zimbabwe, Africa. This large office and shopping complex uses biomimicry principles in order to eliminate conventional air-conditioning and heating. It finds this solution through studying the local mounds that are built by African termites, which construct these towers of land in order to provide living conditions for themselves and a fungus that satisfies their appetite. This food source demands a nonnegotiable temperature of 87 degrees F, although the exterior temperature fluctuates between 35 to 104 degrees F from night to day respectively. Such accomplishment is achieved thought the termites' ability to compose an orchestra of opening and closing heating and cooling vents (*Inhabitat*. Web).

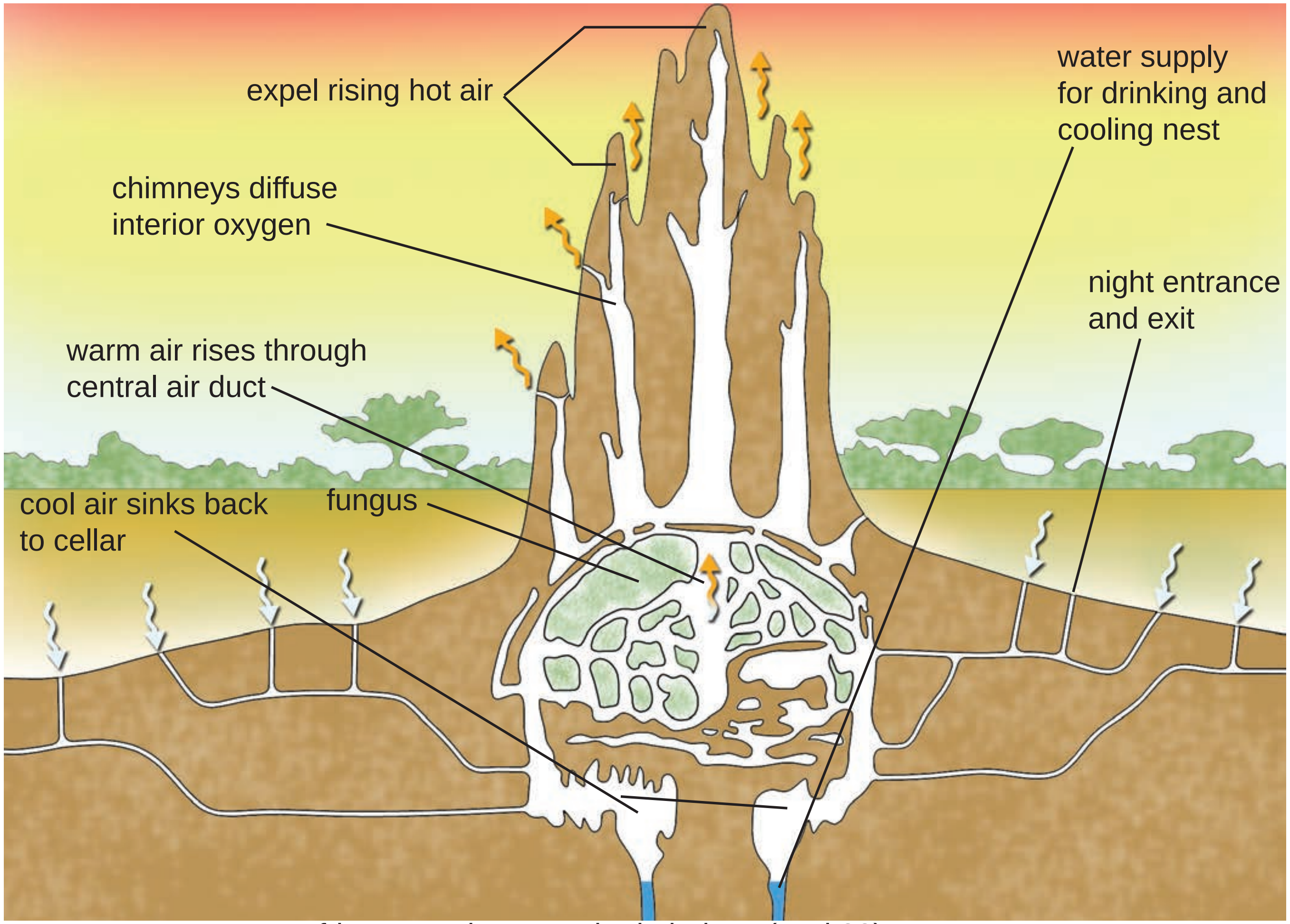
Architecture that Imitates Nature's Functions



Stack effect
"Due to the temperature difference, the air inside a building is either more or less dense than the air outside. If there is an opening high in the building and another low in the building, a natural flow will be caused." (Wright).

The Eastgate Center complex contains two buildings with an open space between them. A glass canopy covers the top of the open space, while the sides adjacent to the building remain open to allow natural airflow. Similar to the termite mound, the building appears as a thick solid mass (due to the dense use of concrete) with smaller openings that are displayed through its outer facade. The actual biomimetic process highlights the buildings ability to draw air from the outside, "which is then warmed or cooled by the building's mass depending on which is hotter, the concrete or the air". Fans in the first floor of each building, pull air from the open space and push it upwards through vertical spines that are located in the center of each structure. This process creates a cycle where cool fresh air continuously passes through the buildings from the bottom and exits from the top chimneys through exhaust systems as it warms up and becomes stale. On top of all this, "the building uses 10% less energy than a conventional building of its size". Therefore, the owners have saved $3.5 million alone form air conditioning that would have taken place. "Outside of being eco-efficient and better for the environment, these savings also trickle down to the tenants whose rents are 20 percent lower than those of occupants in the surrounding buildings" (Inhabitat. Web).

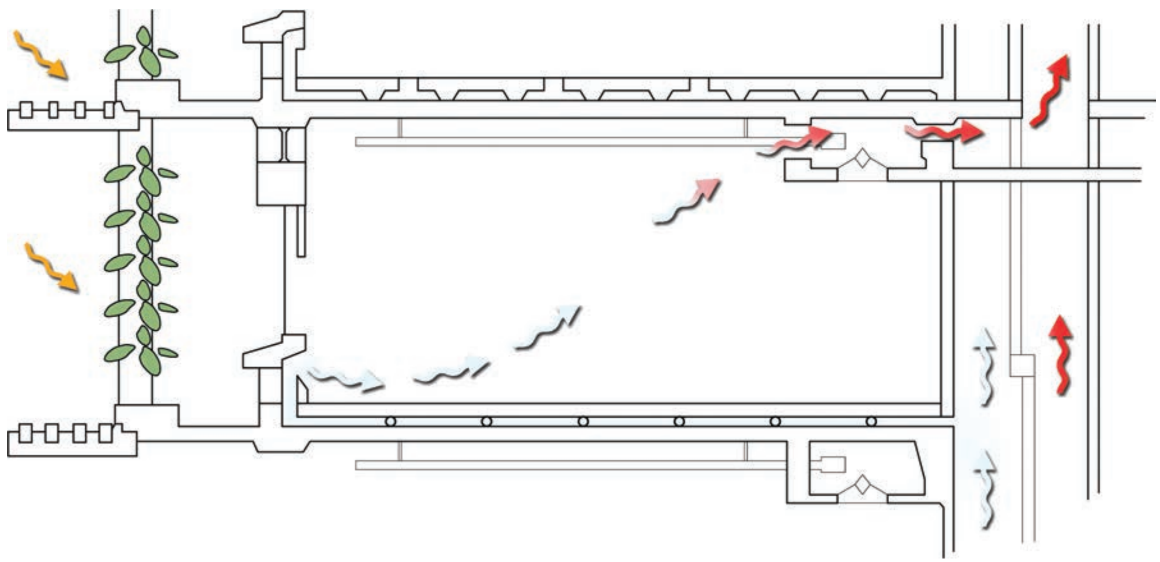
Architecture that Imitates Nature's Functions



African Termite Mound, Zimbabwe (Tsui 88).

The termites rely on their labor to control the temperature inside their mound. Michael Pearce has substituted this labor with the electrical energy that is used to power the fans which redirect the air. Due to our nature, labor-intensive culture and other factors, we would fail to operate the windows of a building with the same discipline that the termites operate theirs. Therefore; we rely on our inventions (electrical machines) to perform these mundane tasks.

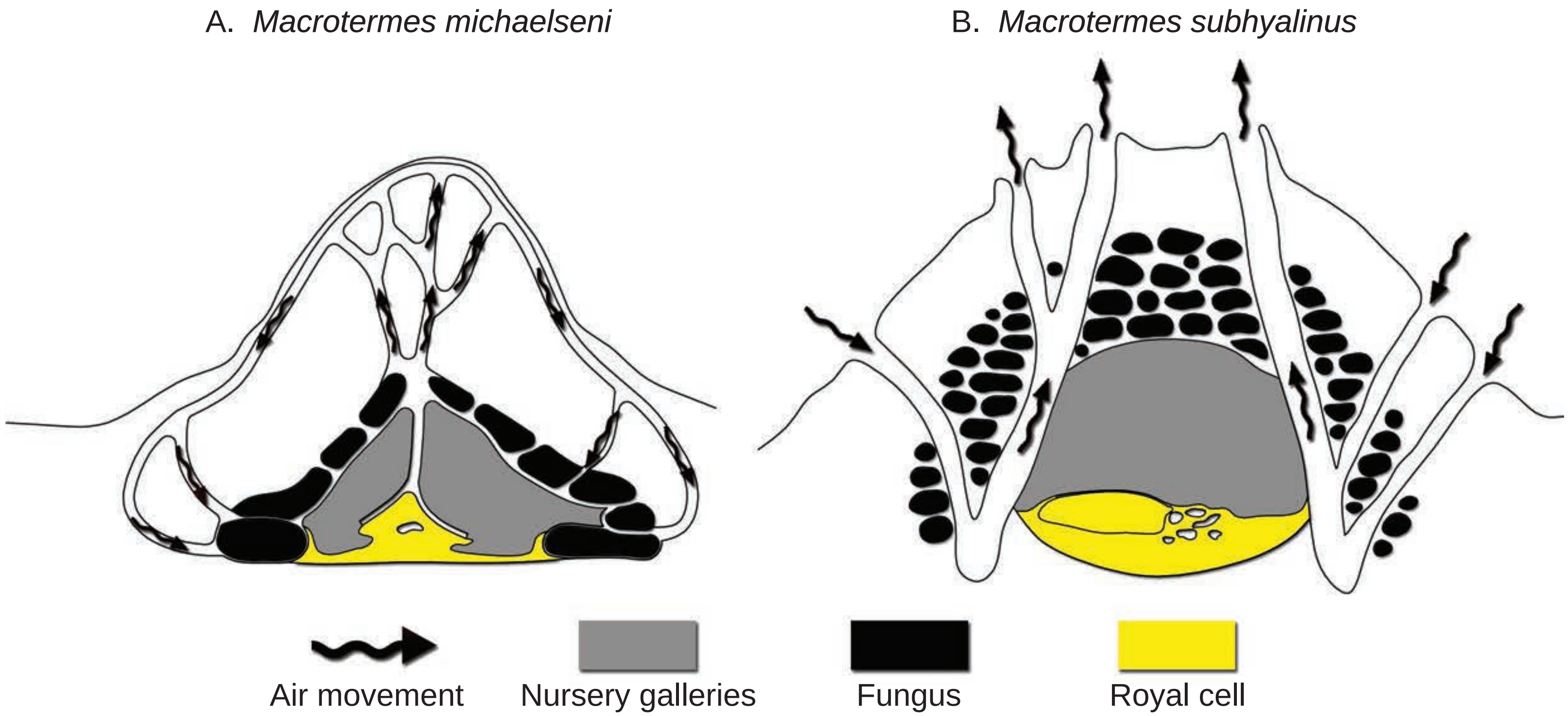
Architecture that Imitates Nature's Functions



Detail of a single level space

The direct sunlight is blocked by louvers when the sun is high and by plants when it is low. Fresh air circulates through the building's core ducts and is dispersed into each space though the openings at the edges of the elevated floor. Underneath the floor, cold water pipes make the air cooler. Once the air enters each space, it gradually warms up and begins to float to the ceiling, where it escapes through an opening back to the building's core. Within the core, this warm air travels through a different chamber as demonstrated in the diagram above (*Inhabitat*. Web.)

Architecture that Imitates Nature's Functions



The diagrams above display two different species of termites, who arrange the program in a similar manner. In the image on the left, air has entered the mound and the termites have closed the openings. This demonstrates the circulation of air in a closed system. The open system is demonstrated on the right. The two species reconstruct their mound both ways. The type of construction depends on the climate change. Perhaps this technique suggests that we should be prepared to plan architecture with room for change, in order to better respond to the site's conditions.

Architecture that Imitates Nature's Functions

Residential Building, New Songdo City, South Korea
Architect: HOK

HOK, one of the world's largest architectural firms, applies the twisting properties of the human spine to a honeycomb-like structure, in order to design a series of towers. In collaboration with the engineering firm Arup, which we previously encountered in the Eastgate Center, the team finds that the honeycomb structure is able to maintain its strength after the applied twist. This biomimetic function generates a structurally sound tower, which significantly reduces the amount of structural members used in its construction, resulting in lower building costs (Gendall).

Architecture that Imitates Nature's Functions

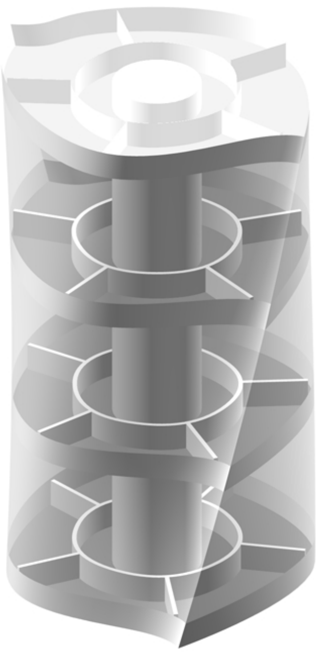
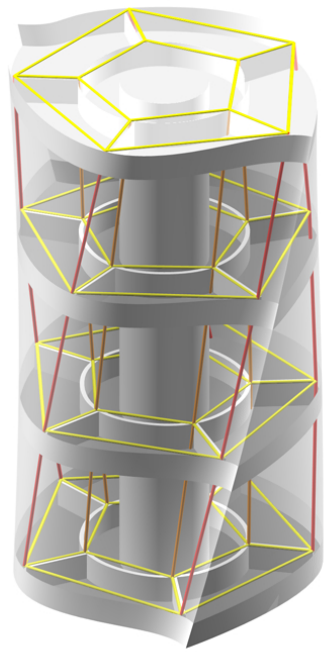
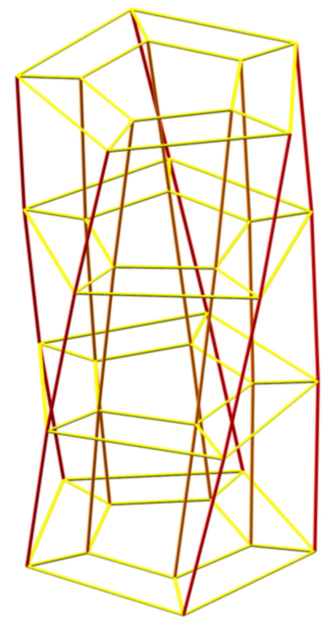


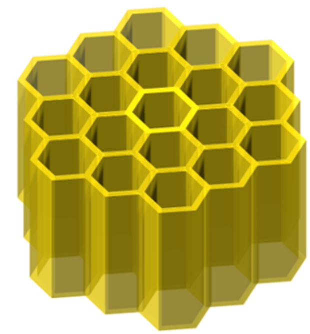
Diagram of tower's structure



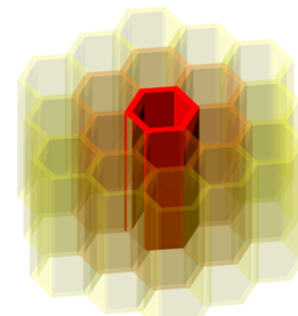
Structure with integral structure



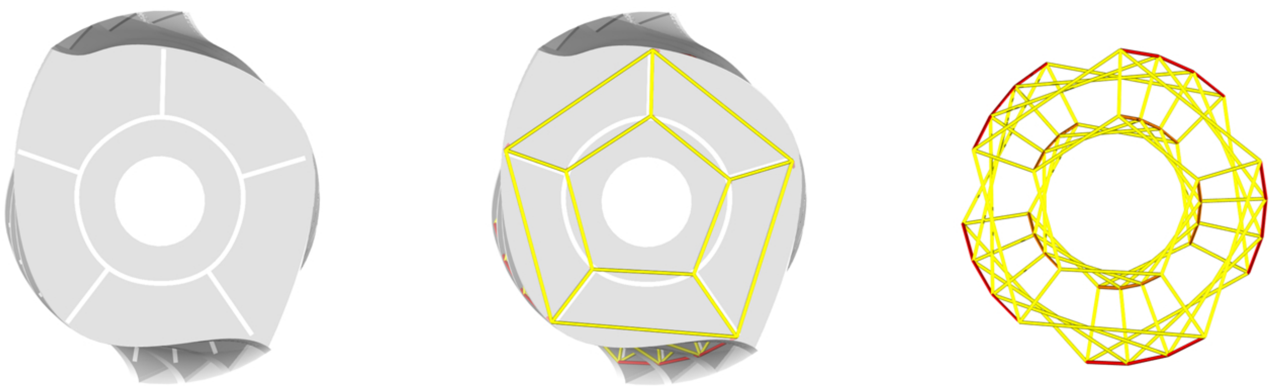
Integral structure



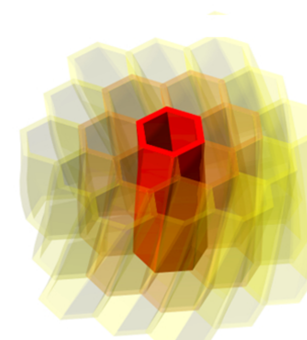
Honeycomb structure



Central component highlight



Top view of the above diagrams

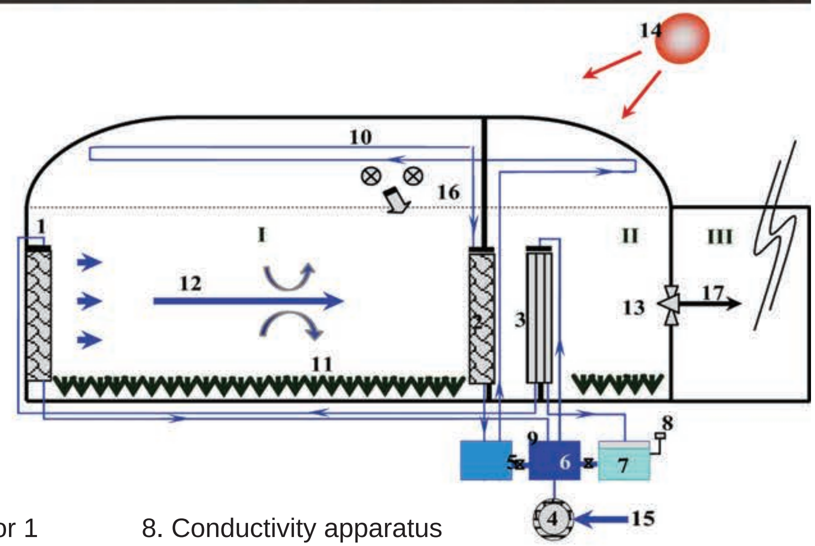


Twisting motion applied to central component

Architecture that Imitates Nature's Functions

Seawater Greenhouses and the Sahara Forest Project
Architect: Ken Yeang, Michael Pawlyn

The Seawater Greenhouse mimics nature's hydrological cycle to humidify and condition the interior space. This process generates fresh water for the plants through condensation. Seawater cools and humidifies the air that ventilates the greenhouse, while sunlight distills the seawater to produce fresh one. Such system, allows for "year round cultivation of high value crops that would otherwise be difficult or impossible to grow in hot, arid regions." In its entirety, this system demonstrates high efficiency (Tree Hugger. *Web*).



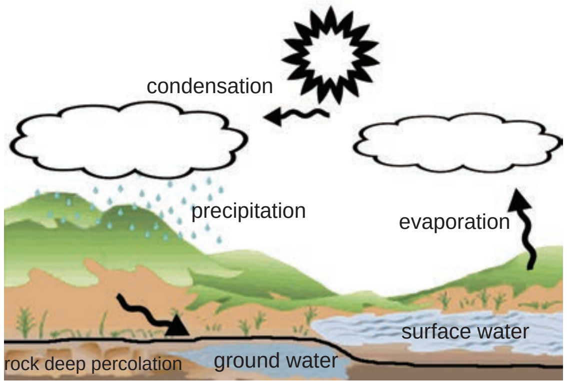
1. Evaporator 1
2. Evaporator 2
3. Condenser
4. Well
5. Hot seawater tank
6. Cold seawater Tank
7. Fresh Water
8. Conductivity apparatus
9. Supplement valve
10. Solar heating pipes
11. Crops,
12. Cooled and humidified air
13. Fans
14. Solar energy
15. Seawater intake
16. Roof fans
17. Dry and hot air

I. First compartment
II. Second compartment
III. Shadow room

Architecture that Imitates Nature's Functions

In addition to mimicking nature's hydrological cycle, the architects are inspired by a desert beetle, which has its own trick of harvesting water in the dry desert (*John Wiley & Sons, Ltd. Web*).

In the desert, the beetle lives in harsh arid conditions where precipitation is rare. To deal with these conditions, its shell has a unique bumpy surface structure that can collect water from temporary fog cover. The peak of each bump is smooth and attracts water. The slopes of each bump along with the troughs in between repel water. The texture is arranged to form channels so the water runs off its back and into its mouth *(Biomimicry Guild. Web)*



Nature's Hydrological Cycle

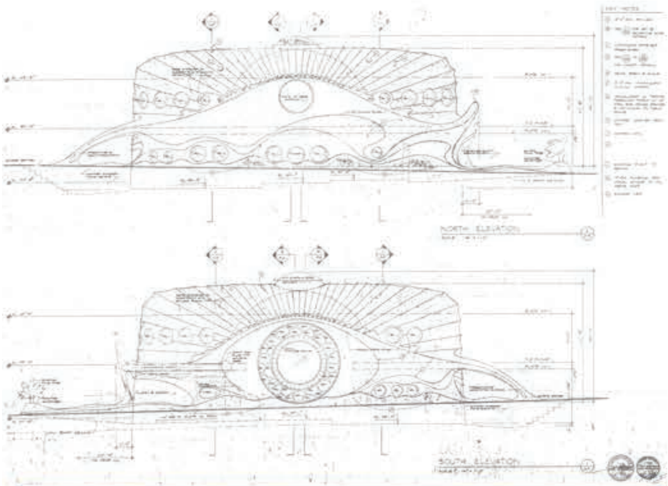
Architecture that Imitates Nature’s Forms

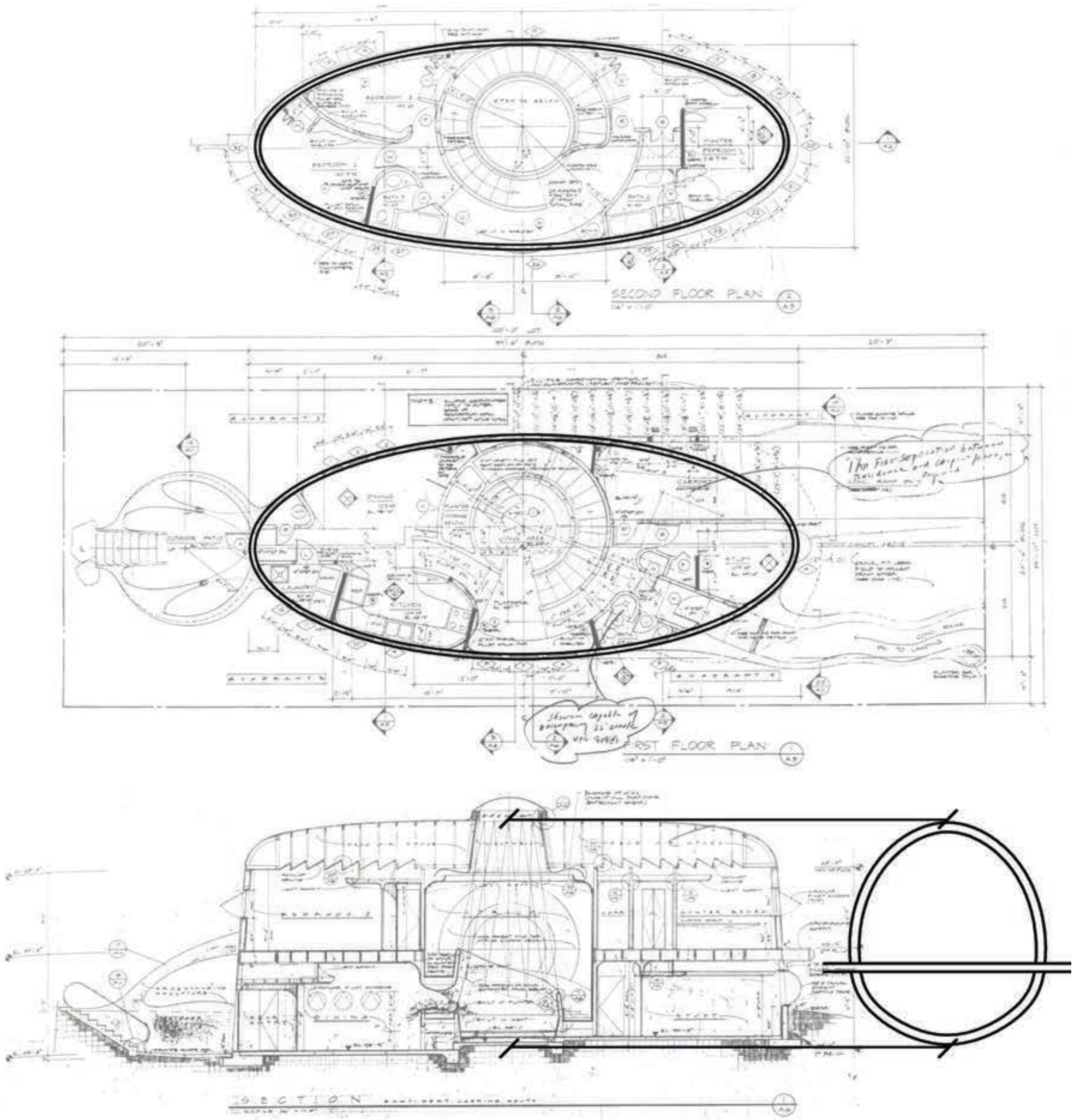
Architecture that imitates nature’s forms also highlights the process of extracting the structural properties that are embedded in natural forms. Natural structures have gone through billion years of evolution. They indicate an unimaginable level of perfection through “trial and error”. Today’s living structures represent nature’s successes, while failures simply become extinct. These existing natural examples display a large pallette of “resourceful materials” and structural forms, which are endowed with the ability to “respond to every kind of climatic and environmental force.” Such “superior designs” become crucial to our architectural development (Tsui 86).

Architecture that Imitates Nature's Forms

Tardigrade, Electron Microscope Photo
Eugene Tsui - TDR Inc. Home. *Web.*

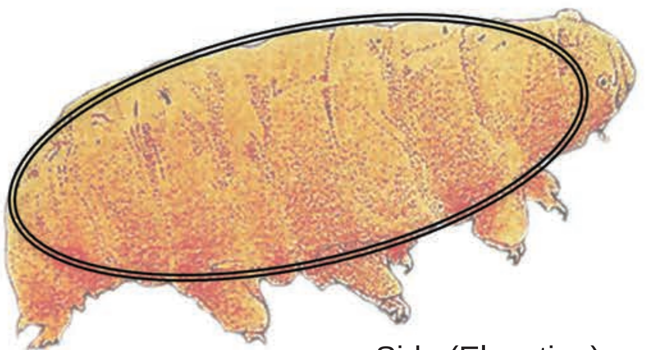
Architecture that Imitates Nature's Forms



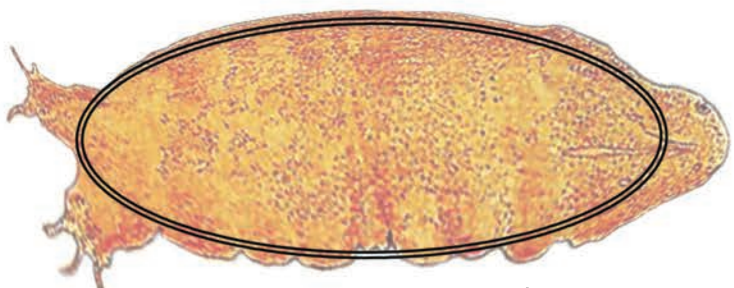


In 1993, Eugene Tsui designs a house for his parents in Berkeley, California. The house's ability to withstand earthquakes becomes one of Tsui's major concerns, due to the frequent occurrence of seismic activities that this location experiences (Tsui 209).

Architecture that Imitates Nature’s Forms

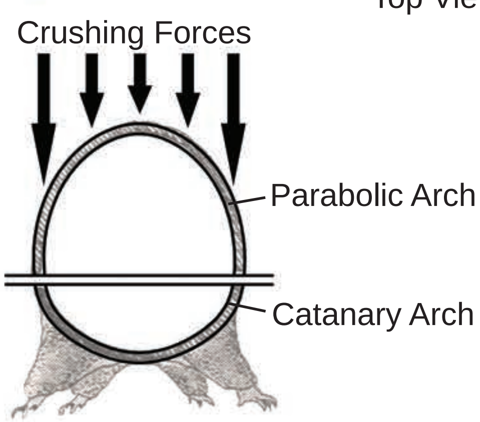


Side (Elevation)



Top View

In his search for strong, but elegant structures, Tsui tumbles across a microscopic creature known as the tardigrade, which can be found everywhere in the world except the tropics of Antarctica. This being is classified somewhere between a worm and an insect, and spends its life in “mud, damp seashore sand or the water film surrounding the leaves of mosses and lichens”. This creature’s ability to withstand extreme circumstances, becomes the main reason that attracts Tsui’s attention. The Tardigrade has survived in laboratory experiments that have placed it in liquid helium of -272 degrees Celsius (-457 degrees Fahrenheit). “They have left it at -192 degrees Celsius (-313 degrees Fahrenheit) for 20 months, and cooked it for a week at 92 degrees Celsius (197 degrees Fahrenheit). Some specimens have been brought back to life after 120 years in a dry and dusty museum. What makes this creature so indestructible? Tsui’s research finds the tardigrade’s “oval or ellipse shape and it’s series of flexible shell-like body pieces” to be one of the main reasons for this creature’s incredible strength. Therefore, he applies this structural findings to the design of his parents’ house. He states, “the elliptical plan provides an excellent ability to dispense stress and strain, pushing laterally, as happens in an earthquake” (Tsui 92, 210).

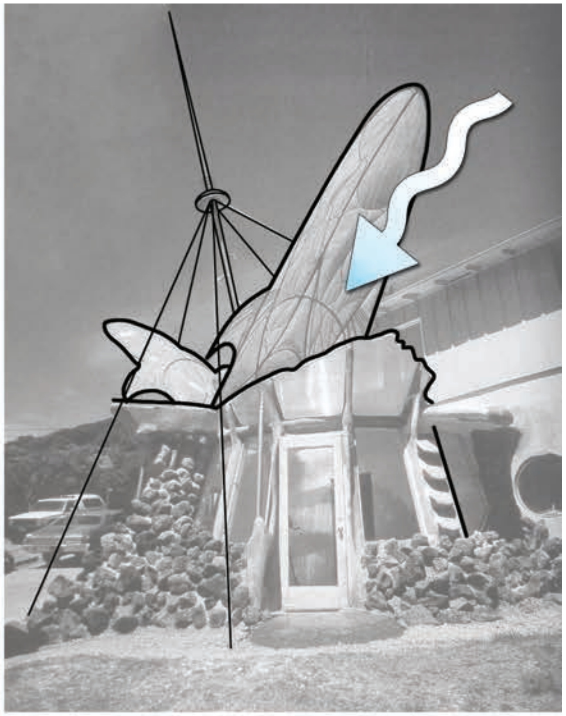


Cross-Section

Front View

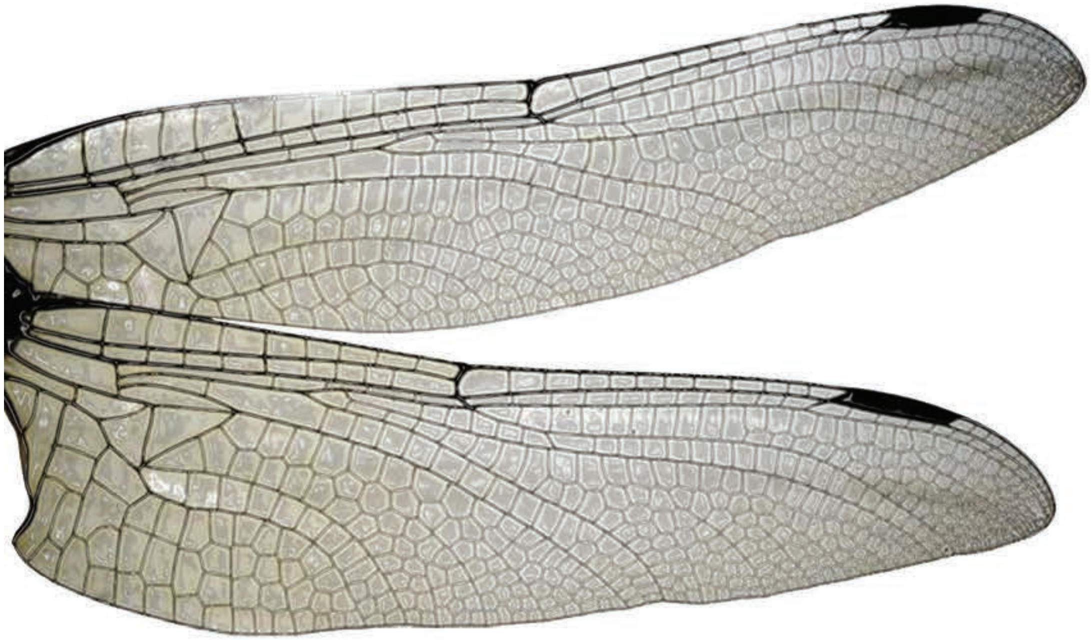
“A series of flexible body panels expand and contract, possibly to adjust to changing stress and strain forces acting on it. Its body is a combination of continuos parabolic and catenary arch combined to create one of the most efficient structural system combinations for resisting crushing forces” (Tsui 92).

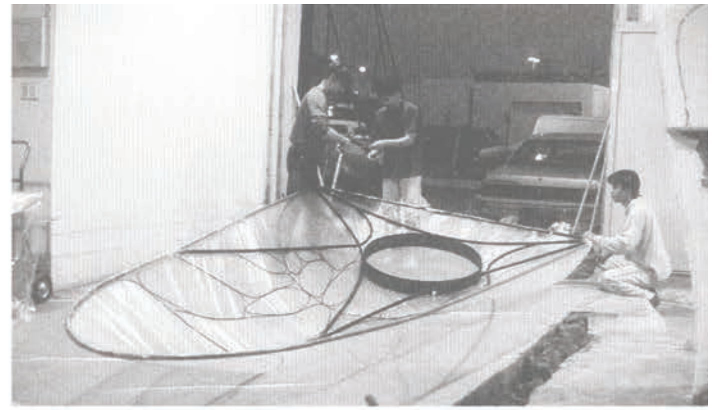
Architecture that Imitates Nature's Forms



Above is another design by Eugene Tsui for Vince and Remy Reyes in Oakland, California, 1991-1993. Tsui calls this design "living architecture". As he "uses nature as basis for design", he produces something that consists of moving parts in order to "respond to environmental, technological and programmatic requirements". Tsui moves away from the "static machine" by representing architecture as a "living organism". The center image shows the Southwest view of the house. In this instance, the wings are closed, in order to keep the space warm during the winter months. Under each wing, Tsui positions air suction louvres to allow for continuos fresh air circulation. The image on the right depicts the same view, but this time the wings are open. In this position, they are able to "deflect breeze and draw cool air into the house" (Tsui 176-181).

Architecture that Imitates Nature's Forms



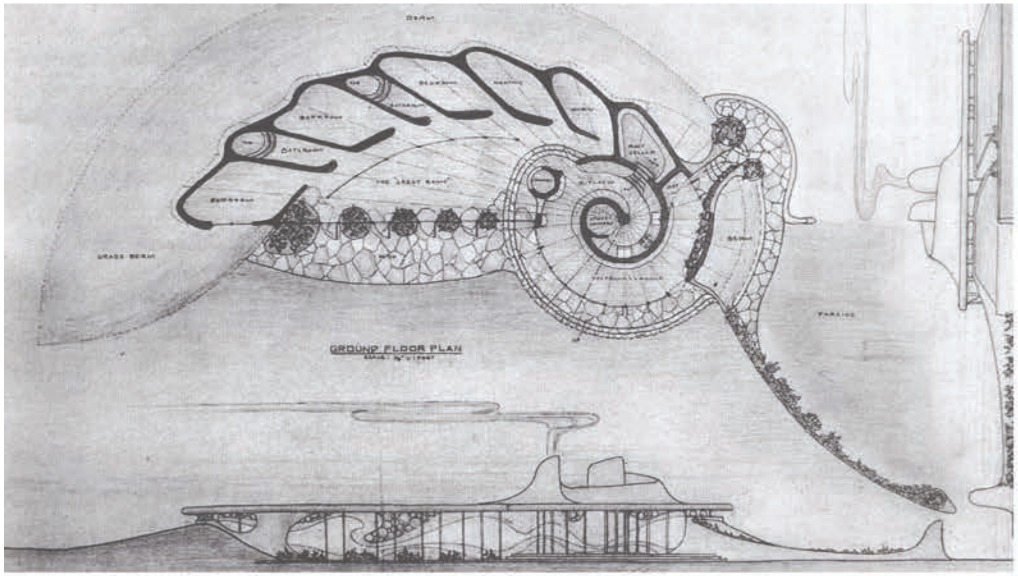


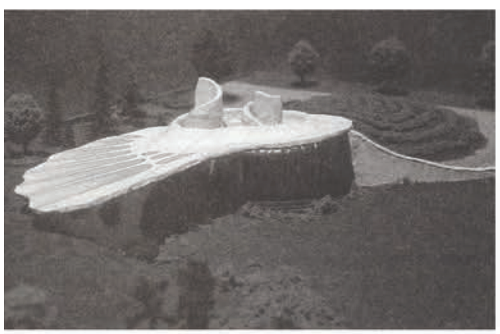
This photo illustrates a detail of the fiberglass wing canopy. The wing is positioned upside down during the installation of the fiberglass, in order to allow gravity to "create rigid membranes of the wing components" (Tsui 185).

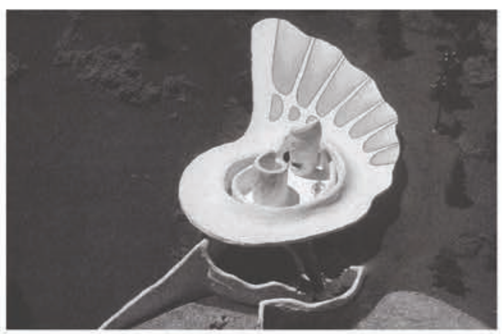
Tsui studies the dragonfly's wings in order to design these "movable light weight structures". The large rigid elements that are apparent in Tsui's artificial wings, along with the interior secondary cross bracing, result from the details of the natural wing structure. The team gathers these high resolution images through using a stereoscopic microscope (Tsui 180).

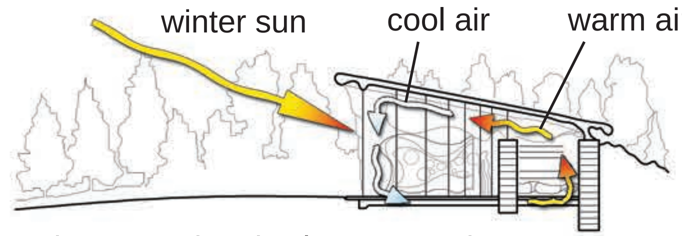
Night photograph of the wing opening and closing. (Multiple-exposure)

Architecture that Imitates Nature’s Forms

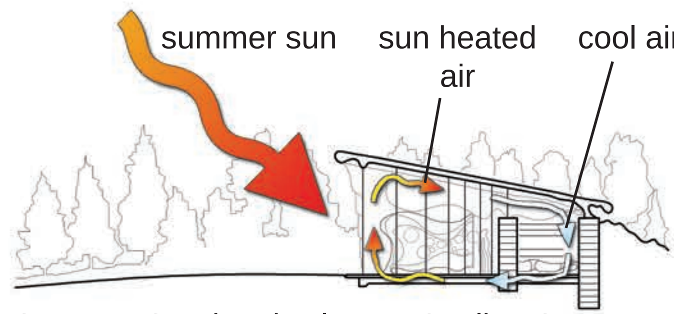








Winter Gravity Air Plenum Heating System



Summer Gravity Air Plenum Cooling System

“In the winter, cool air at the south glass surface drops below the floor to be attracted to the warm north-side insulated air. The air rises and follows the ceiling to the south glass. In the summer, the entire direction is reversed because the south glass is hot, heating the air. All of this occurs with no mechanical devices and moving parts” (Tsui 286).

Above is the last example of biomimicry of form by Eugene Tsui, known as the *Wilson House Two,* Point Arena, California. Although this particular project has not yet been built, Tsui performs a series of formal experiments, which call for attention toward this work. He finds the spiral plan to be easily “expanded without disrupting the original configuration and automatically enlarges the living area to fit future expansion,” as it can be seen on the plan at the top of this page. This plan, in correspondence to its shell-like outer surface, “creates an excellent soil berm resistant wall. The more the soil pushes in, the stronger the wall as it compacts (Tsui 284-286).

Architecture that Imitates Nature's Forms

Tsui mimics the structural integrity of a snail's shell when he designs the *Wilson House.* This assures him that his design will withstand great compressive forces. The office's research experiments find the common snail shell to "withstand downward loading forces of 2218 times its own weight" (Tsui 133).

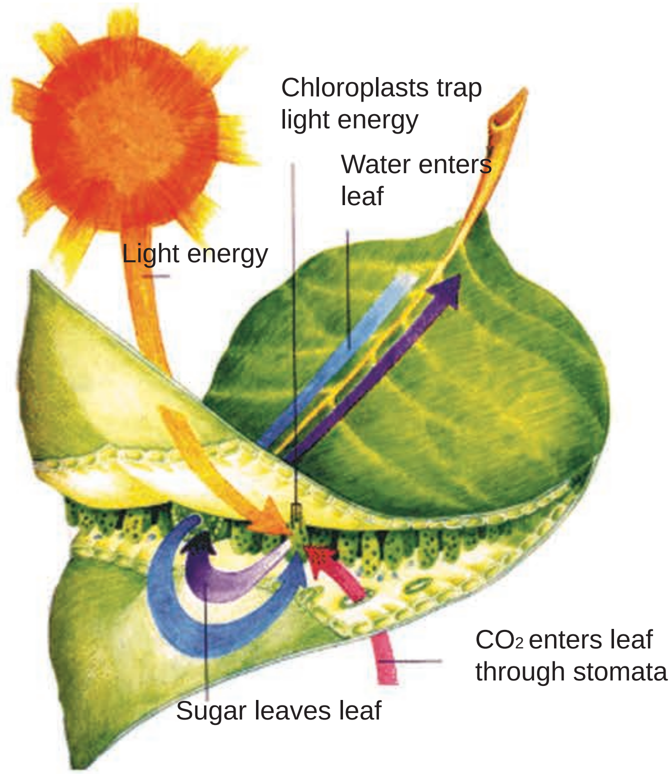
Architecture that Imitates Nature’s Parts

Architecture that imitates nature’s parts highlights the process of extracting structural, formal or functional properties from nature’s examples and applying them to specific building components. This method can be used to replace building skins and mechanical systems, or it can simply be applied as an additional layer to the existing. The goal is to seek optimal building performance, which results in high efficiency and, of course, blending with the natural environment.

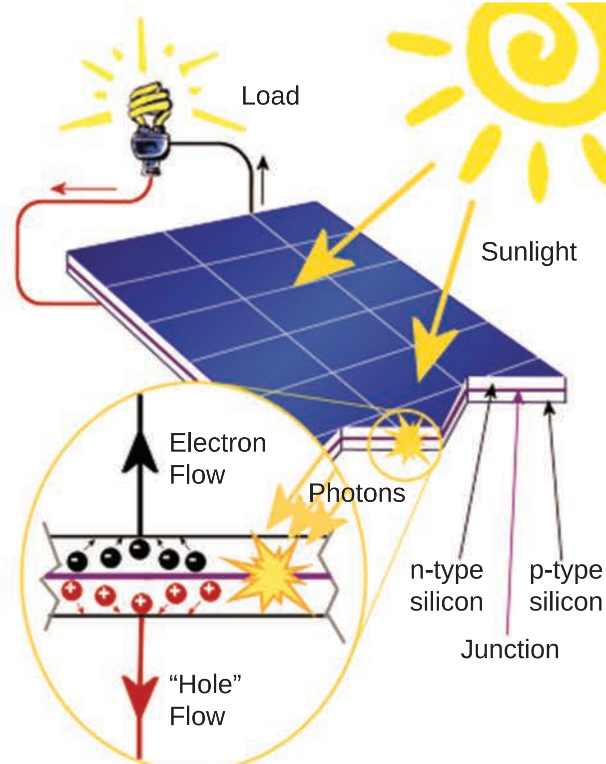
Architecture that Imitates Nature’s Parts

A company in Brooklyn, New York, titled SMIT (Sustainably Minded Interactive Technology) has developed a product called “Solar Ivy”, which is composed of artificial leaf-like photovoltaics. This invention mimics the ivy’s natural growth on vertical surfaces in order to establish its artificial branching and tectonic qualities on such planes. Similar to the plant’s leaves, it possesses a level of flexibility, which allows each artificial leaf to flap from the wind. The designers take advantage of this “flapping motion”, by introducing another device, which attaches to the back of each leaf and generates electrical energy. This compensates for some of the energy that is lost in cloudy weather and at night (SMIT. *Web.*).

Architecture that Imitates Nature’s Parts



Photosynthesis
Water + Light = Chemical Energy
Chemical Energy + CO_2 = Sugar

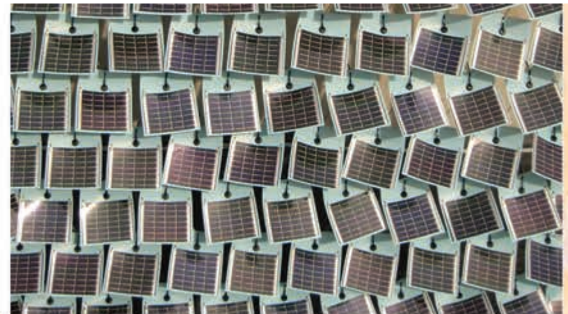


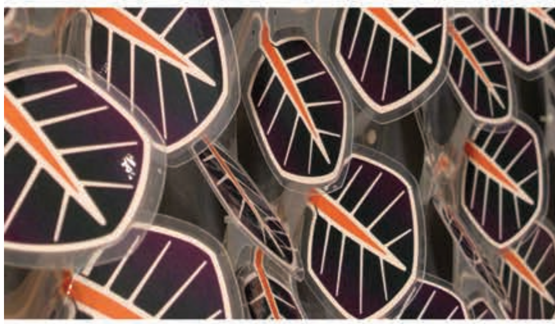
Solar Panel Diagram
By Ron Curtis & MrSolar.com

Solar Ivy conduces artificial photosynthesis without water. Instead of sugar, it produces electrical energy. Unlike other types of solar panels, which do not work well enough to be installed on vertical walls, solar ivy performs just right. It is able to achieve this through mimicking the real plant. Nature has designed the ivy to populate vertical planes and still perform photosynthesis. Every leaf is positioned a certain way in order to capture the sun’s rays, which is one of the key elements that makes SMIT’s design successful.

Architecture that Imitates Nature’s Parts

Installation of Solar Ivy at MoMa, New York.

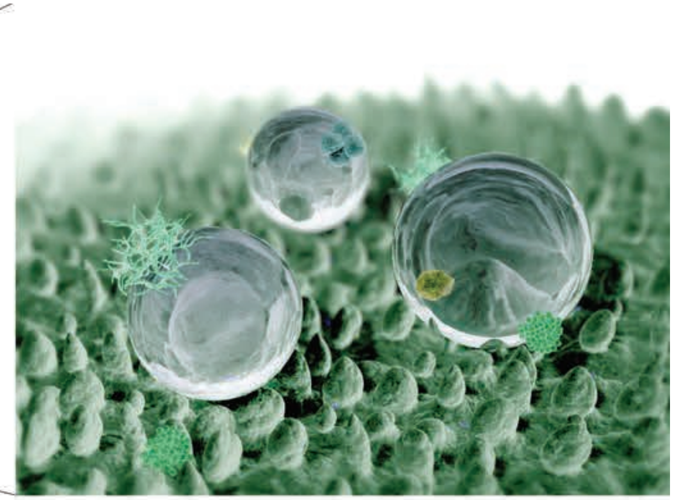




Notice how leaves are positioned a certain way to maximize solar energy capture.

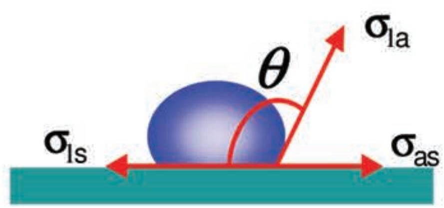
Another variation of representing the same biomimetic process

Architecture that Imitates Nature's Parts

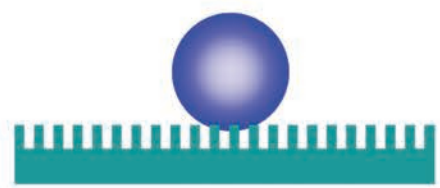


Nano scale of Lotus' surface

Ferro Glass Systems, is a glass-manufacturing company with worldwide factory locations. Among many glass types and glass-related products, this company specializes in a glass-coating surface, which mimics the lotus plant to achieve self-cleaning. Company researchers, scientists and members of the Biomimicry Guild discover how the lotus plant is able to remain clean although it grows on extremely muddy regions. This plant's secret lays on the surface of each petal. As illustrated on the enlarged image on the top right, this bumpy surface uses a little drop of water to cleanse itself. It does so by rolling the spherical droplet to pick up the tiniest particle of dirt (Benyus, Video. *Web*).



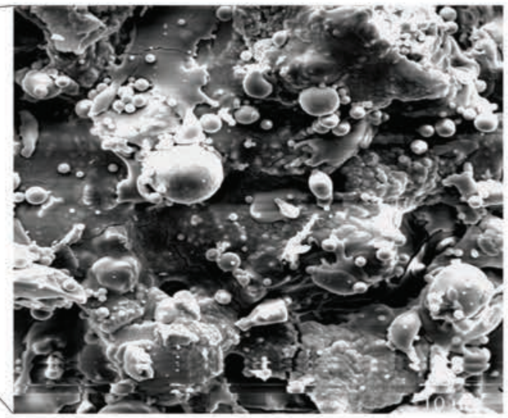
with Lotus Effect

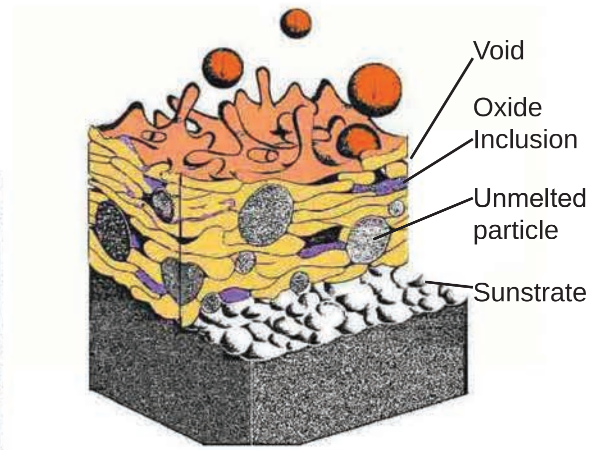


without Lotus Effect

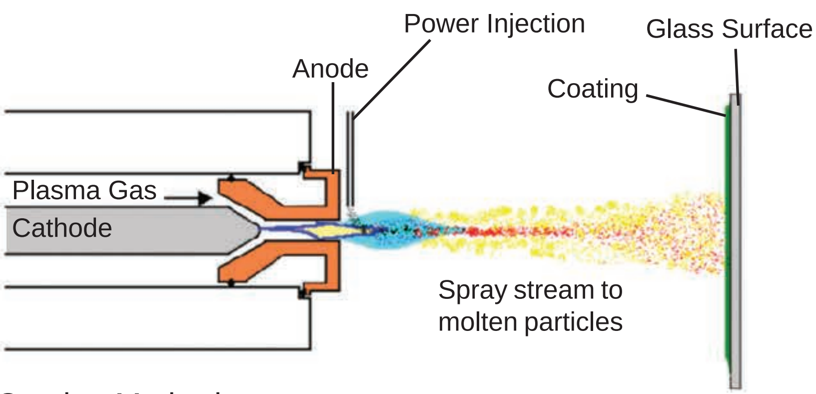
Architecture that Imitates Nature's Parts

Nano Scale of Coating Material





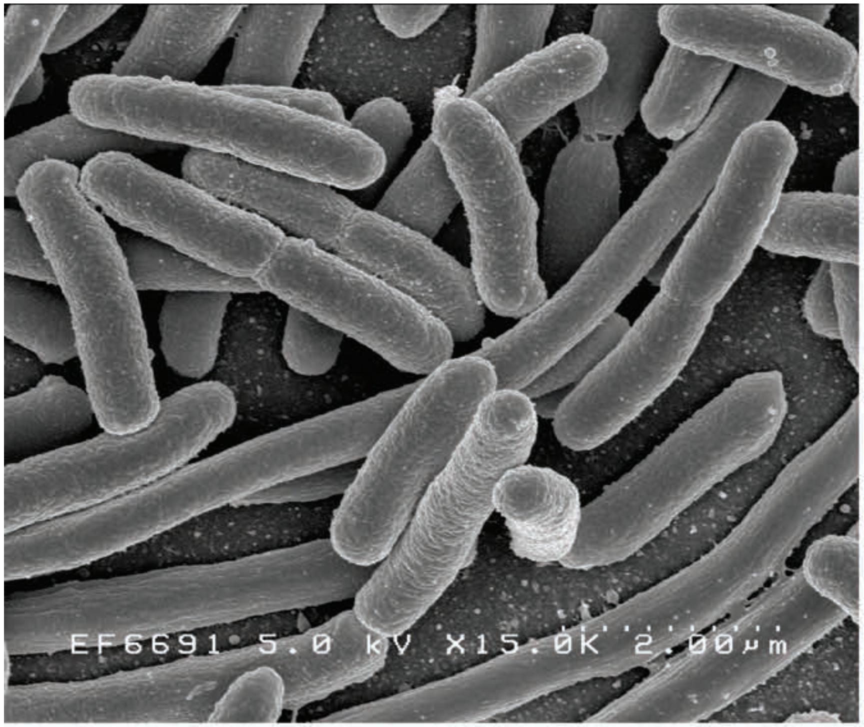
Coating Layers
(Ferro - The Performance Materials Company. *Web*).

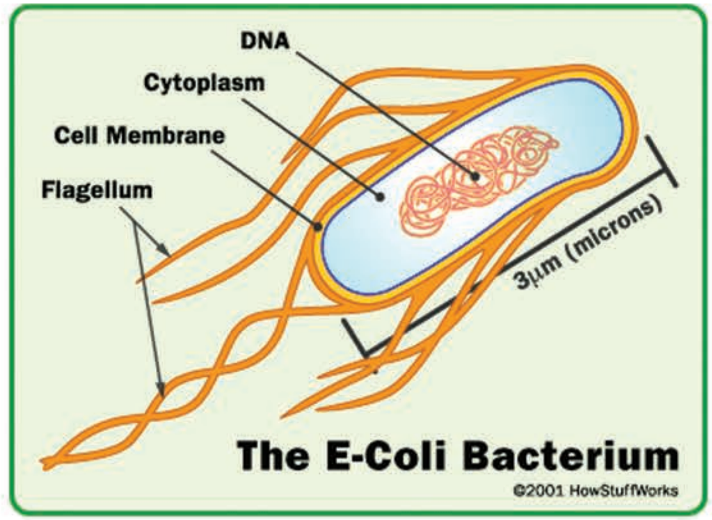


Coating Method (Ferro - The Performance Materials Company. *Web*).

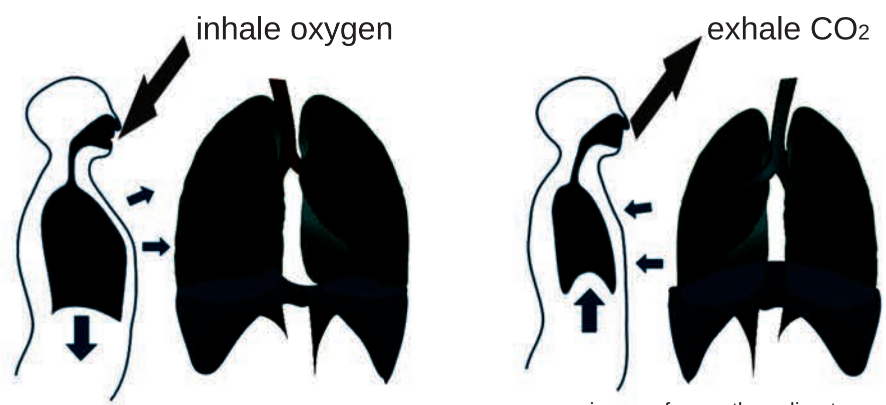
Improves photovoltaic panel's energy intake by 10%

Architecture that Imitates Nature's Parts





CO_2 Solutions Inc. is a company located in Quebec Canada. This establishment "has developed a proprietary bio-technological platform for the efficient capture of carbon dioxide," which is known as the most detrimental greenhouse gas as it comes to contact with our ozone layer. The company mimics "biocatalyst," which refers to "natural chemical transformations on organic compounds" that are caused by enzymes located in the lungs of humans and other mammals. In simpler terms, we breathe-in oxygen and breathe-out carbon dioxide. CO_2 Solutions does that, but reverses the order of the chemical transformation. E. coli bacteria become important to this company as they are "genetically engineered to produce an enzyme that converts carbon dioxide into bicarbonate." This enzyme can than "capture carbon dioxide emissions from power plants that run on fossil fuels" (CO_2 Solutions, *Web*).

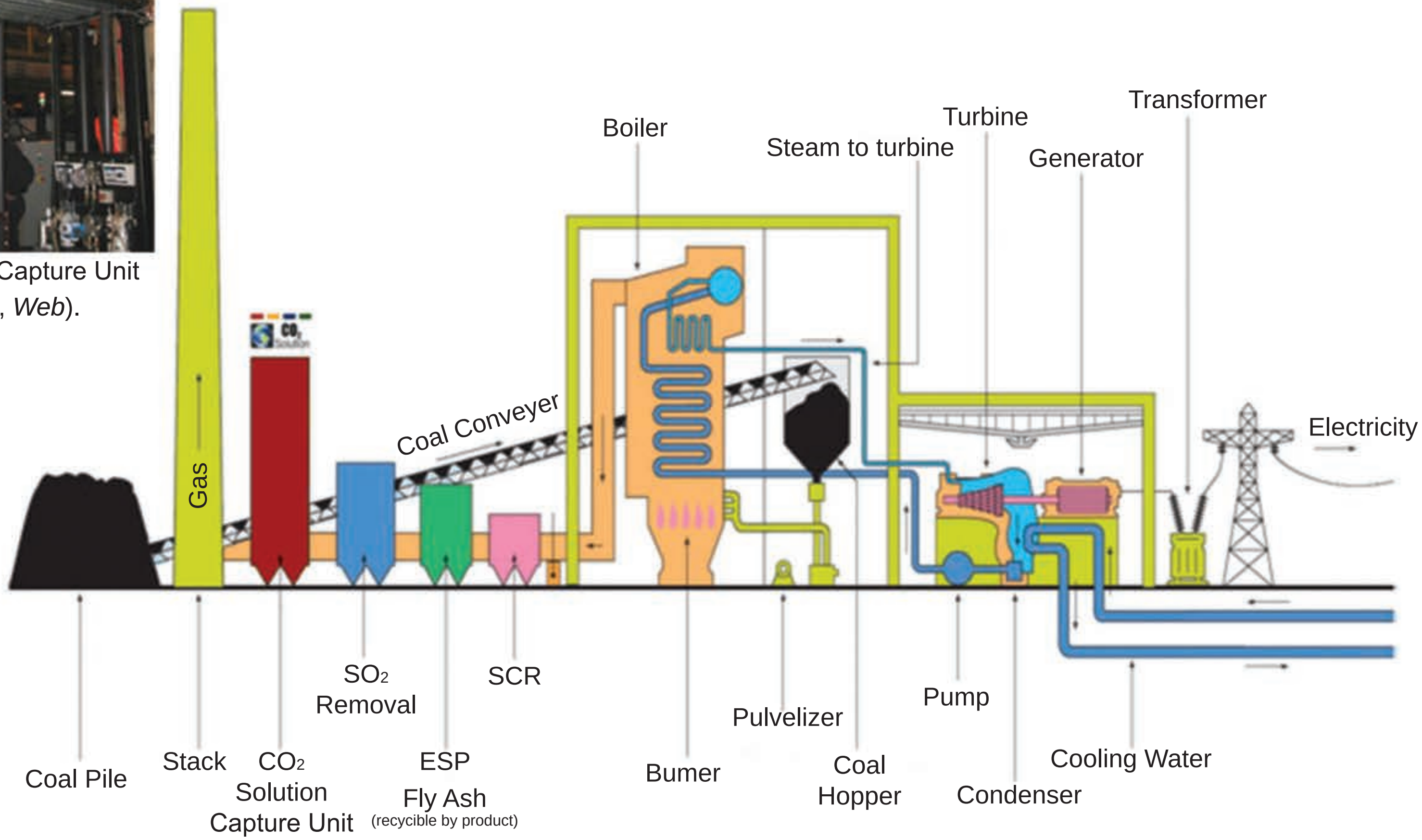


images from arthursclipart.org

Architecture that Imitates Nature's Parts

Prototype CO_2 Capture Unit
(CO2 Solutions, *Web*).

Diagram of Placement of CO_2 Solution's Equipment in Coal-Fired Power Plant



(CO2 Solutions, *Web*).

Design Proposal

Biomimicry of function, biomimicry of form and biomimicry of parts is applied to the following project in order to demonstrate the biomimetic process as a design tool in architecture. This process is executed through the design of an exhibition center, which is sited in Worcester, Massachusetts.

The exhibition center:

- This type of building encompasses the dual ability to display biomimicry through the composition of its structure, form, material, and through the biomimetic themes that will take place inside its exhibition spaces.

- This building can fluently allow different functions to take place, or it can reuse its spaces for greater future modifications, without influencing its structure.

- This building can have dynamic and flexible skins, which could be continually replaced as biomimetic knowledge grows in the future.

The site:

The site is located in an urban area in downtown Worcester. Redevelopment is currently taking place on this site, as an old mall, along with offices and a parking structure are being demolished due to the lack of use for almost a decade. This area signals great opportunity for creating a dialogue between the existing urban fabric and the proposed biomimetic design, which depicts itself as a measure toward evolution in architecture.

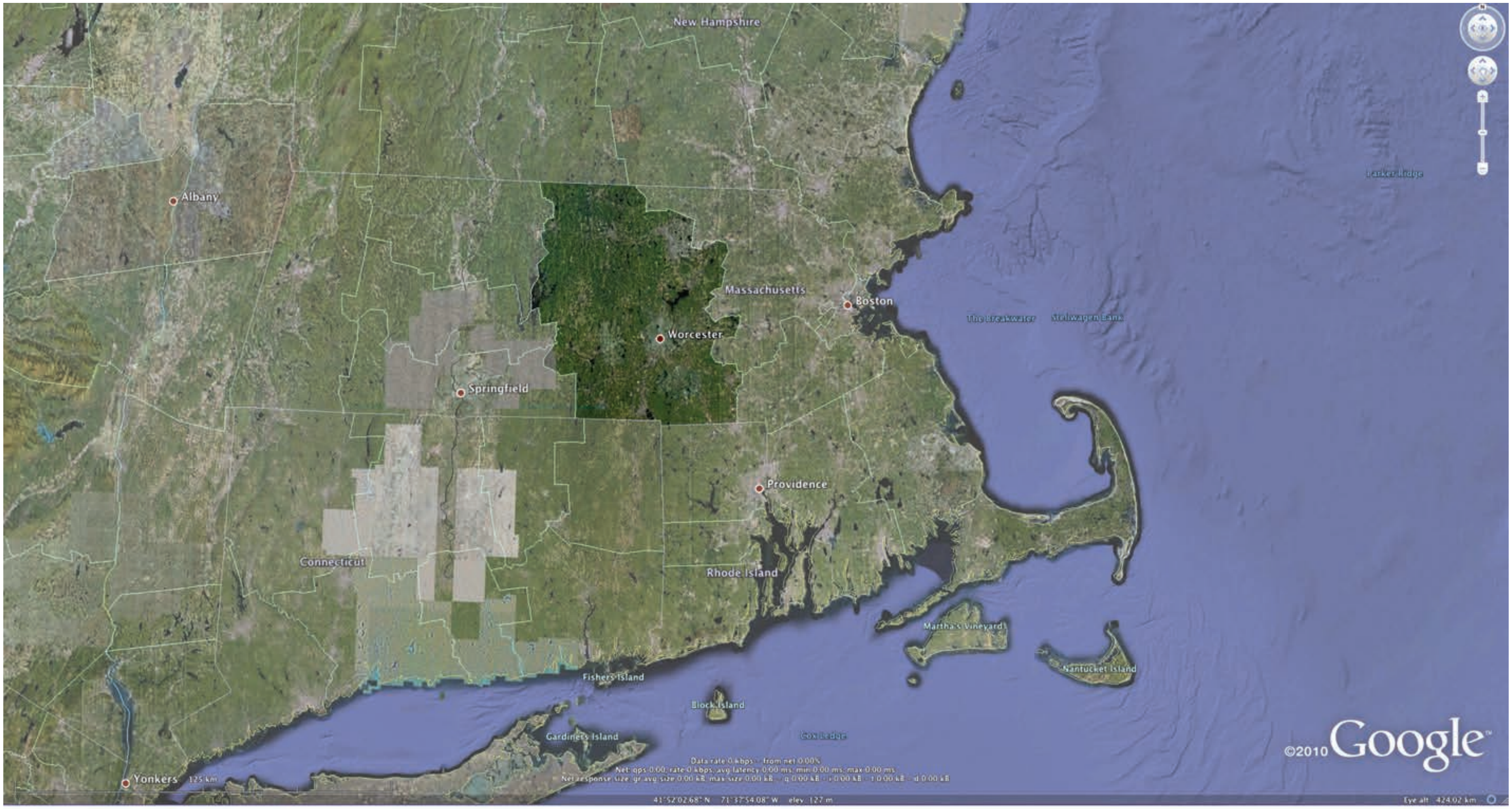
Program Prior to Precedent Analysis

- Exhibition Space(s)
- Public Space(s)
- Private Space(s)
- Loading Dock(s)
- Loading Vehicle Area(s)
- Green space(s) Indoor
- Green space(s) Outdoor
- Cafeteria(s)
- Parking
- Storage
- Mechanical / Electrical space(s)

Site

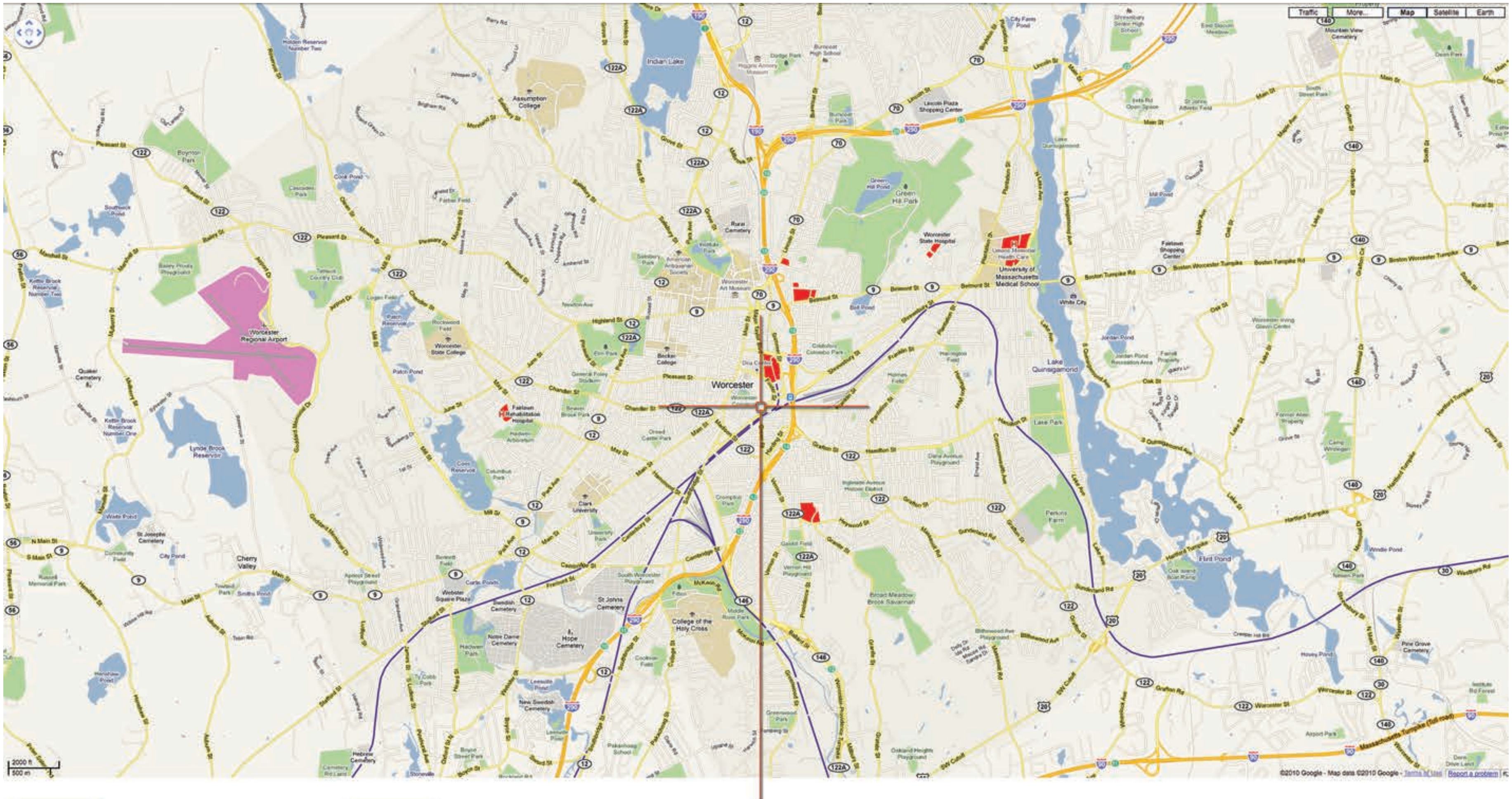
Worcester, Massachusetts

Site



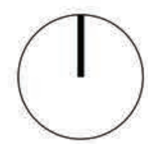
Worcester, Massachusetts

Site



Proposed Site

Highways	Body of Water
Major Roads	Colleges
Minor Roads	Cemetery
Rail Road	Hospitals
Airport	Parks



Site

Proposed Site

Redevelopment Area

Site

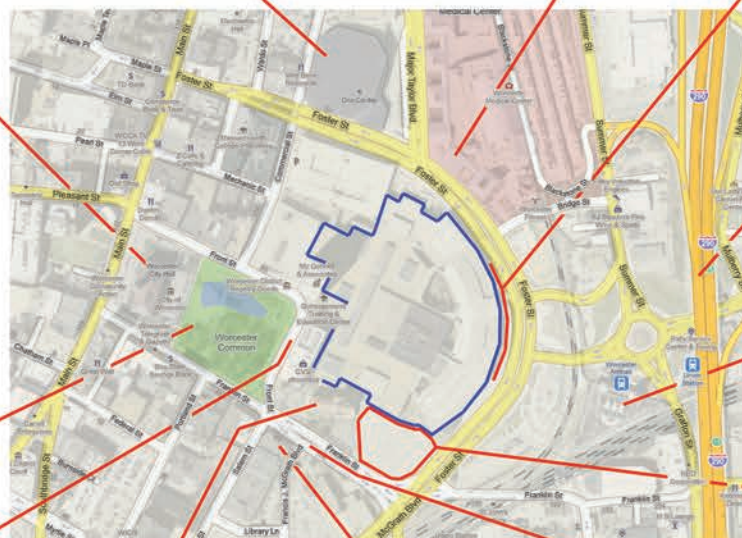

City Hall from Main St


DCU Center (concerts, sporting events, circus, etc.


St Vincent Hospital


Foster St


City Hall from Worcester Common

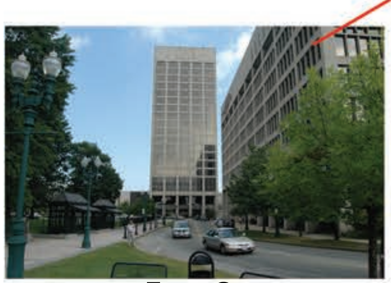



Highway 290


Train Station


Worcester Common


Proposed Site


Front St

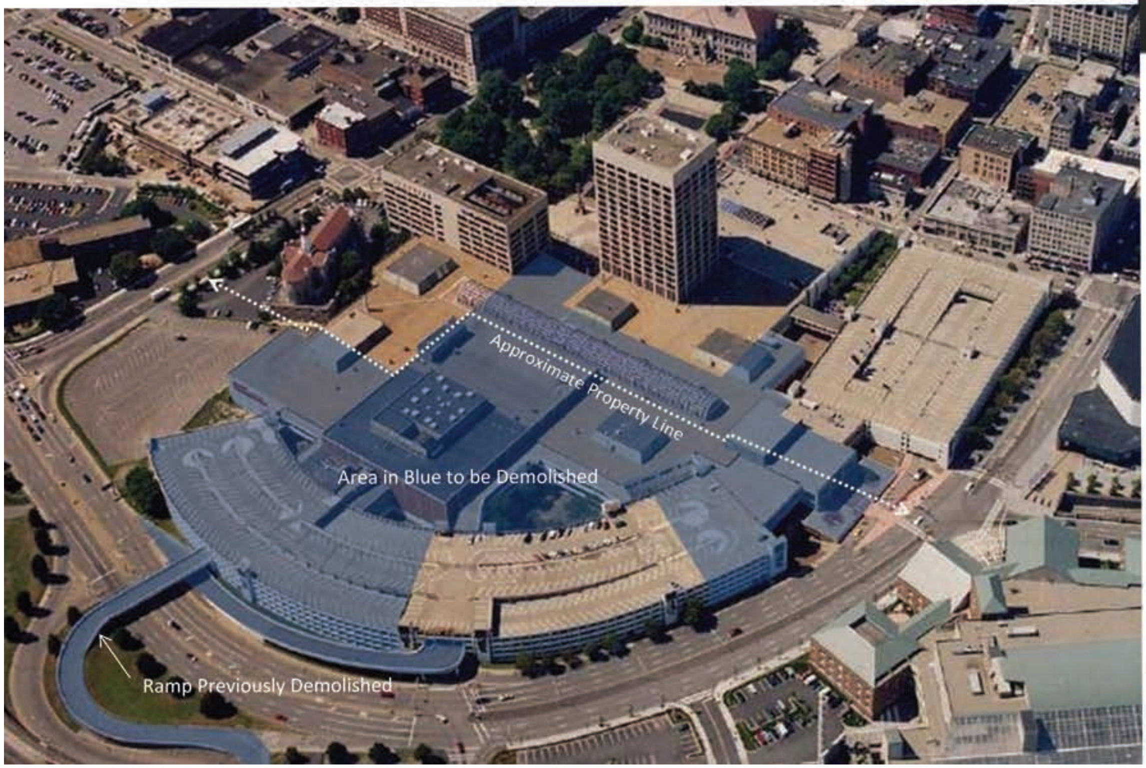

Church


Public Library


Franklin St

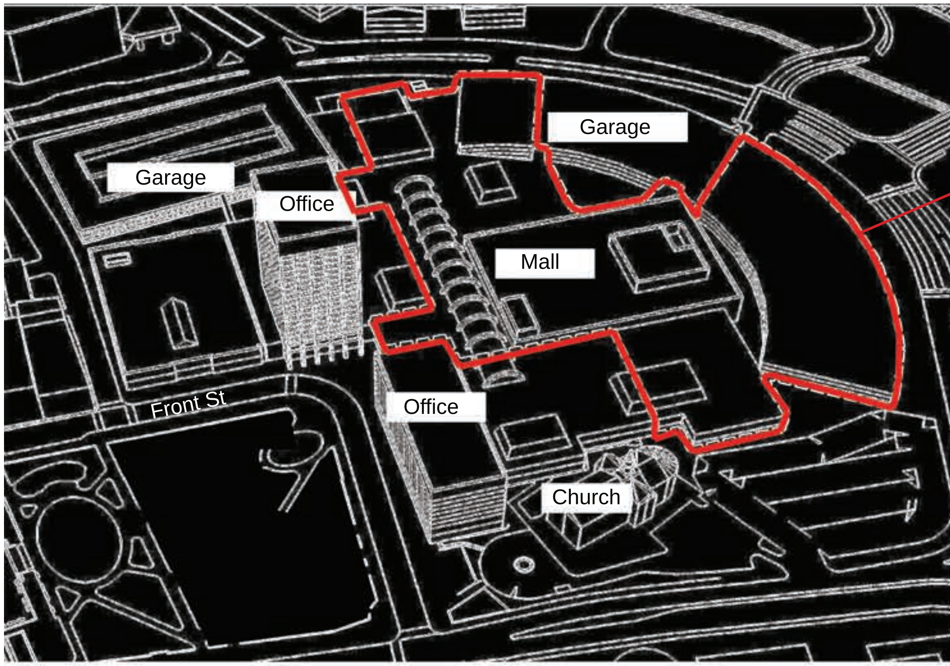
Site

“Worcester, with its population just over 182,000, is home to 10 colleges and universities (a half-dozen more in neighboring communities), including the University of Massachusetts Medical School, Worcester Polytechnic Institute, College of the Holy Cross, Clark University, the Massachusetts College of Pharmacy and Health Sciences and Tufts Cummings School of Veterinary Medicine. Thirty-eight percent of all jobs in the city are in the education and medical fields. Over 36 percent of residents between the ages of 25 and 34 have a bachelors or post-graduate degree, placing Worcester among the leaders of all New England cities.
“CitySquare is a $563 million multi-phased private/public commercial real estate project and the largest development project in the Commonwealth outside of the Boston area. The investment in private capital of $470 million will create more than 2.2 million square feet of commercial, medical, retail, entertainment, and residential space. The public investment of $94 million will allow for the creation of a new, pedestrian-friendly, small street and block pattern in the heart of downtown Worcester.” (New City Square. *Web*.)



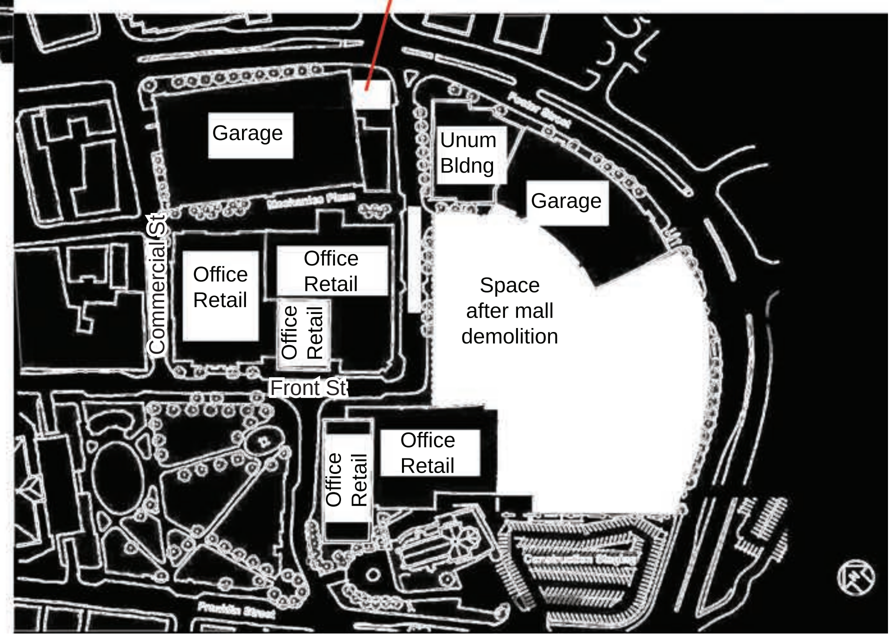
“Unum will occupy more than 194,000 square feet of rentable space in a newly constructed building, known as Building H. The building is targeted for LEED Silver certification and is expected to be completed within 19-22 months.” (New City Square. *Web*.)

Site



Area to be Demolished

Plaza



Precedents

The following precedents are examples of exhibition/convention buildings. They are **not** intended to be examples of biomimicry for this book. They are only used to analyze programmatic and dimensional purposes, which includes the following:

- to extract a list of the program
- to evaluate programmatic arrangement
- to evaluate programmatic hierarchy
- to evaluate circulation (public and private)
- to evaluate public and private spaces
- to evaluate means of egress
- to evaluate the relationship between indoor and outdoor spaces

Precedents

Compared to Proposed Site

All four sites are at the same scale and position

Worcester MA (Proposed Site)

Exhibition Center, Milan, Italy 2.1 million sqf (20,000 parking spaces)

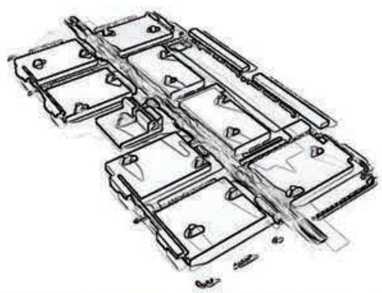
Convention Center, Boston, MA 857,000 sqf

Exhibition Hall 26, Hanover, Germany 27,000 sqf

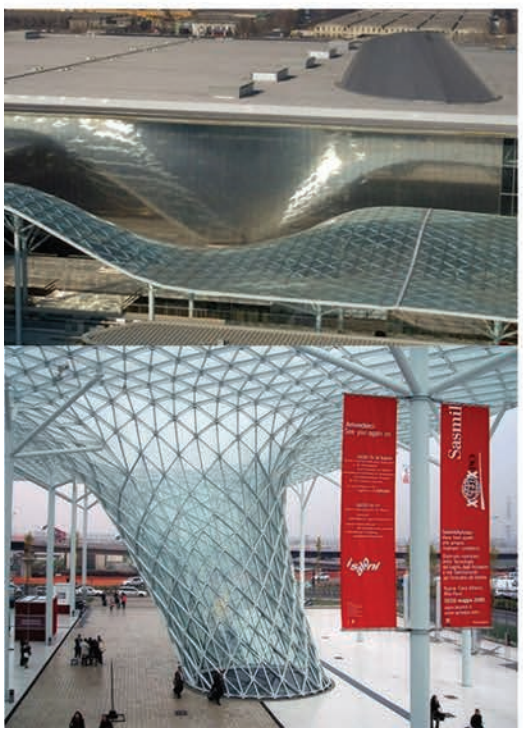
Precedents

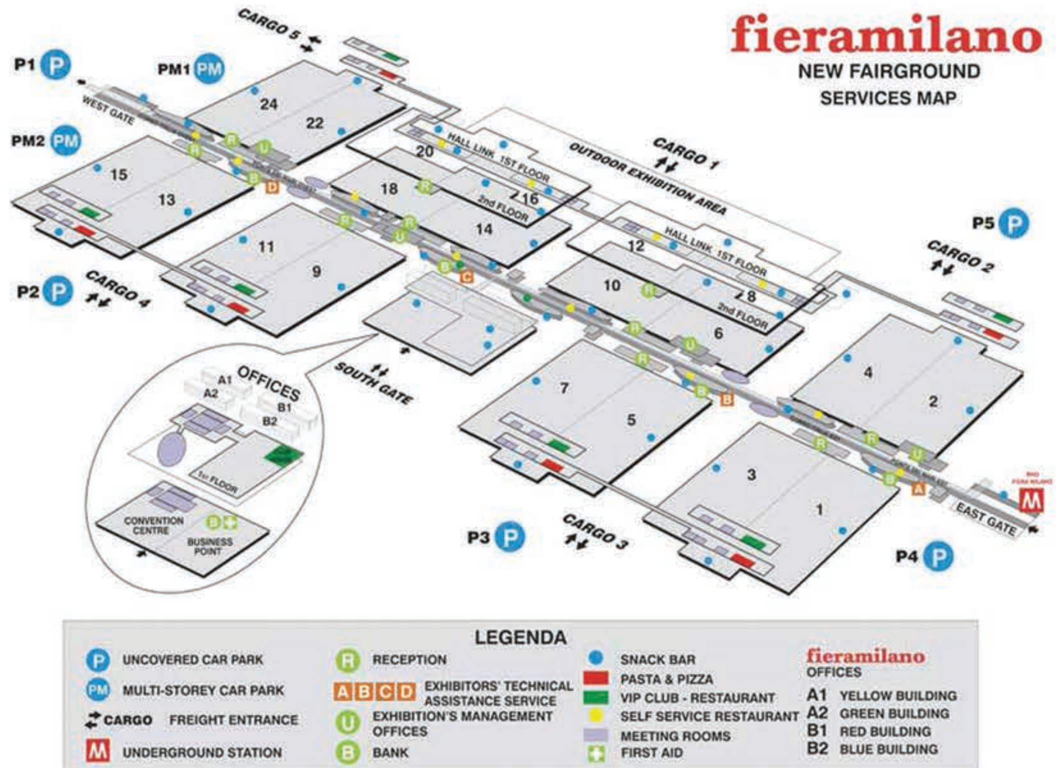
Milan Trade Fair, a Convention Center, Milan Italy
Architect: Massimiliano Fuksas

World's biggest rooftop solar power installation
Article by Karen Sprey, August 10, 2009



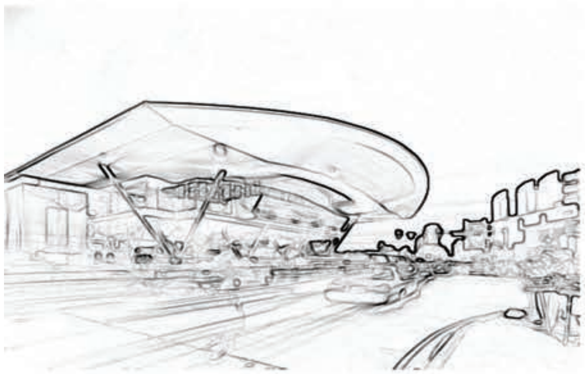
5 km from Hotel Accursio
375.000 m2
8 pavilions
74 meeting rooms
84 restaurants
10.000 parking spaces (plus another 10,000 in progress)
subway station

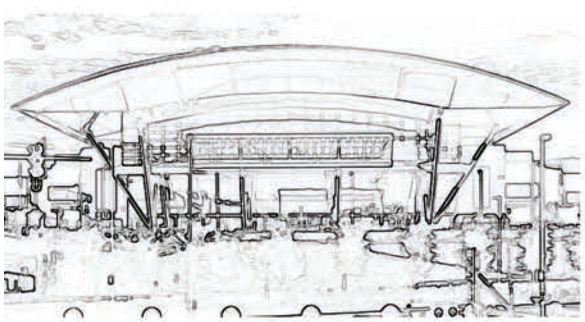




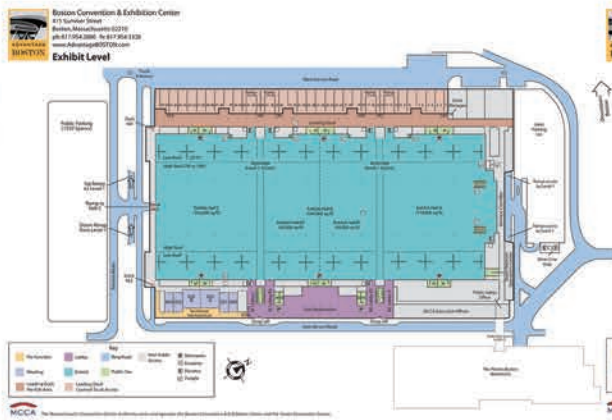
Precedents

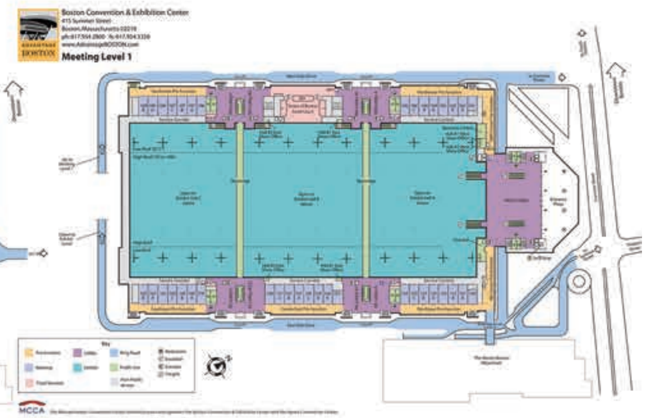
The Boston Convention and Exhibition Center, Boston, MA
Architect: Rafael Vinoly Architects

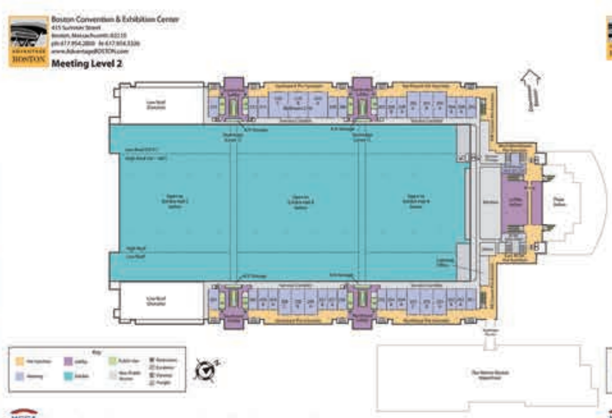


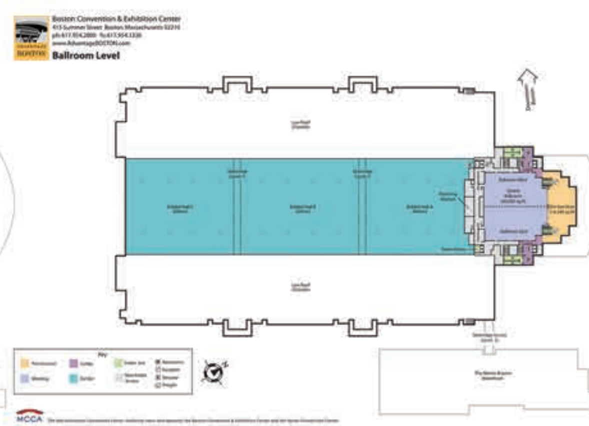


516,000 square feet of contiguous exhibit space
84 configurable meeting rooms
over 300,000 square feet of function areas
eight registration areas
40,020 square foot ballroom



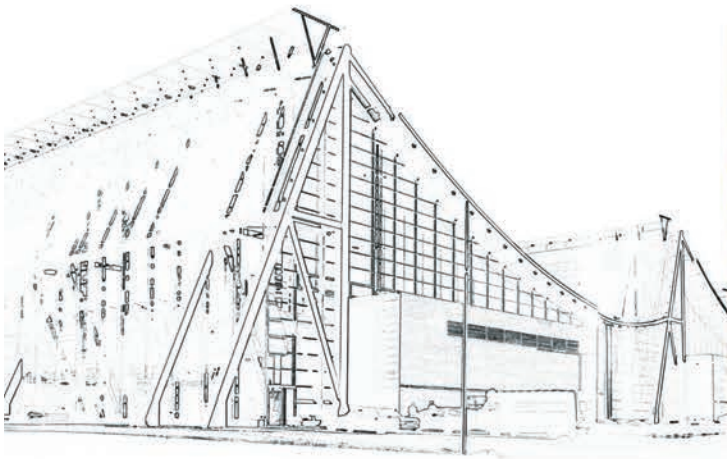


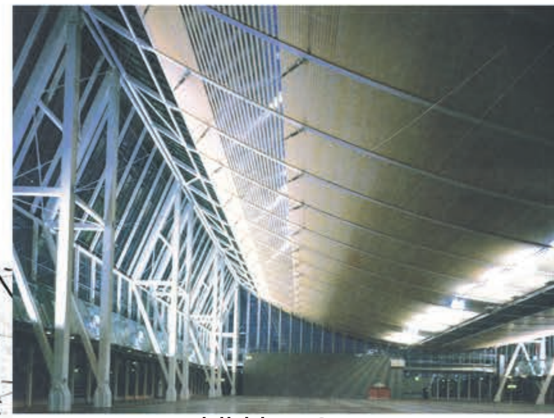




Precedents

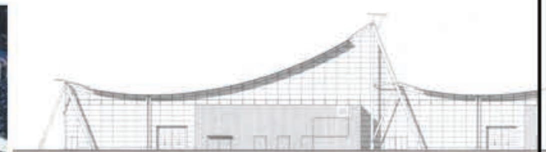
Exhibition Hall 26, Hanover, Germany
Architect: Herzog + Partner





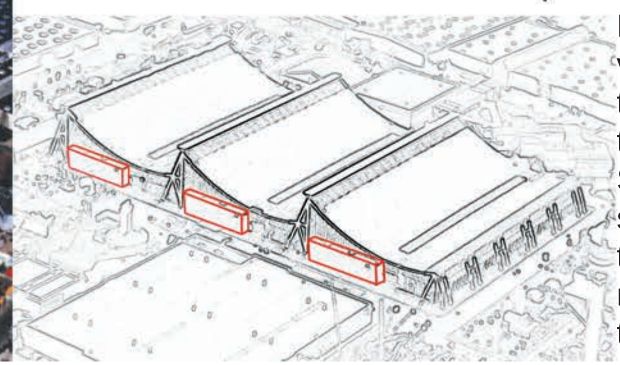
Exhibition Space

Enclosed public circulation inside exhibition space



Elevation

Section



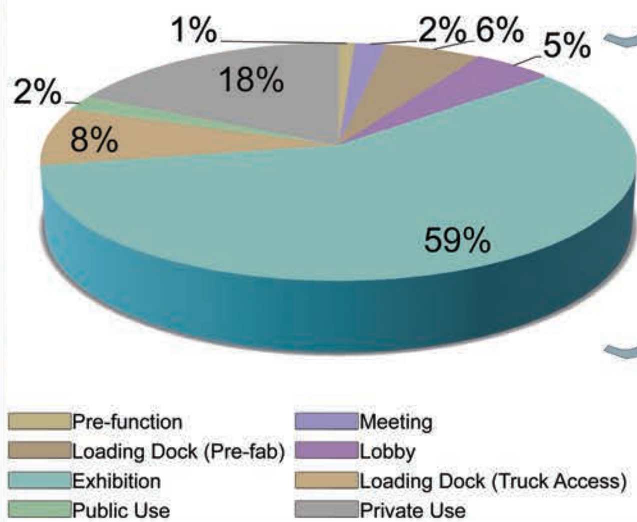
Mechanical units, public and private spaces are located outside the building, leaving the interior of the exhibition area uninterrupted. Such arrangement allows these side elements to undergo partial or total transformations due to technological improvements in the future.

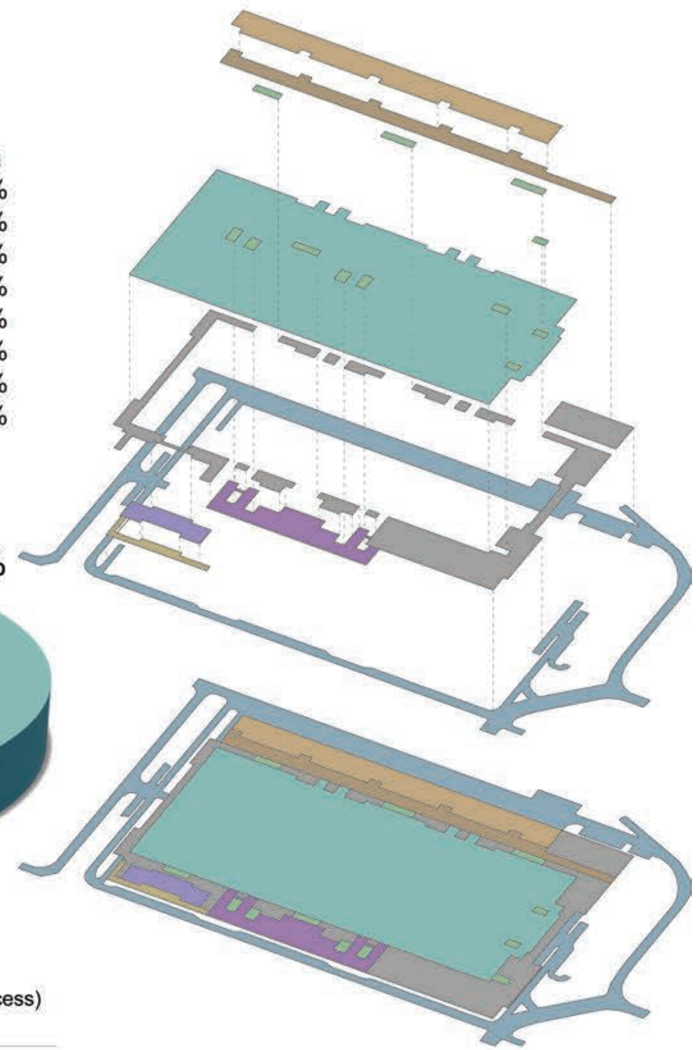
Program Formula After Precedent Analysis

The programs below are derived from the previously introduced convention and exhibition buildings. Their arrangements and spatial hierarchies generate a formula table that partially dictates the program for this project. Zoning analysis and further biological research will implement final programmatic decisions.

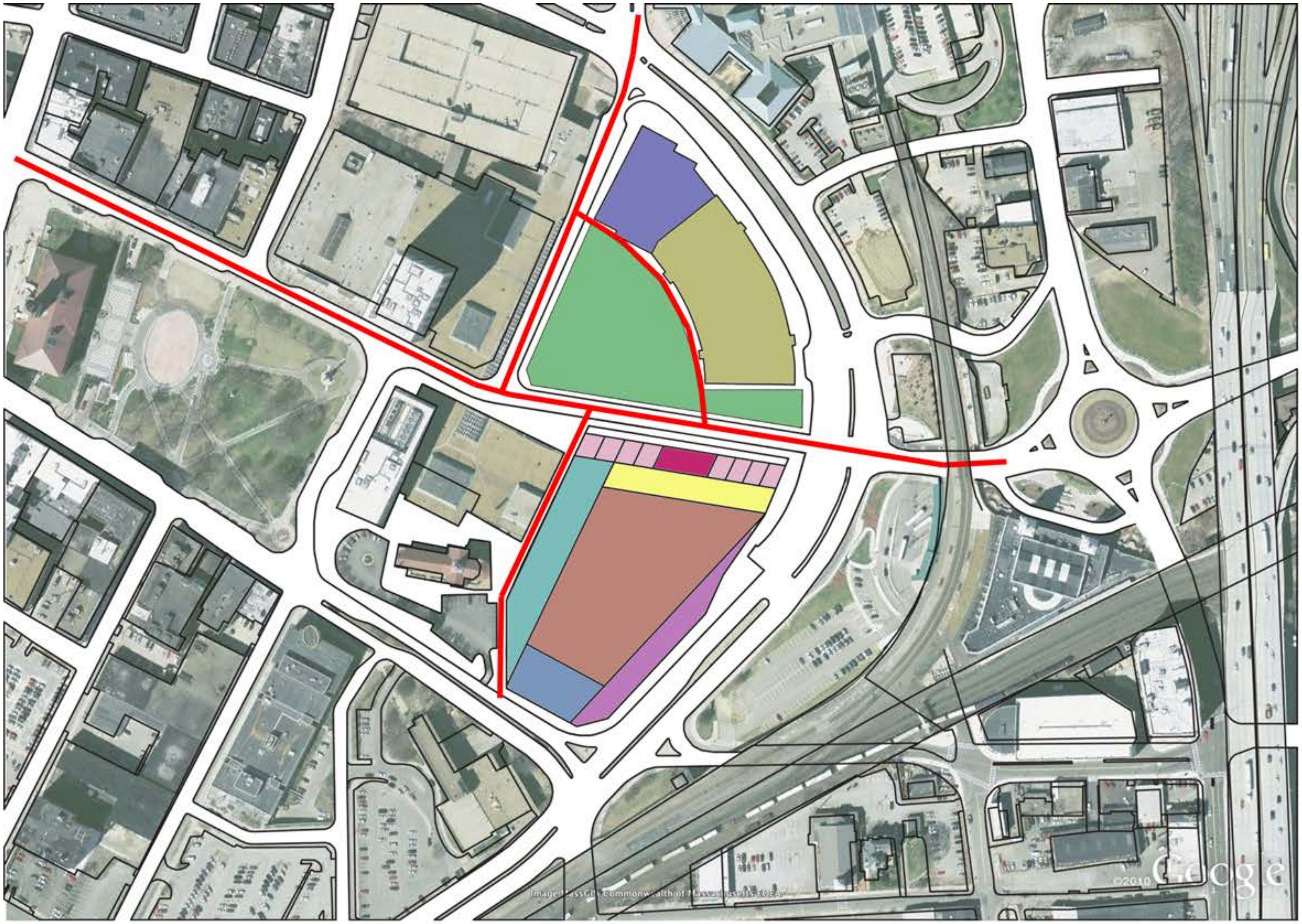
Program	
Public	
Exhibit	
Circulation Corridor	
Lobby	
Outdoor Space	
Restrooms	
Escalator	
Elevator	
Stair	
Fire Stair (See Zoning)	
Cafeteria	
Private	
Outdoor Space	
Freight	
Pre-function	
Meeting	
Food Service	
Kitchen	
Service Corridor	
Vehicular	
Parking (See Zoning)	
Circulation (Loading)	
Loading	
Loading Dock (Pre-Fab)	
Loading Dock (Covered Truck)	
Public Entertainment	
To be determined	

Program	Percentage of Area
Pre-function	1%
Meeting	2%
Loading Dock (Pre-fab)	6%
Lobby	5%
Exhibition	59%
Loading Dock (Truck Access)	8%
Public Use	2%
Private Use	18%





Program



Unum new building

To be built during phase I.
(Year of completion 2012)

Remaining Parking Structure

New Roads

Park, garden

82,000sqft
Potential space for extending exhibition program

Other

14,000sqft
Ground level-Parking. Upper levels- meeting rooms, offices, prefunction...

Lobby

4,800sqft
faces the new street, which indicates the front facade of the exhibition center. Retail shops are located on both sides.

Retail Shops

(8) 1,700sqft
create a connection between the existing urban fabric and the new development.

Public/ Private Spaces

16,000sqft
public spaces: restrooms, firestair, elevators, cafeteria...
private spaces: kitchen, storage...

Public/ Private Spaces

28,000sqft
public spaces: escalators...
private spaces: prefunction, storage, partial mechanical, service ...

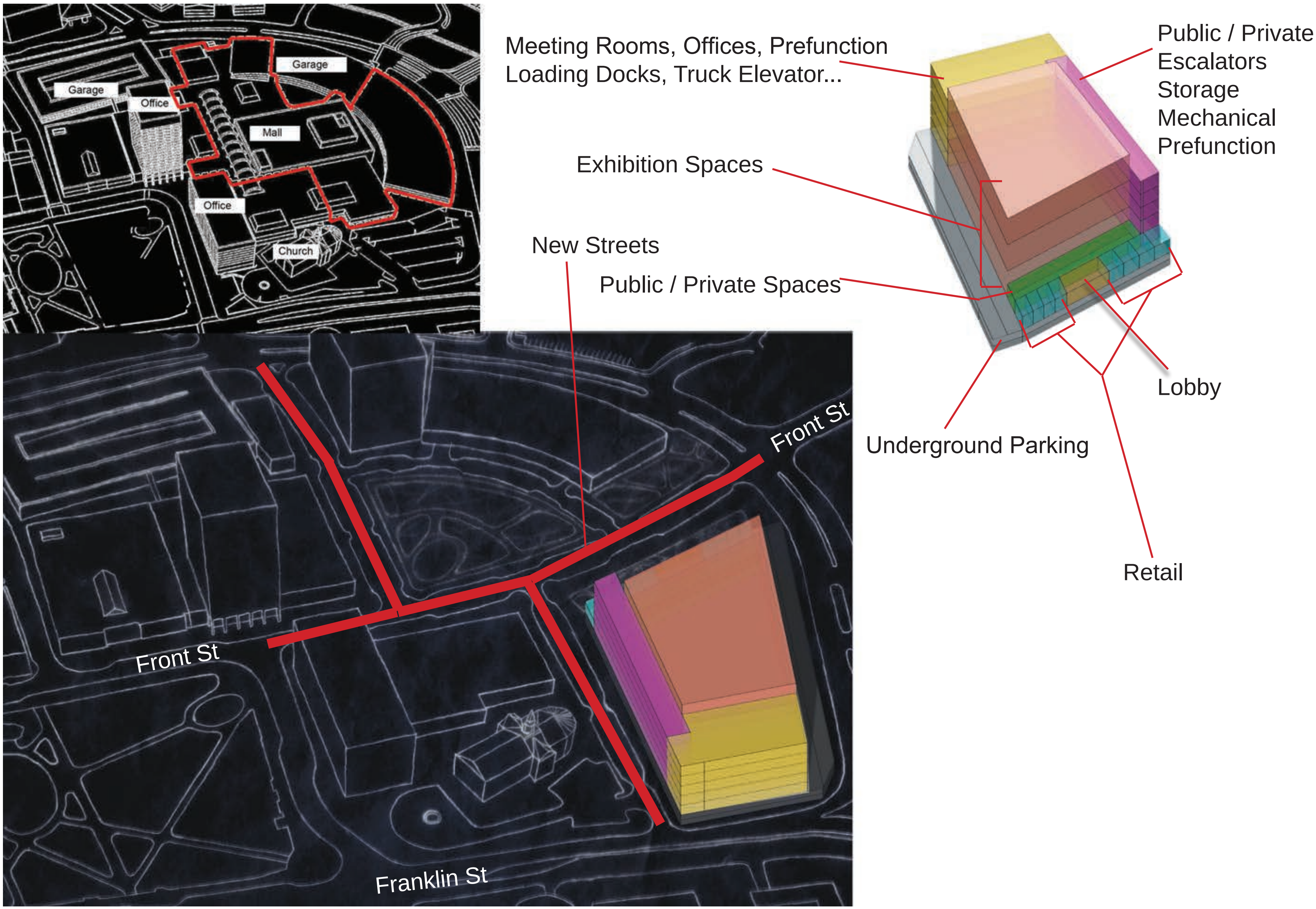
Exhibition Space (3 stacked)

88,000sqft
to be used for other purposes when exhibitions are not taking place. (Celebratory functions, dance halls and other social activities).

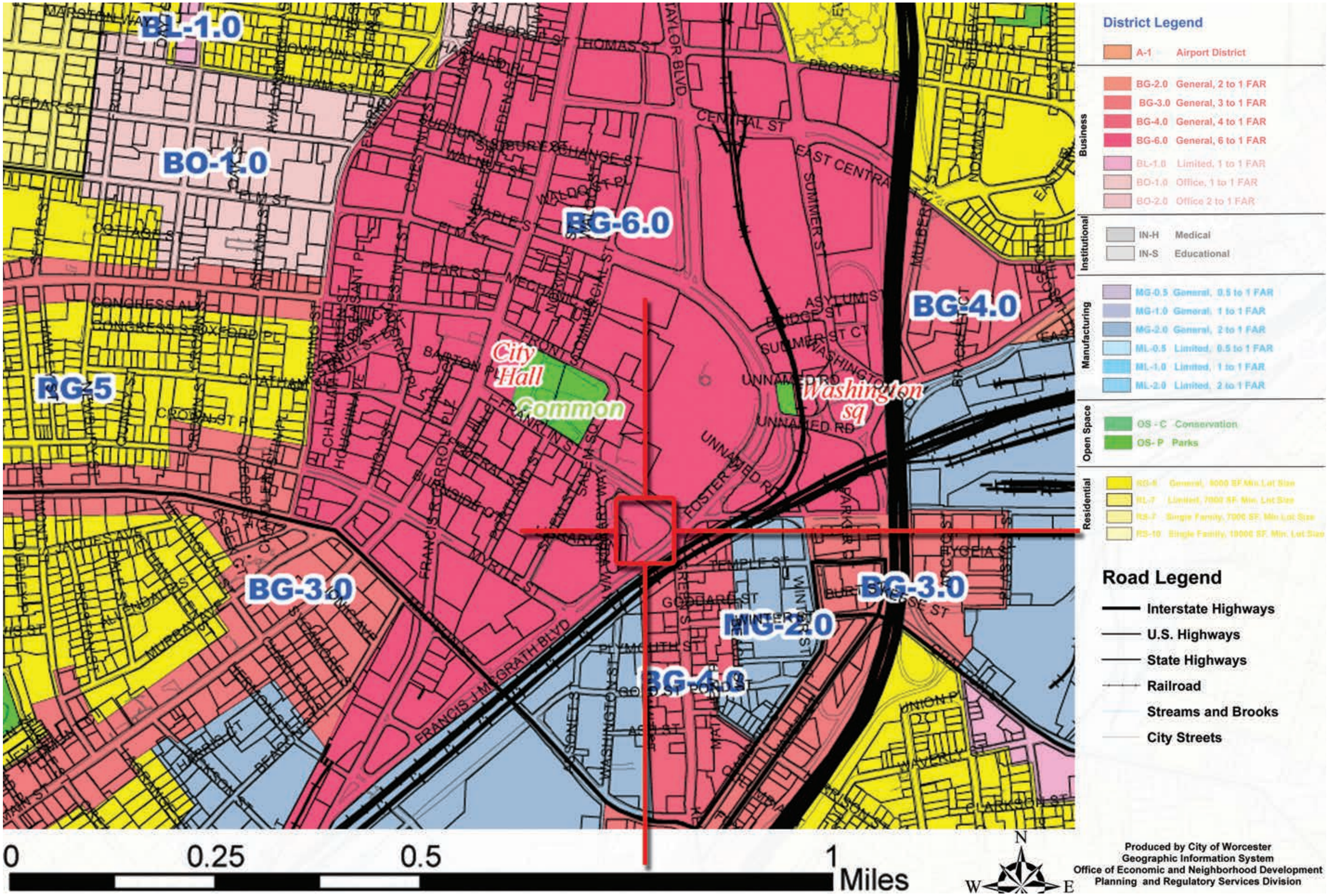
Vehicular Circulation

18,000sqft
pathways to underground garage and loading dock. Bus stop, Truck path and compact cars. Freight elevators for trucks to acces upper exhibition spaces

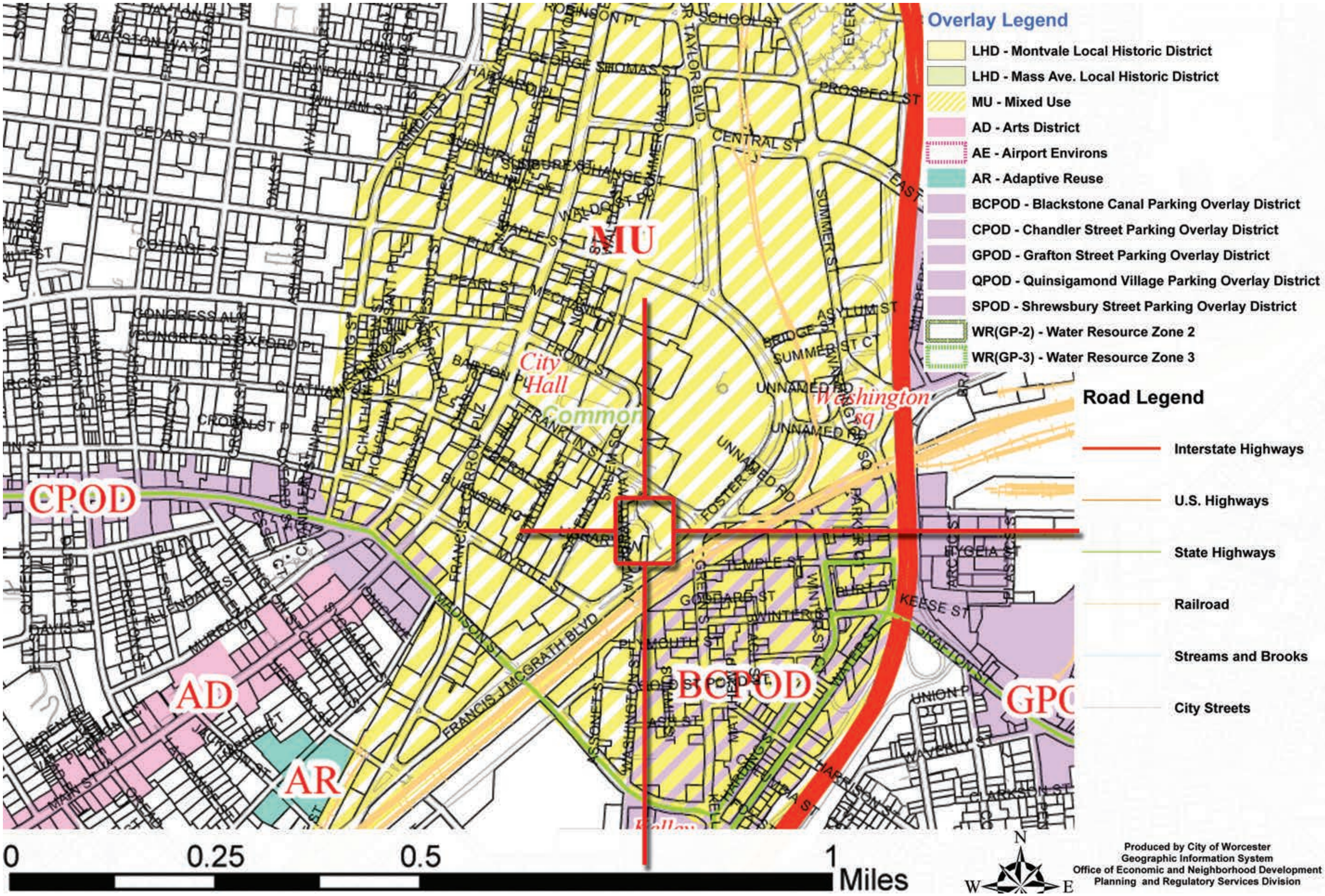
Program


Garage
Office
Garage
Mall
Office
Church
Front St
Front St
Franklin St
Meeting Rooms, Offices, Prefunction
Loading Docks, Truck Elevator...
Exhibition Spaces
New Streets
Public / Private Spaces
Public / Private
Escalators
Storage
Mechanical
Prefunction
Underground Parking
Lobby
Retail

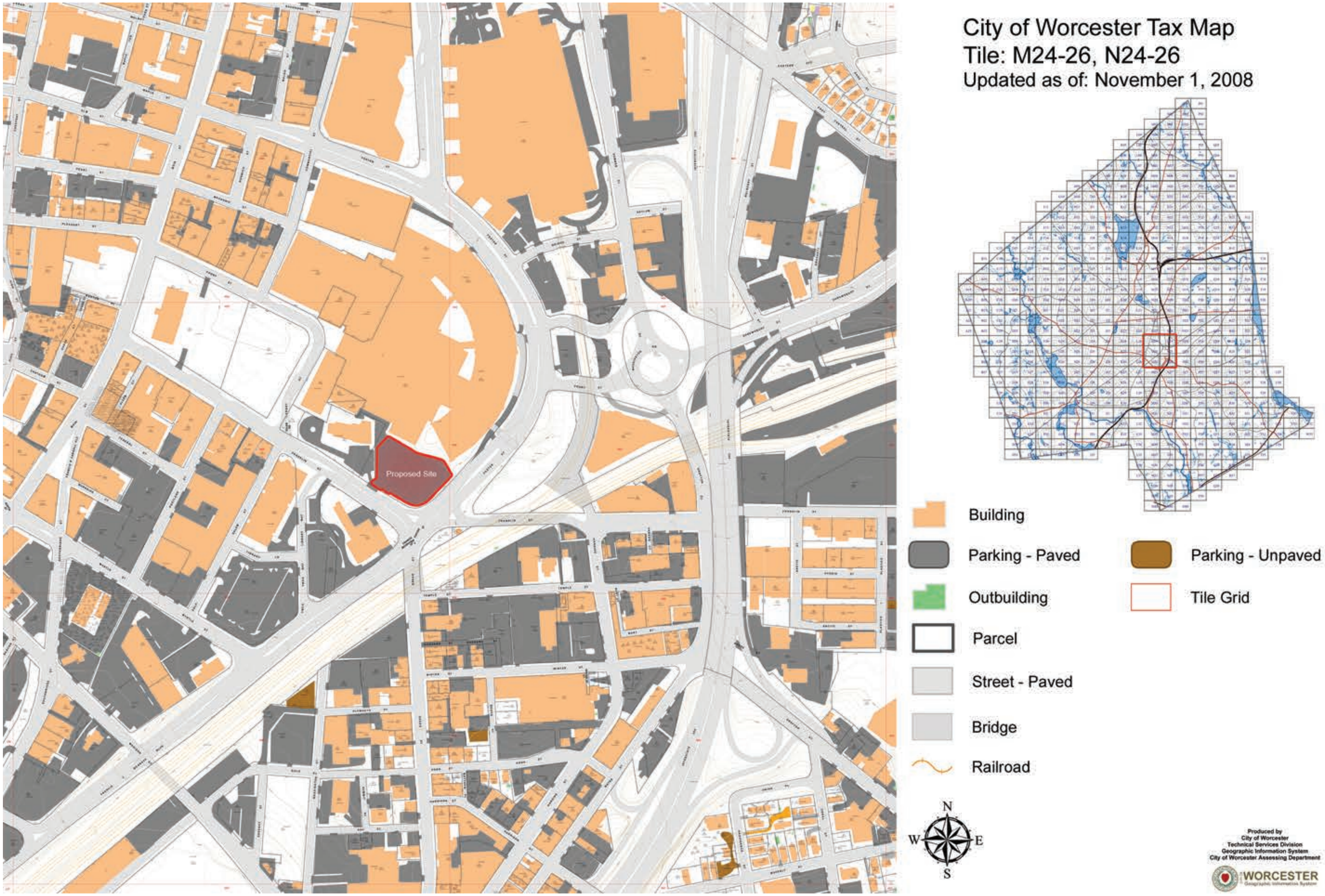
Zoning Analysis



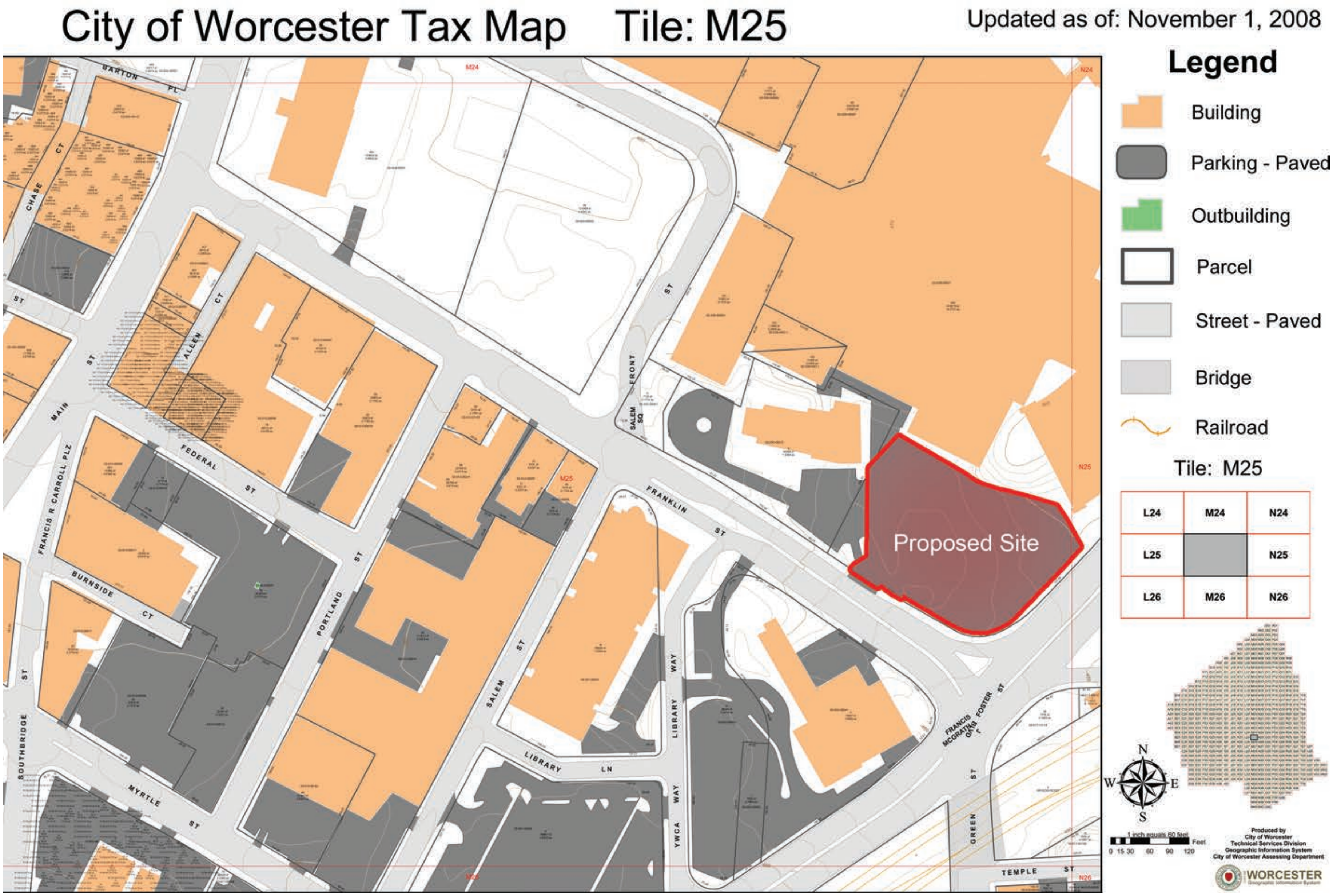
Zoning Analysis



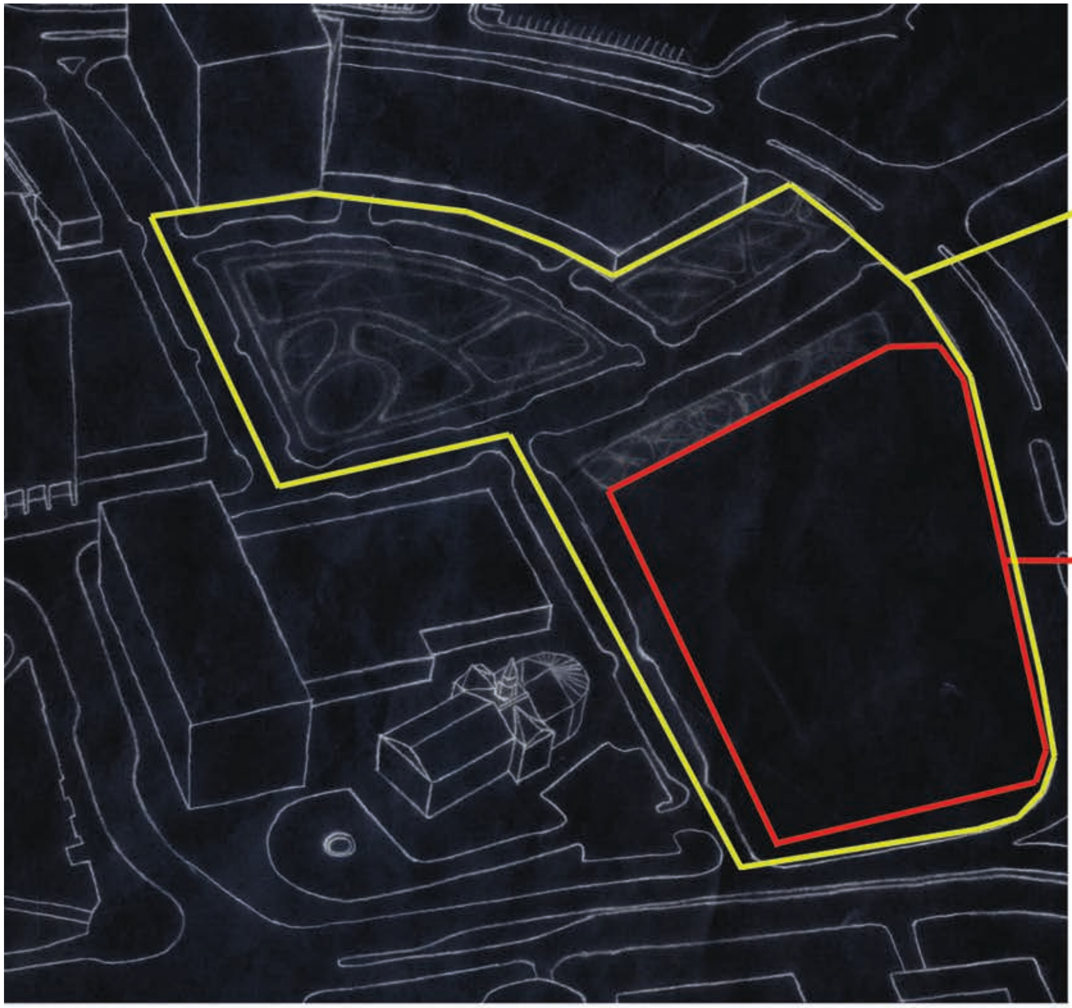
Zoning Analysis



Zoning Analysis



Zoning Analysis



Area available for development
362,600 sqft

Proposed design area
178,600 sqft

Applying zoning restrictions
362,600 sqft / 6 = 60,433 sqft

178,600sqft - 60,433 sqft
= 118,167 sqft

BUSINESS DISTRICTS

FLOOR AREA RATIOS
(Building/land)

6 square feet/ 1 square foot

Zoning Analysis

Dimensional Regulations

PERMITTED DIMENSIONS BY DISTRICT
TABLE 4.2

DISTRICT: **BG-6.0**

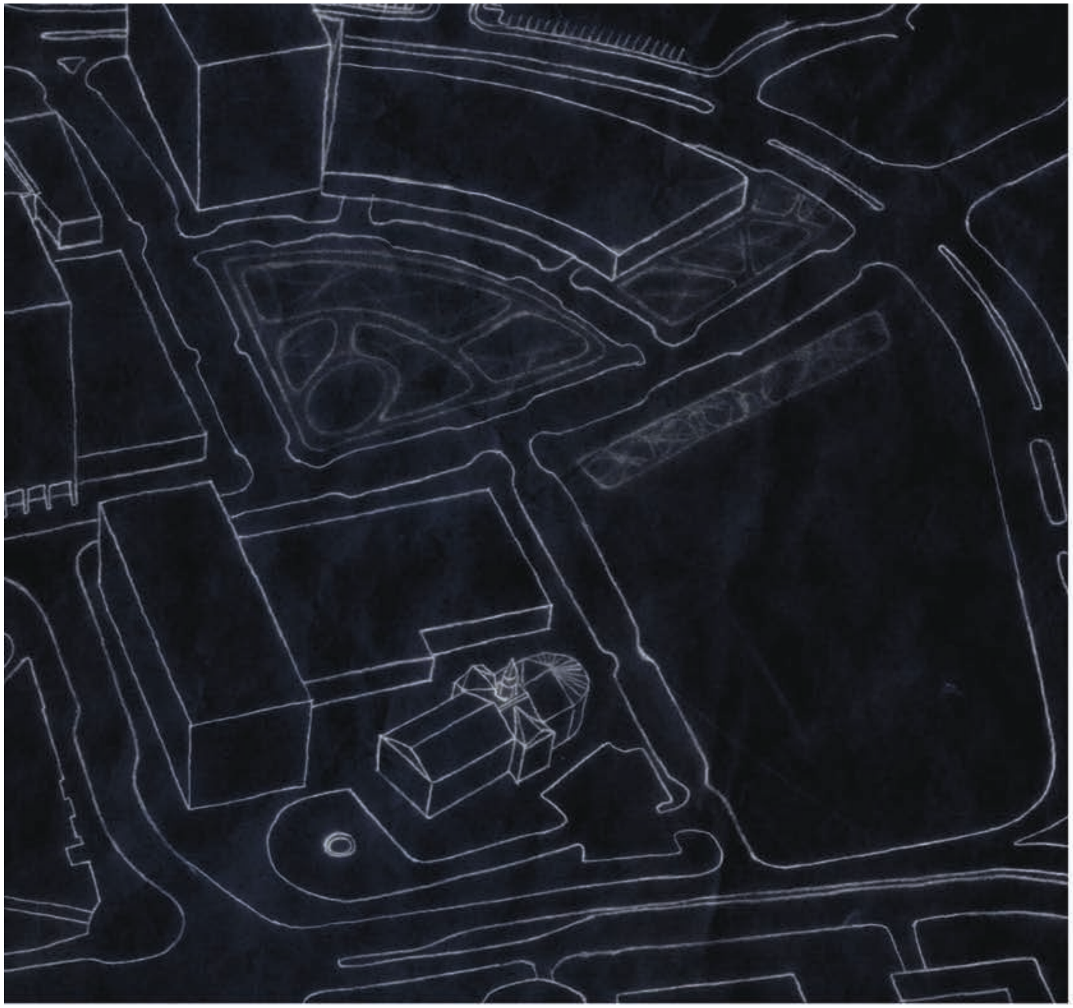
LOT
AREA (Minimum SF) - 5,000 (NA)
FRONTAGE (Minimum linear ft.) - 40 per du 4 (NA)

YARD SETBACKS
FRONT - NA
SIDE1 - NA
REAR - 10

HEIGHT
Maximum in stories - (NA)
Maximum in ft - (NA)

FLOOR TO AREA RATIO (Maximum)
6 to 1

Zoning Analysis



Parking Regulations

TABLE 4.2
Permitted Dimensions by District
Notes to Table 4.2

Substantial irregularity – No lot shall be created that is substantially irregular in shape.
For the purposes of this section, a lot is “substantially irregular” if it has a regularity factor that is less than 0.4 as determined by the following formula:

$R=16A/p^2$

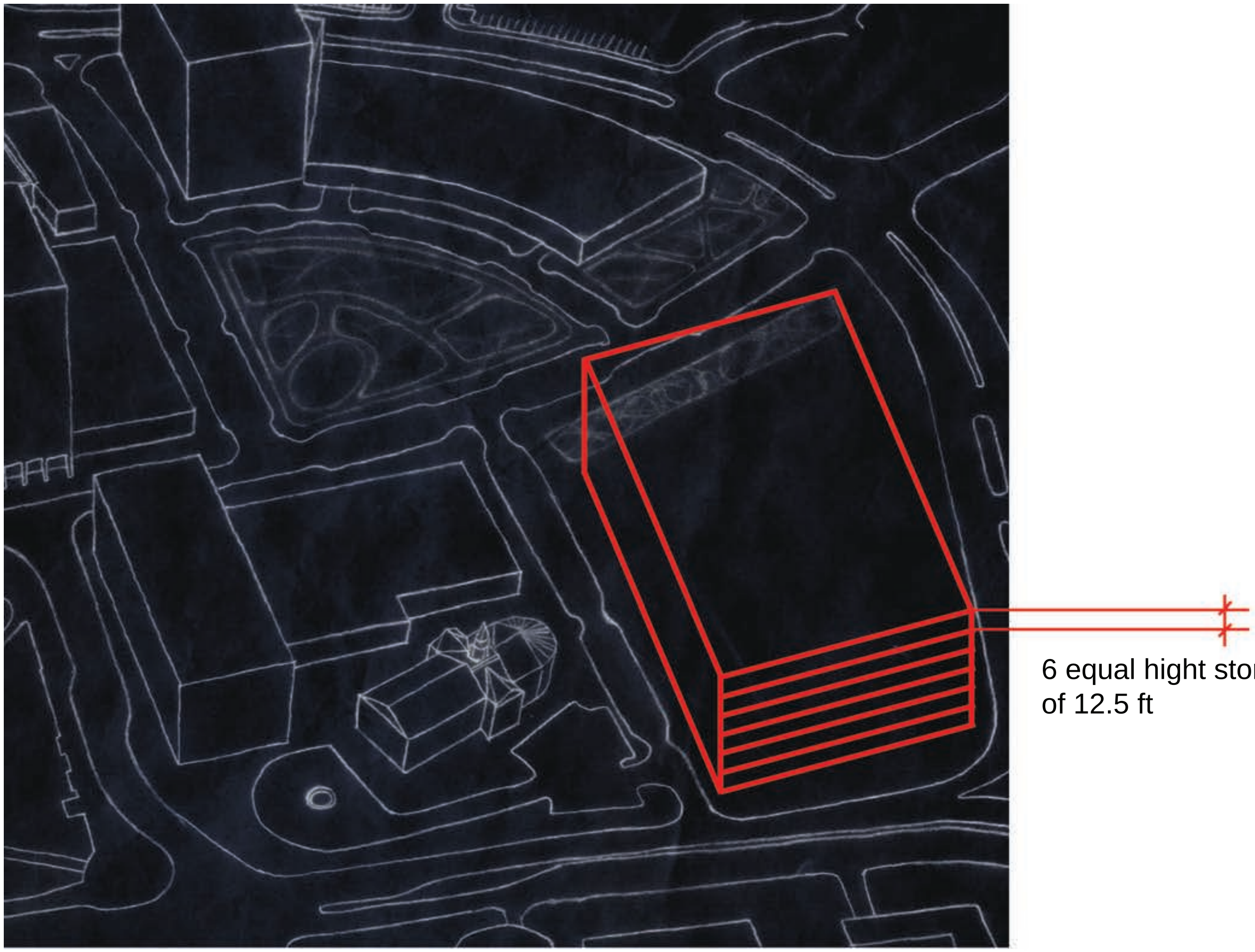
Where: R = regularity factor; A = area of the lot (in square feet); and p = perimeter of the lot (in feet).

In BG-6.0 districts an additional floor space premium is allowed where off street parking is provided on-site of the building or within one thousand (1,000) feet of the facility it is to serve. The premium, six hundred (600) square feet of floor space for each parking space provided, may be used in computing the floor area ratio.

OFF-STREET ACCESSORY PARKING REQUIREMENTS
Notes to Table 4.4

b.) **No** accessory parking is required in a BG-6.0 district.

Zoning Analysis



Height Limitations

LIMITATIONS
ZONE HEIGHT

RS-10 Not Allowed
RS-7 Not Allowed
RL-7 Not Allowed
RG-5 Not Allowed
BO-1.0 40
BO-2.0 40
BL-1.0 40
BG-2.0 50
BG-3.0 100
BG-4.0 150
BG-6.0 75
ML-0.5 50
ML-1.0 50
ML-2.0 100
MG-0.5 50
MG-1.0 100
MG-2.0 100
IP-0.33 50
IN-S 40
IN-H 40
A-1 100

Zoning Analysis

Signs Regulations

General Applications For All Signs In All Districts

SIGNS PERMITTED, BY DISTRICT, BY SIZE AND TYPE TABLE 4.3

MAXIMUM SIZE (in square ft.)
150

TYPES OF SIGNS:

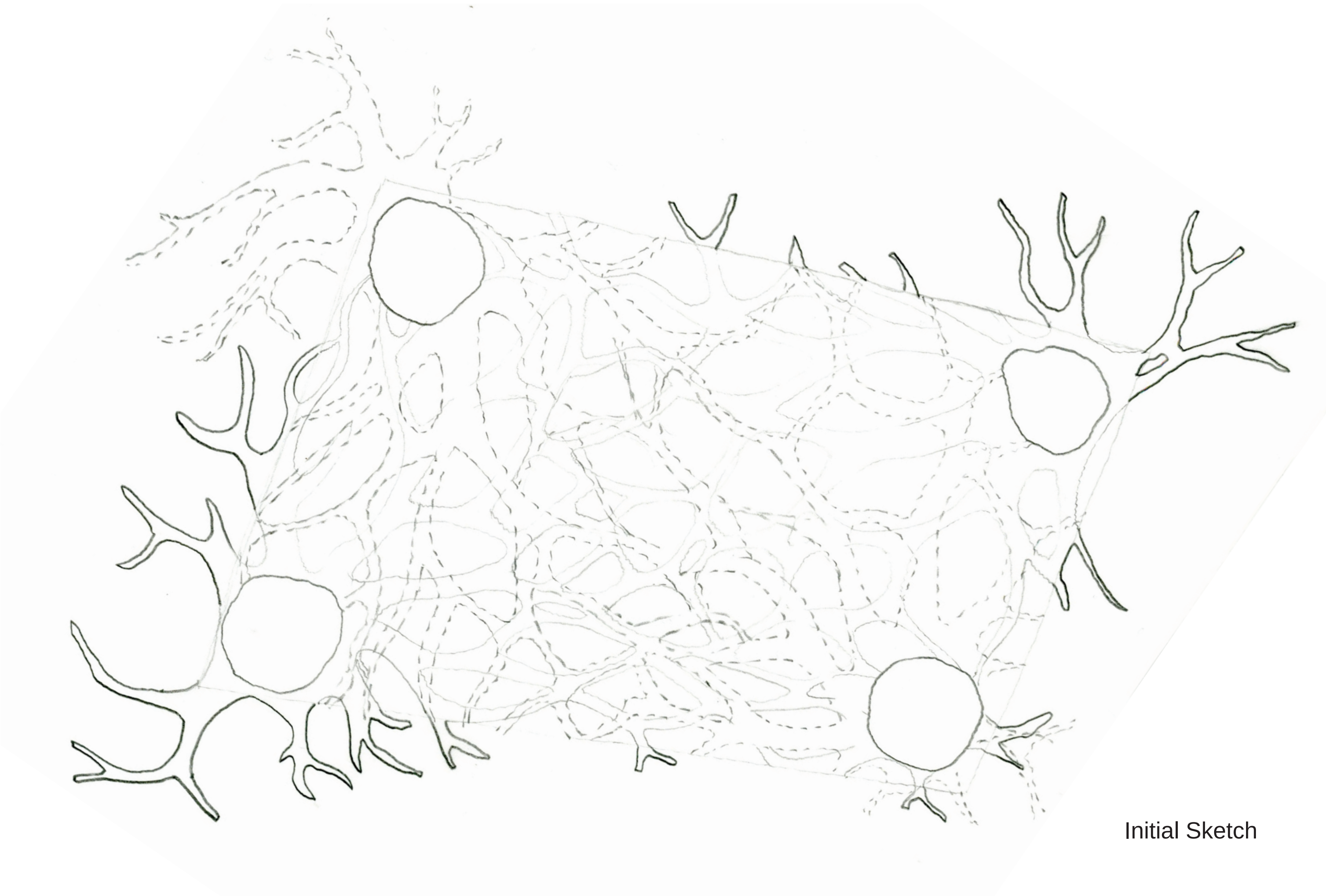
Free-standing
Ground
Illuminated
Motion
Mural/Banner
Non-accessory
Portable
Projecting
Roof
Wall
Window

Design

“The architect should consider that nature hates corners; animals are guided by nature and when they change direction they never walk around a corner, but proceed in a curved fashion. In older days our ancestors always avoided corners and straight lines, especially in temples. Right angles were used in buildings only for comfort’s sake in order to find the best arrangement for beds, tables, and other necessarily angular objects. - Francesco Borromini”(Portoghesi, 2000, 170)

When we walk in a forest, the sun feels gentle, the partial shade keeps us cool, the wind refreshes our bodies, and we experience all this under the tree canopies. This peace of the forest becomes the theme in the creation of this project.

Design



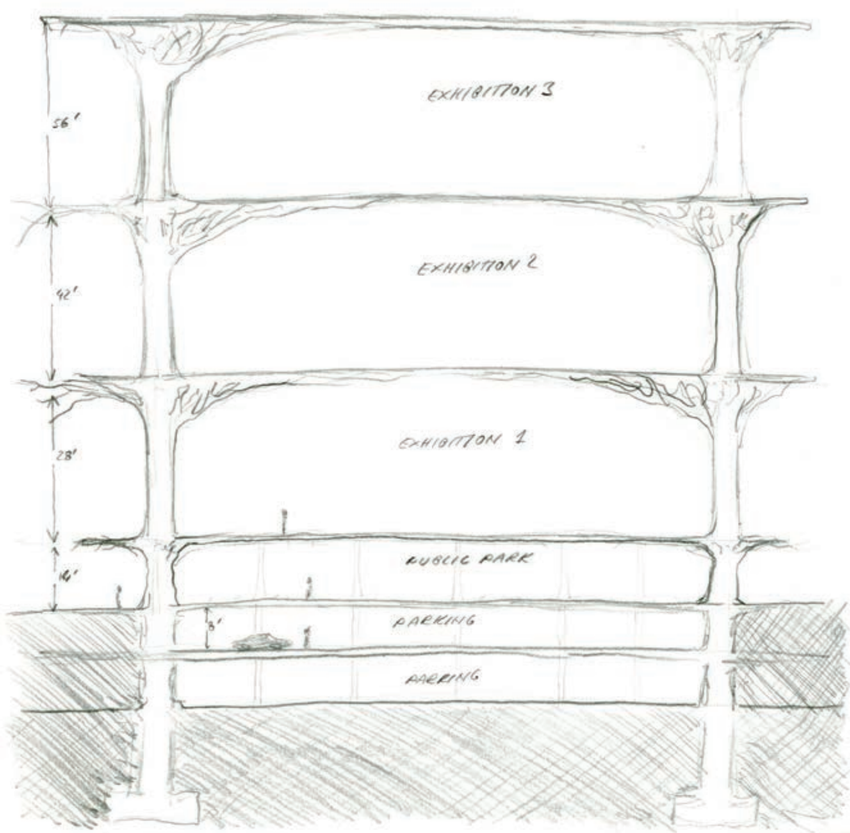
Initial Sketch

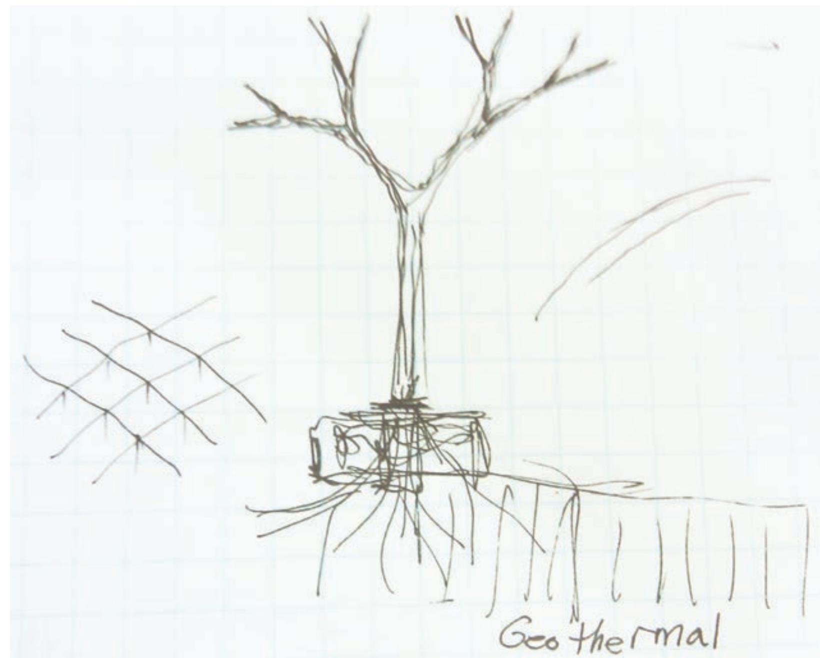
Design

Initial Model

Design

Biomimicry of Nature's Function and Parts

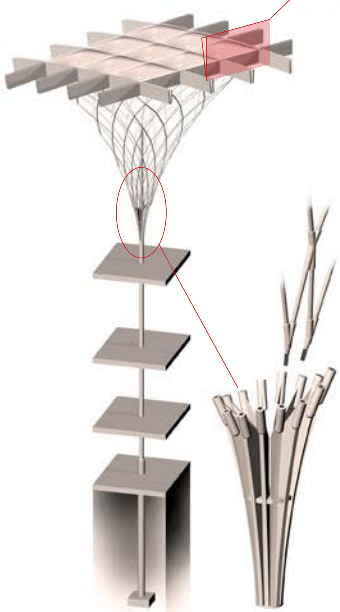




Like the forest, branch-like columns emerge from the ground to play with the effects of light and shadow, and to form organic spaces with greater spans and less material. Pockets filled with air, as shown in figure 1, resemble leaves. They perform photosynthesis through semi-translucent layers of photovoltaics, which are adhered to the pockets' outer skin. These pockets also direct rain water into a vein-like system of pipes that run along the building's skin (as shown in figures 1 and 2), which takes this water to underground tanks for purification. Some of this water is pumped upwards and used to clean the outer skin, other is used in the buildings grey water systems, and the rest is redirected into the city's sewage system. As this water moves along the building's skin, it activates mini-turbines that generate more electricity.

Design

Biomimicry of Nature’s Function and Parts



column branch

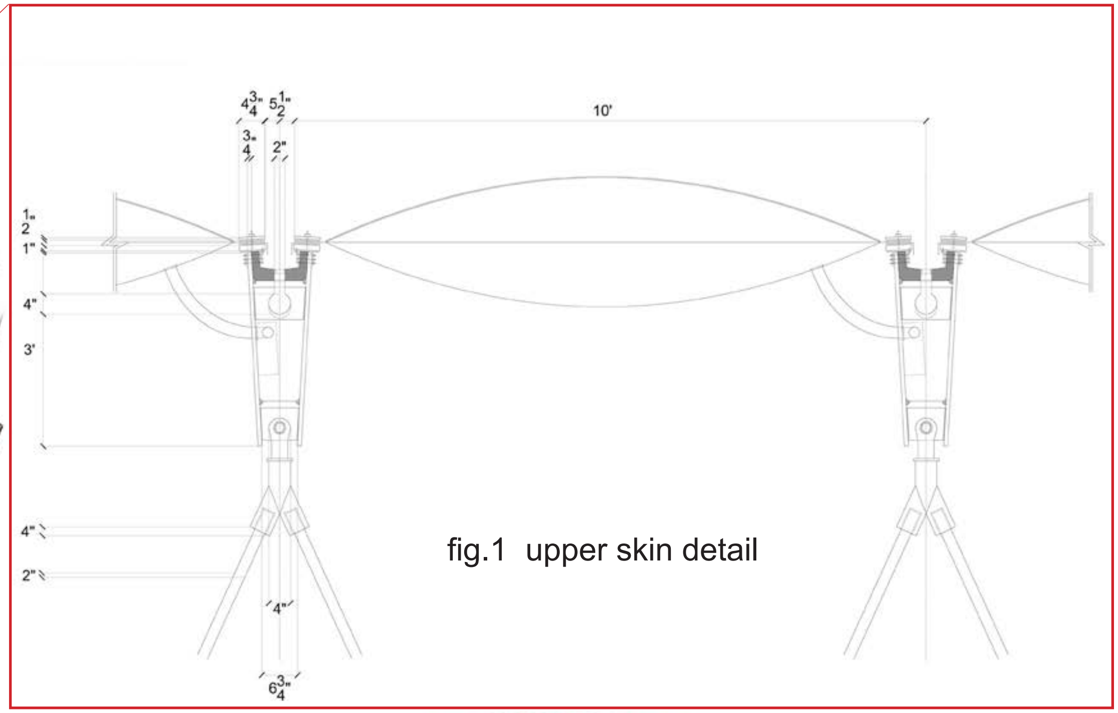


fig.1 upper skin detail

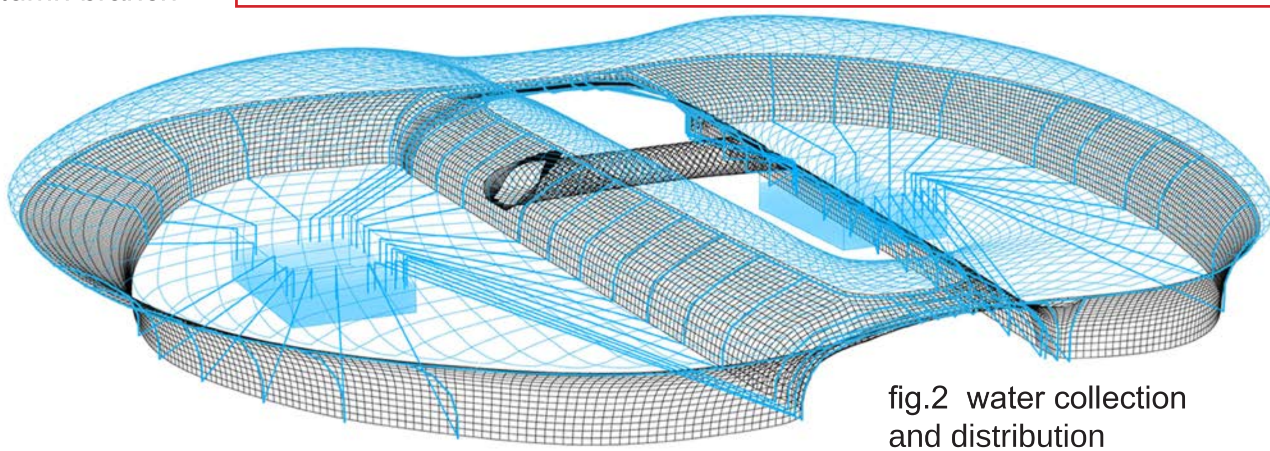
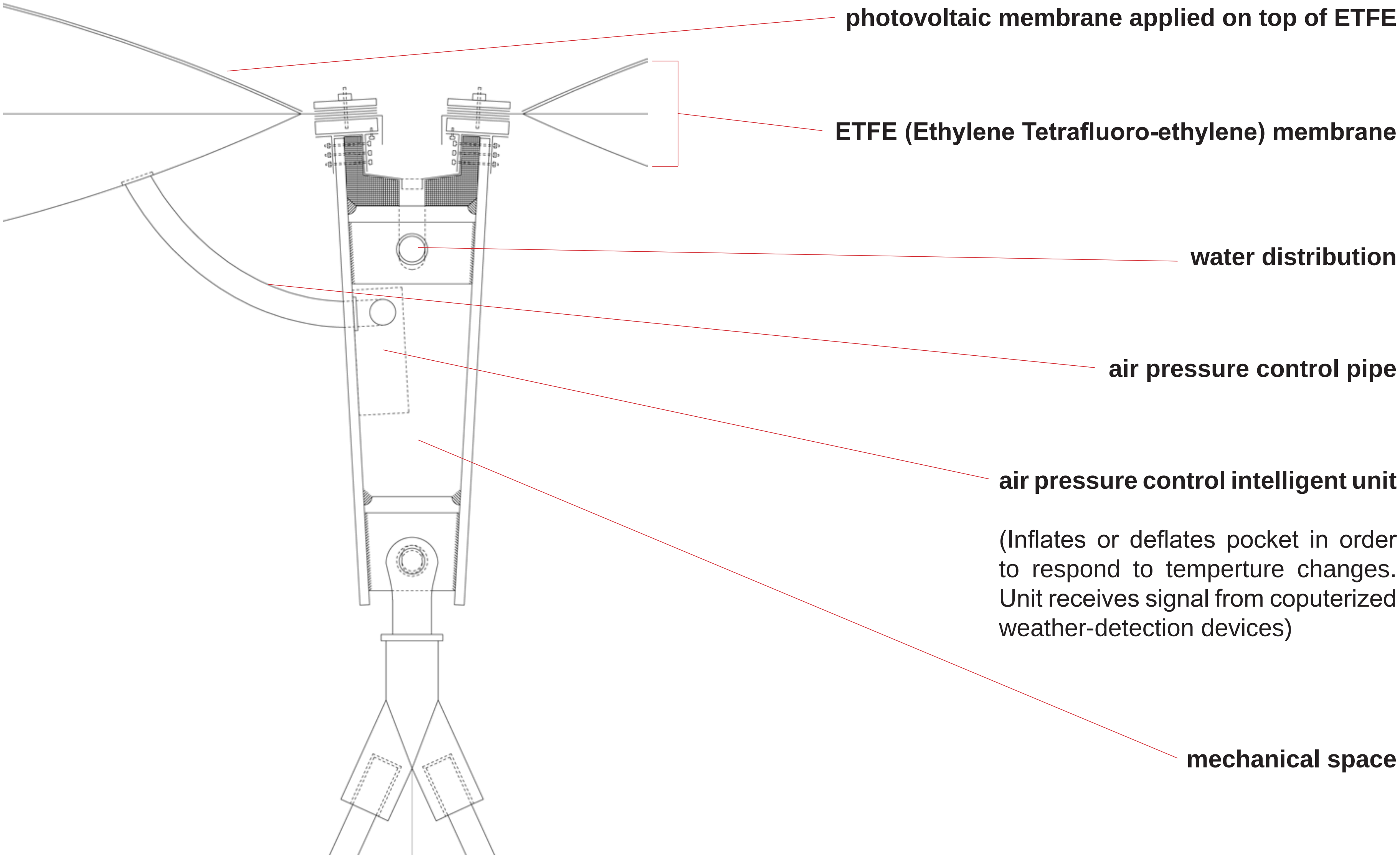


fig.2 water collection and distribution

Design

Biomimicry of Nature’s Function and Parts



Design

Biomimicry of Nature’s Function and Parts (Precedent Analysis)

Allianz Arena, Munich, Germany

Outer skin close-up

Air pressure control intelligent unit

ETFE membrane

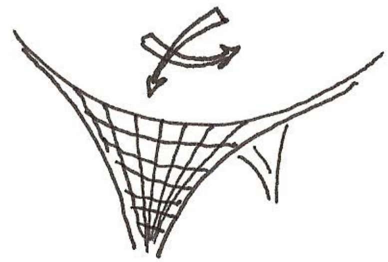
Somewhere in the middle of my thesis research, I visited Munich for a different graduate-research seminar offered by Roger Williams University. Among analysing many architectural works there, the Allianz Arena by Herzog and De Meuron cought my attention. This building’s skin is composed of a metallic frame that holds many air-filled pockets, which are made of a special plastic membrane. These light-weight pockets flow-along the entire surface as it bends at the building’s edges and slowly tapers at its poles. They also provide some degree of shading from the sun and insulate many interior spaces.

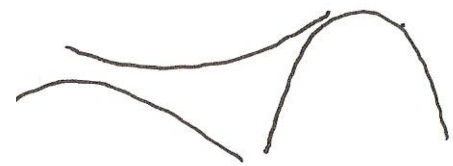
One morning, after our group visited the arena, we stopped by the façade conultant’s office, R+R Fuchs, where they showed us construction details of the arena’s façade, accompanied by a video where the team experimented on the membrane’s fire-resistant ability. In this office, I received answers to many specific questions about this interesting façade and the story behind it. A few months later, I looked back to this envelope system,and in conjunction with con-

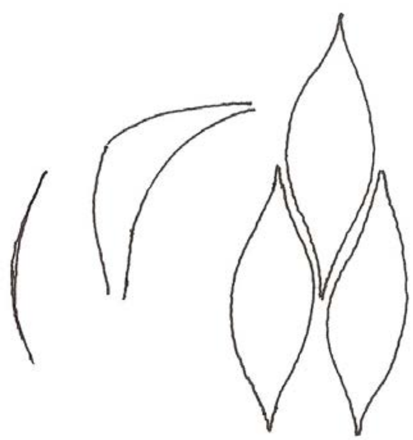
Design

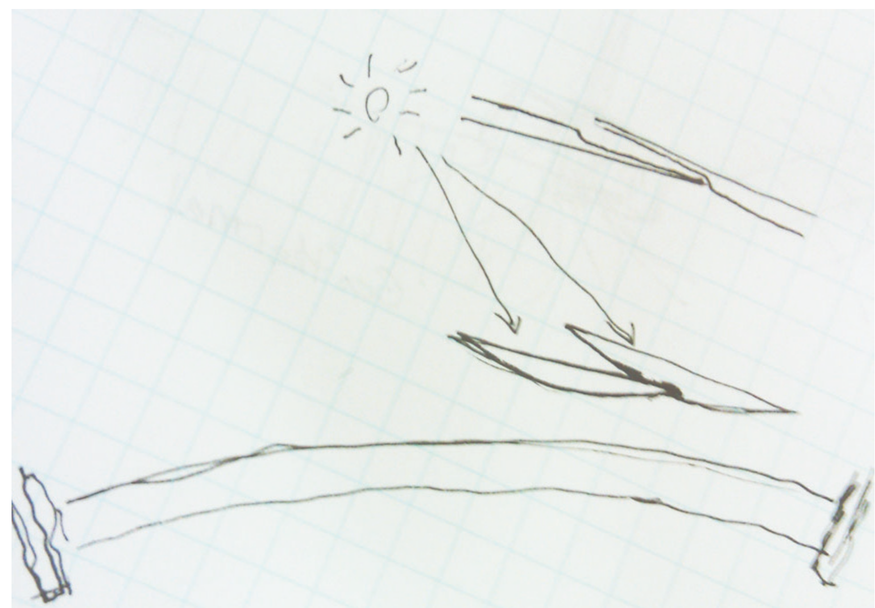
Biomimicry of Nature's Function and Parts

sulting a faculty memeber from Roger Williams Univerity, I decided to apply the idea to my thesis design. Herzog and De Meuron's façade for the Allianz Arena, seemd to satisfy my search for a surface that was composed of leaf-like pieces that would easily morph to cover an organic shape, which I had previously designed. After several weeks of trying to develop a structure that would house the leaf-like pockets, and respond to the overall form and its function, I finally made a breakthrough. With the additional help of the Rhino software, I was able to compile the structure and the skin into a building envelope. The following images better demonstrate some of the steps that took place in the making of such skin.



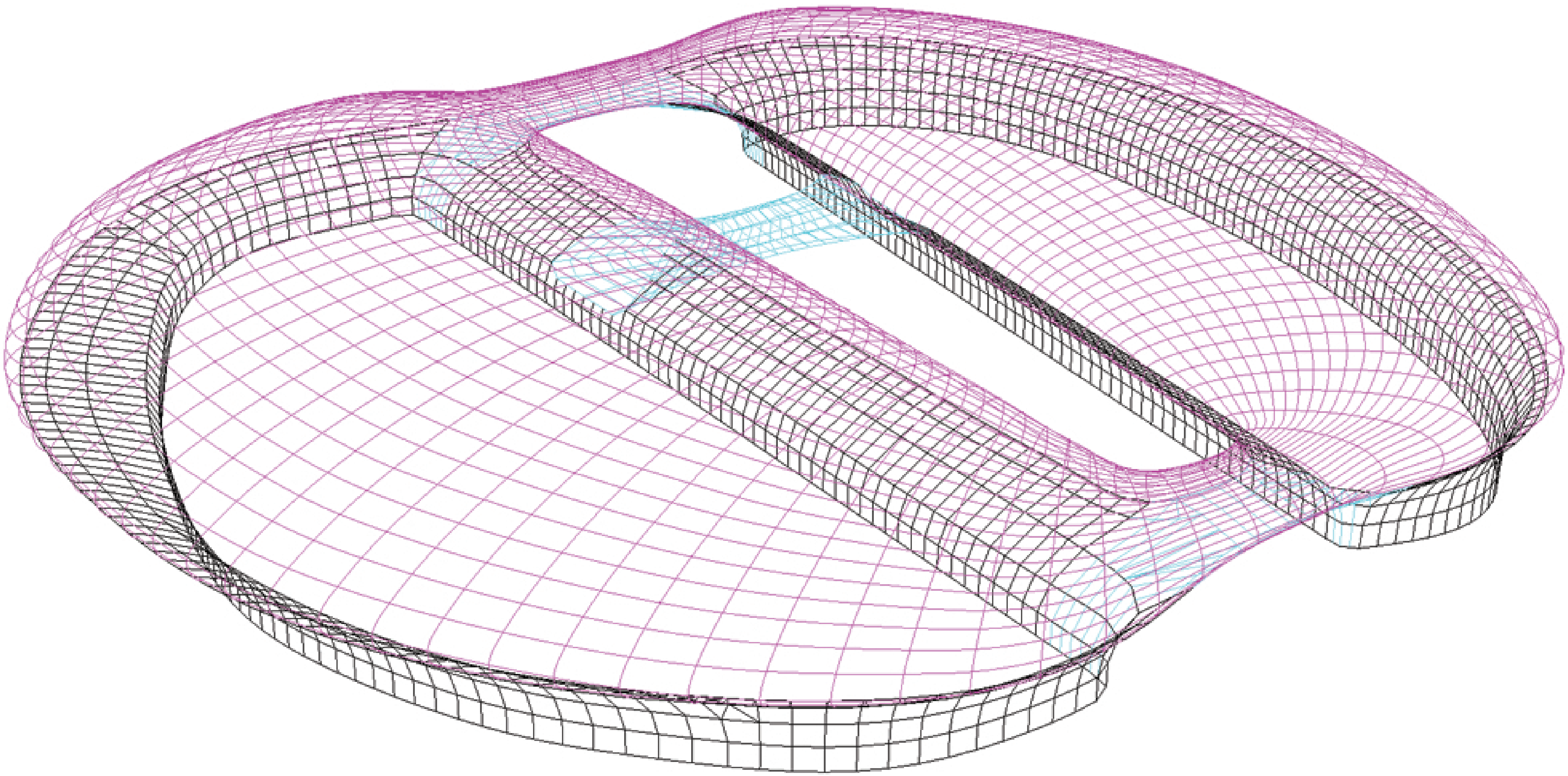






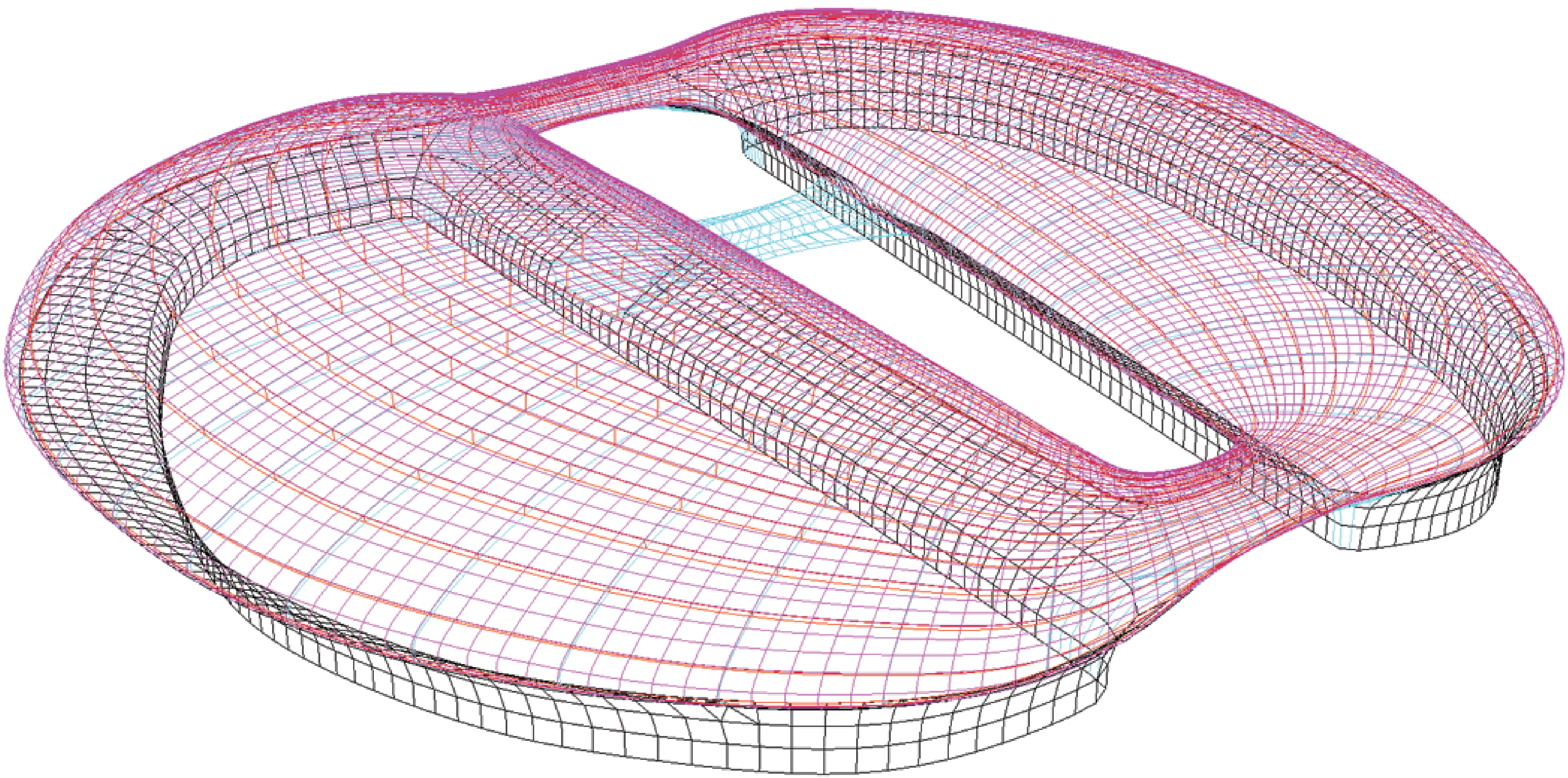
Design

Biomimicry of Nature's Function and Parts (Skin and Envelope Structure Development)



Design

Biomimicry of Nature’s Function and Parts (Skin and Envelope Structure Development)



Design

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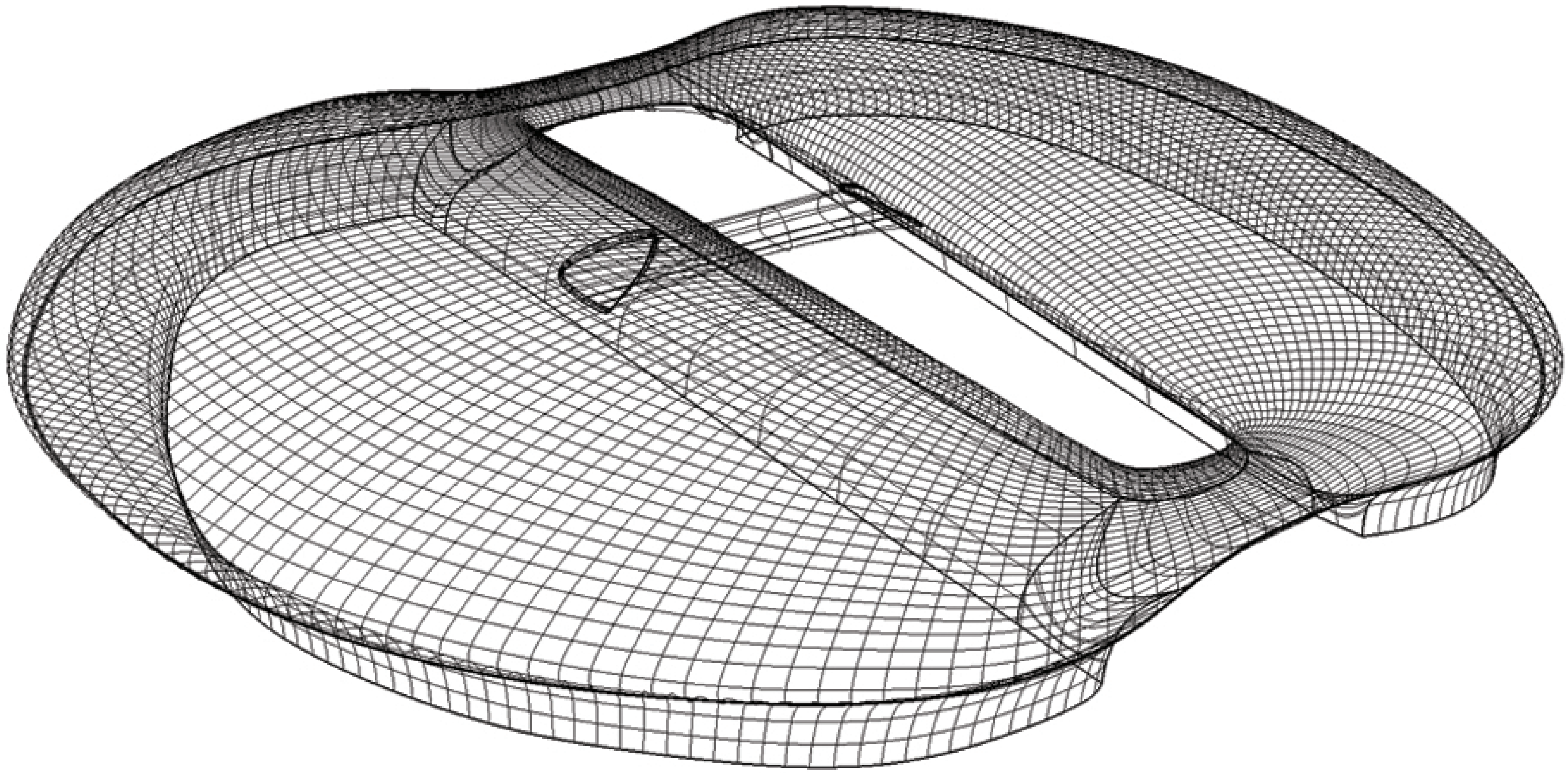
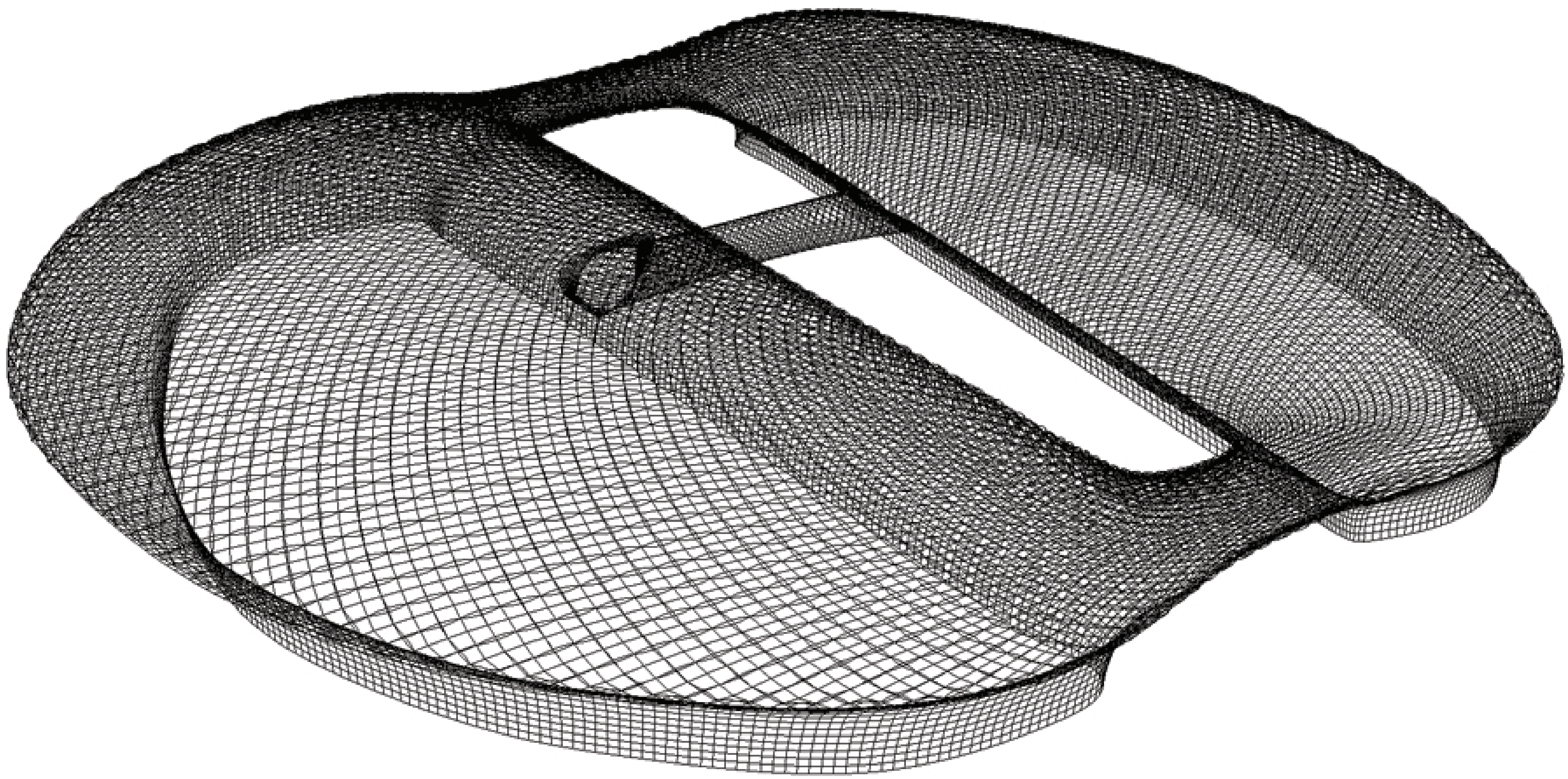


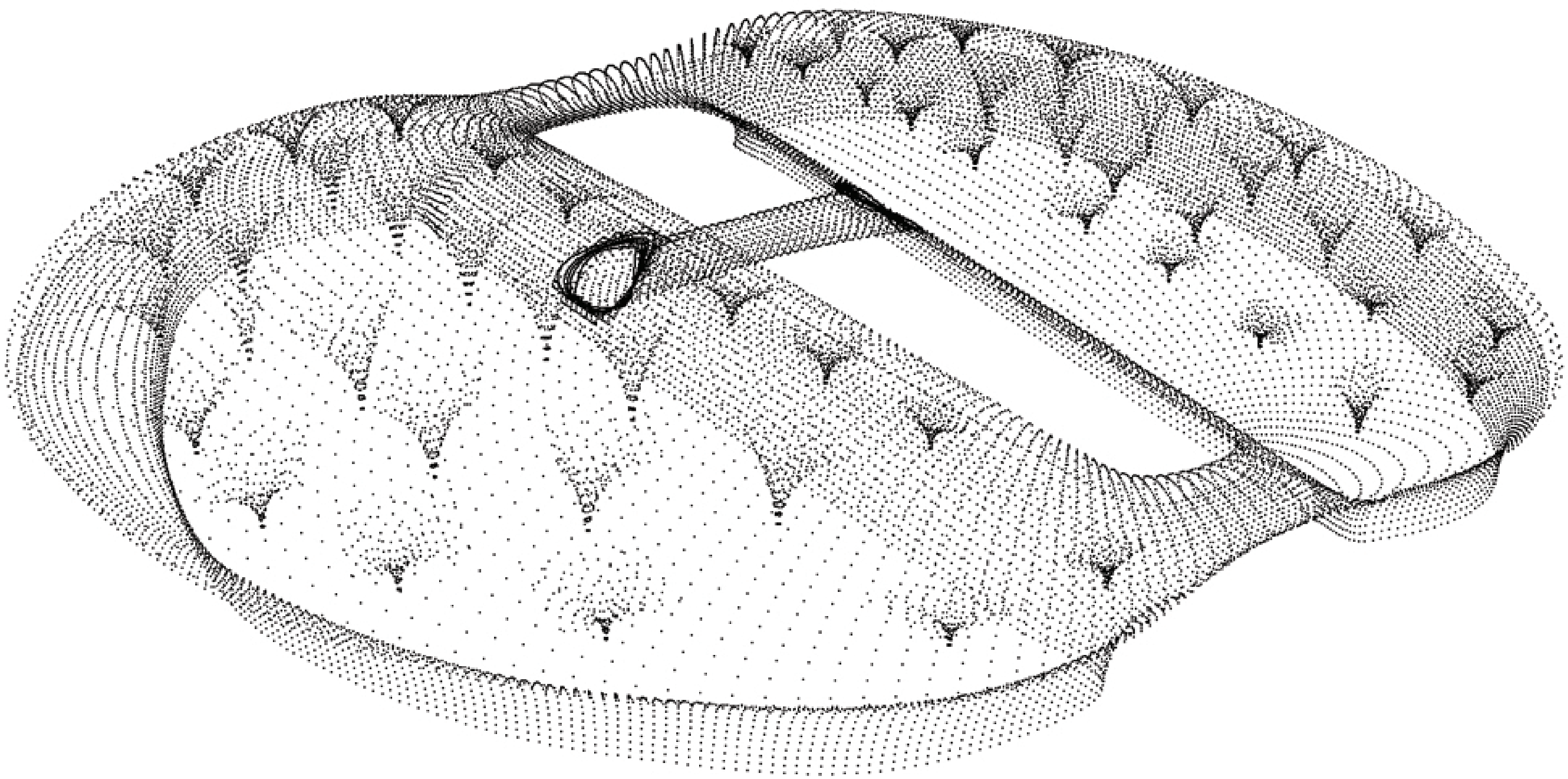
Design

Biomimicry of Nature’s Function and Parts (Skin and Envelope Structure Development)



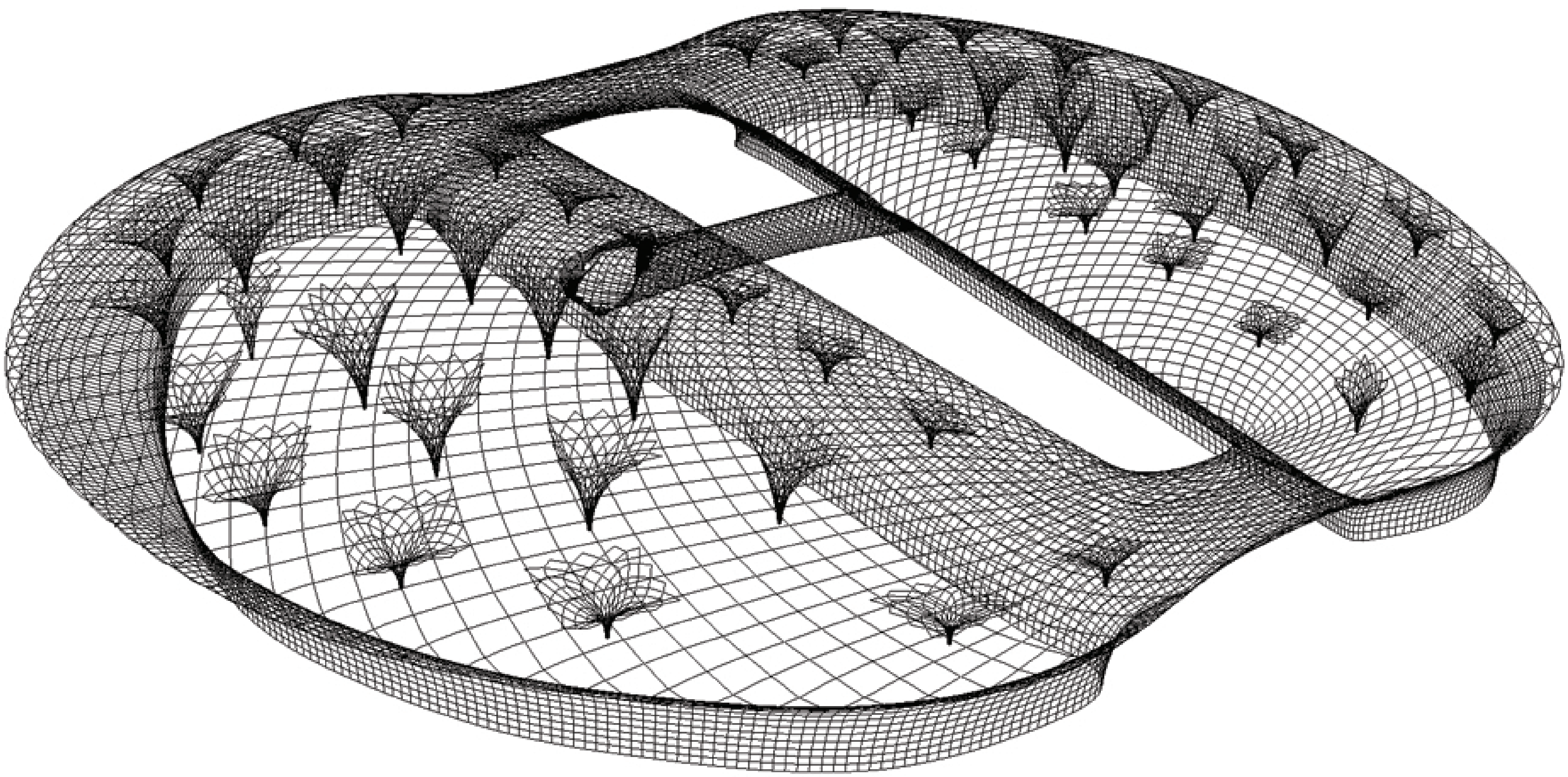
Design

Biomimicry of Nature's Function and Parts (Skin and Envelope Structure Development)



Design

Biomimicry of Nature's Function and Parts (Skin and Envelope Structure Development)



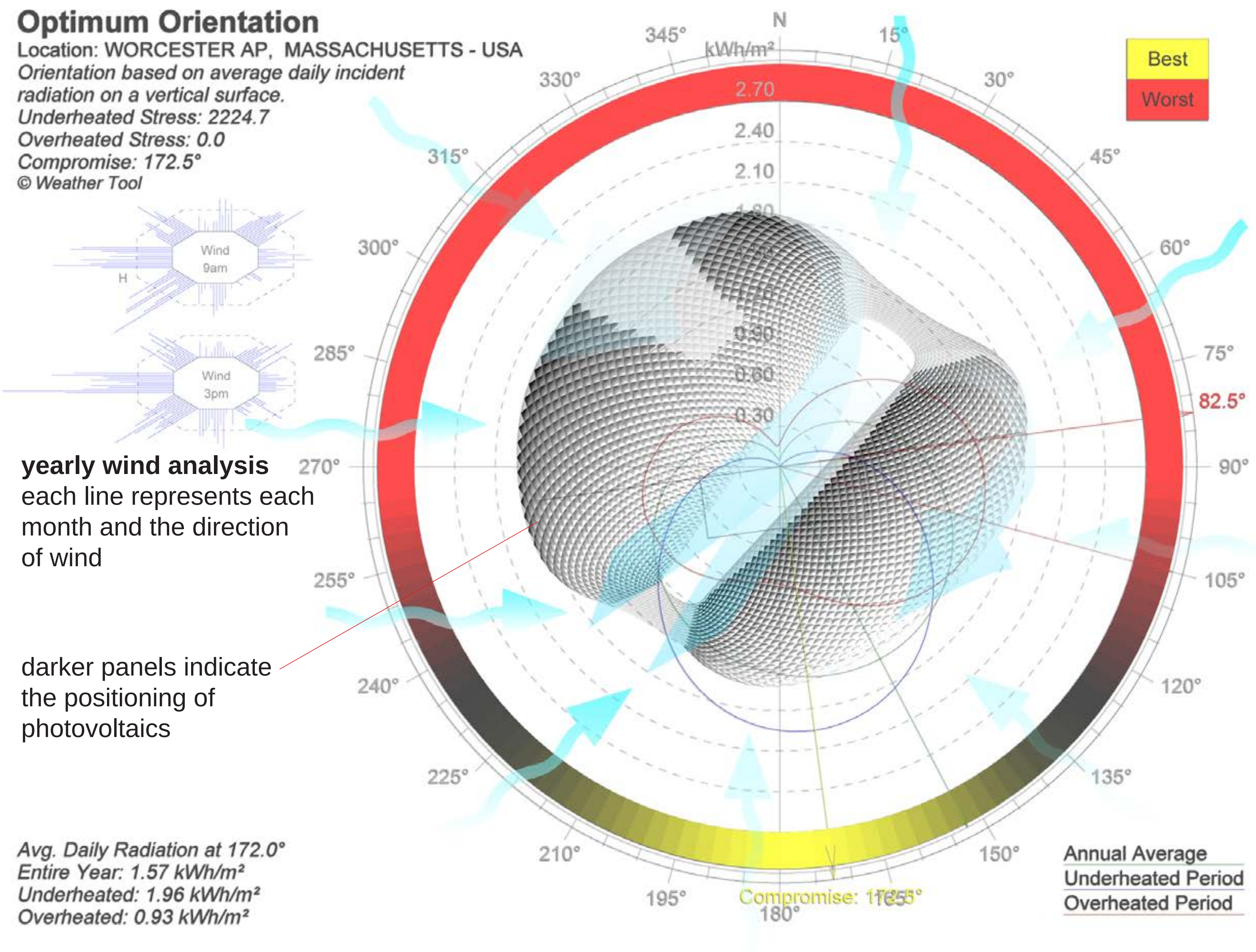
Design

Biomimicry of Nature's Forms

In order to capture the most solar energy, and allow the greatest amount of ventilation from wind, a certain positioning and shape takes place. This gesture also focuses on a dialogue between the existing urban fabric and the proposed biomimetic design, which depicts itself as a measure toward evolution in architecture.

Design

Biomimicry of Nature's Forms (Solar and Wind Analysis)

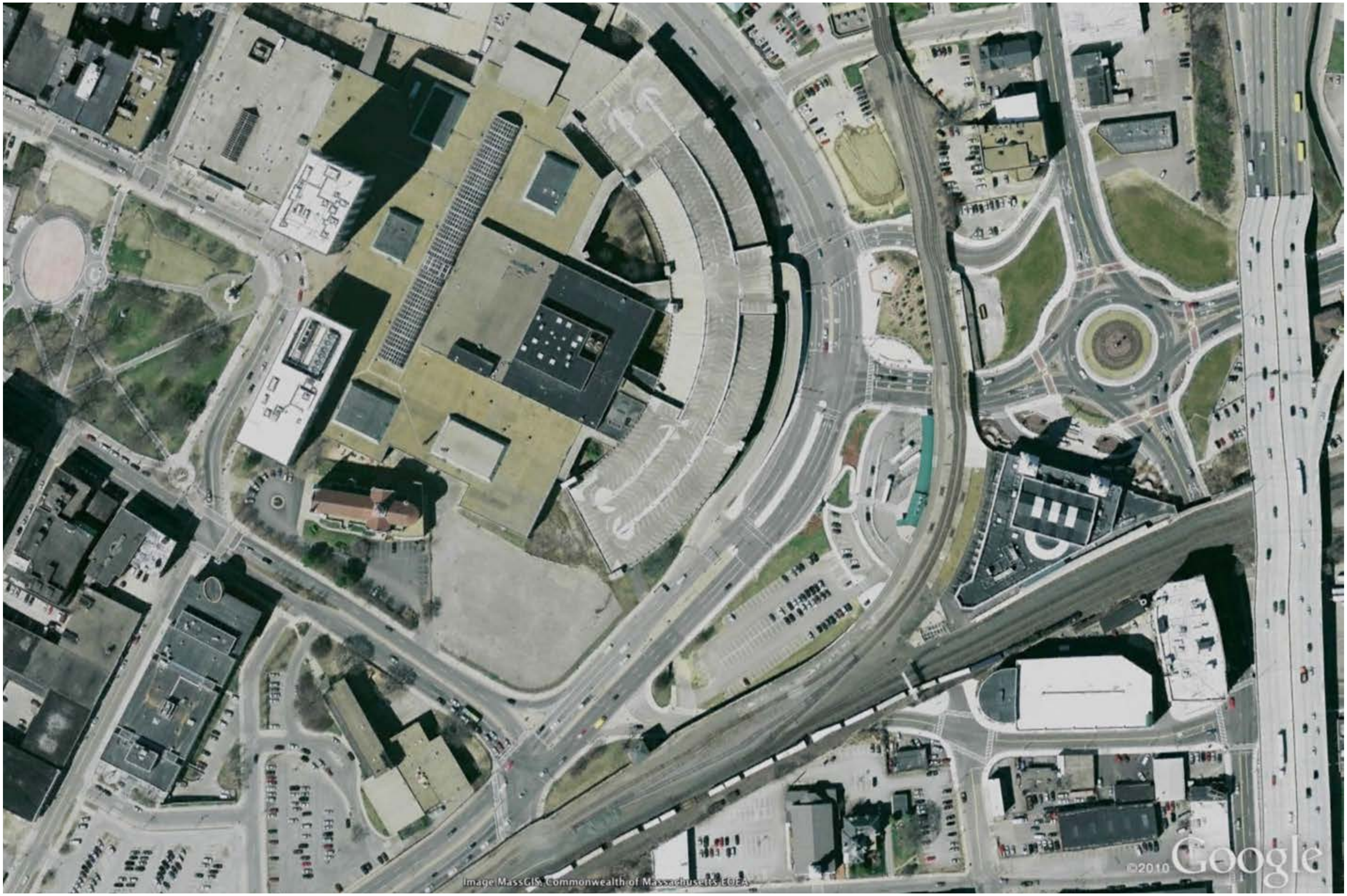


yearly wind analysis
each line represents each month and the direction of wind

darker panels indicate the positioning of photovoltaics

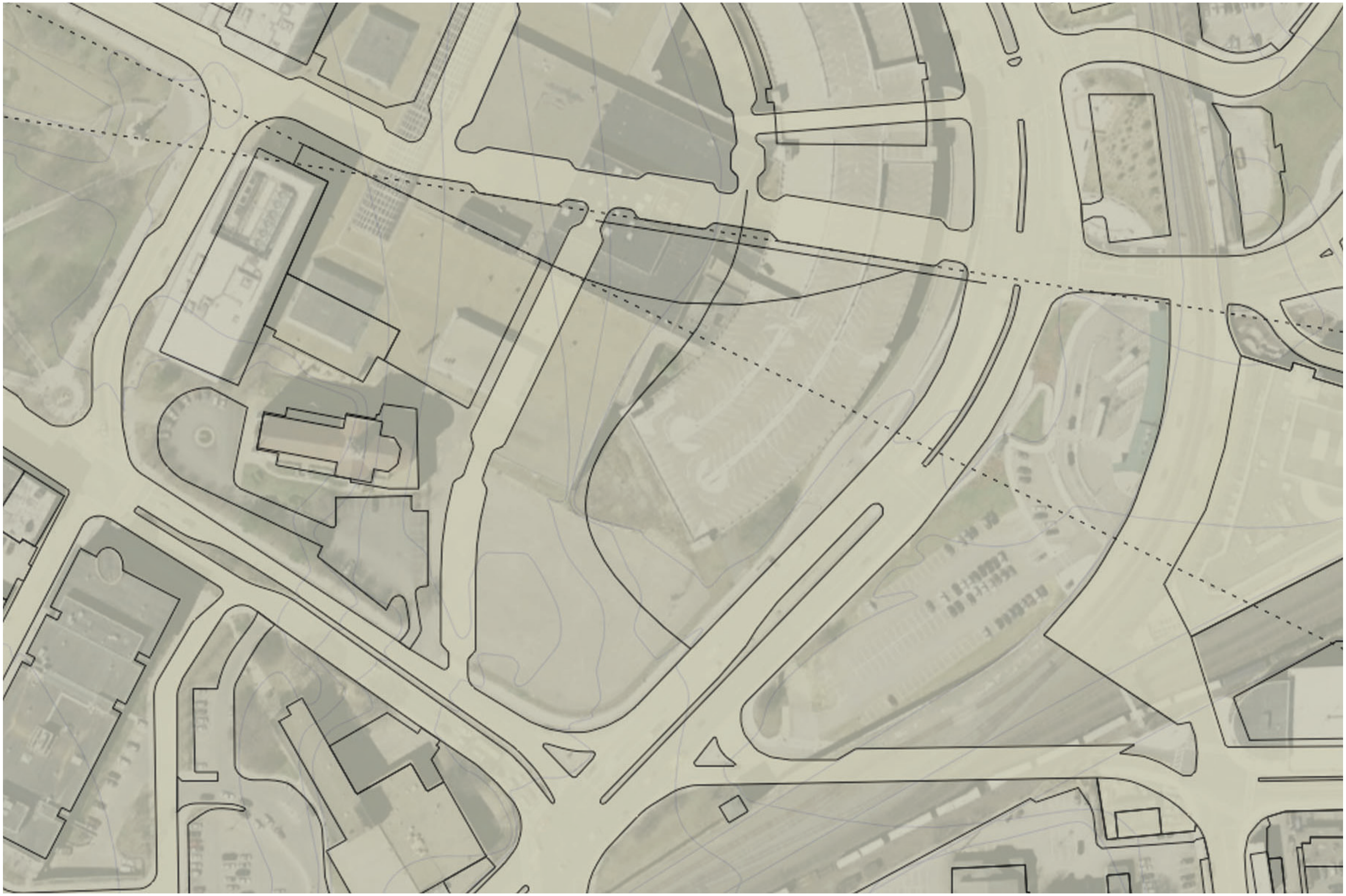
Design

Biomimicry of Nature's Forms (Building Footprint)



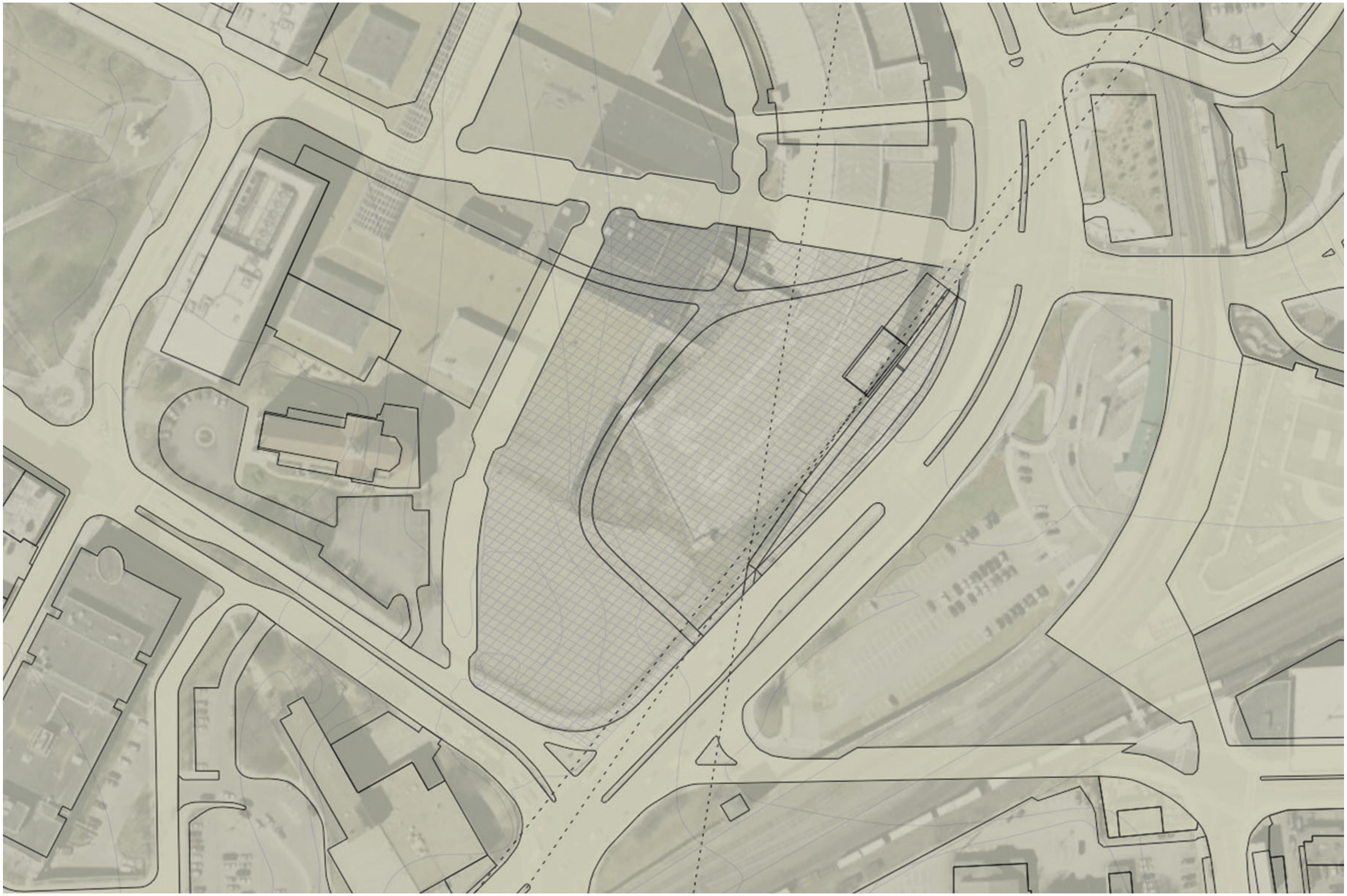
Design

Biomimicry of Nature's Forms (Building Footprint)



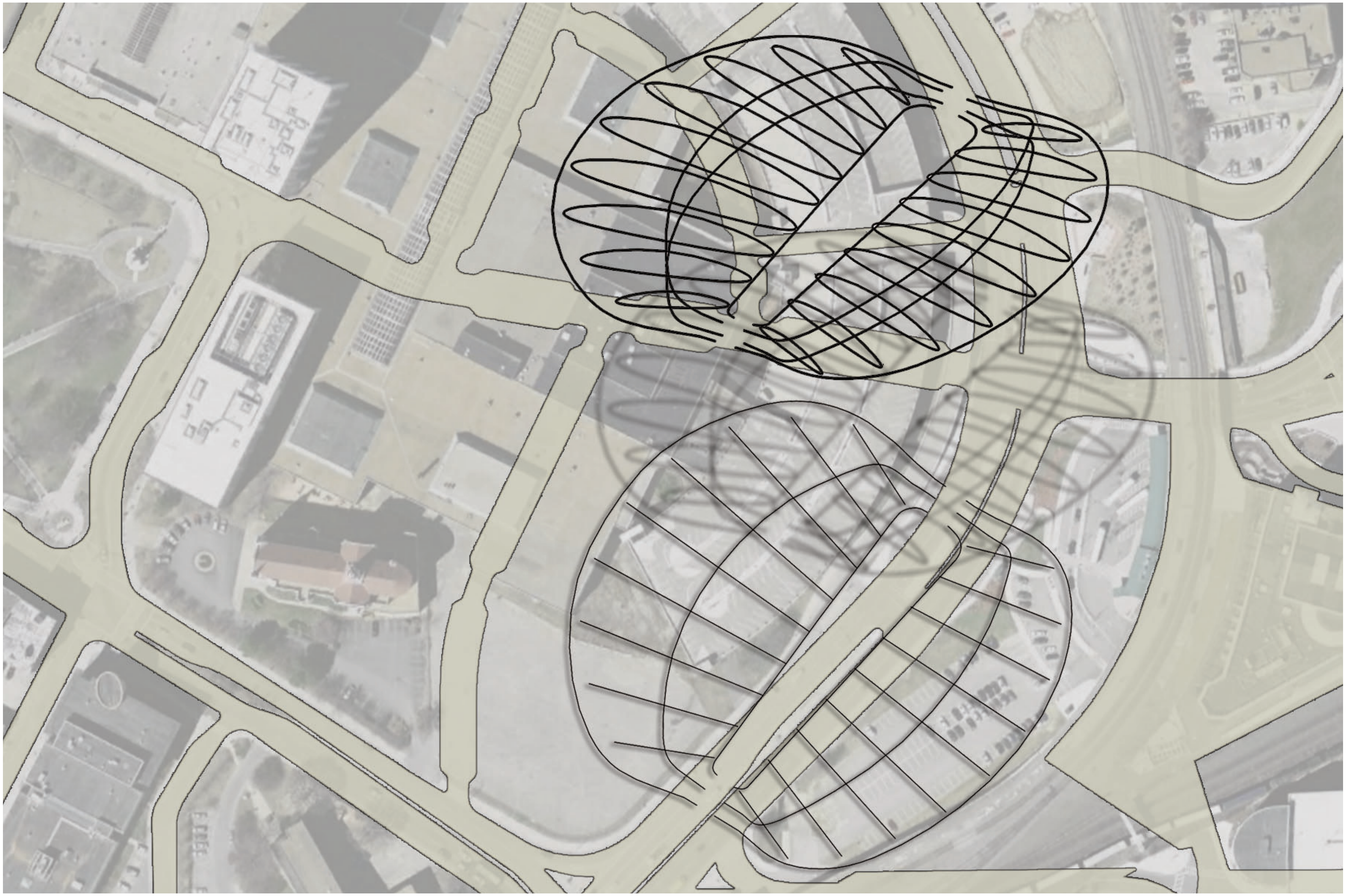
Design

Biomimicry of Nature’s Forms (Building Footprint)



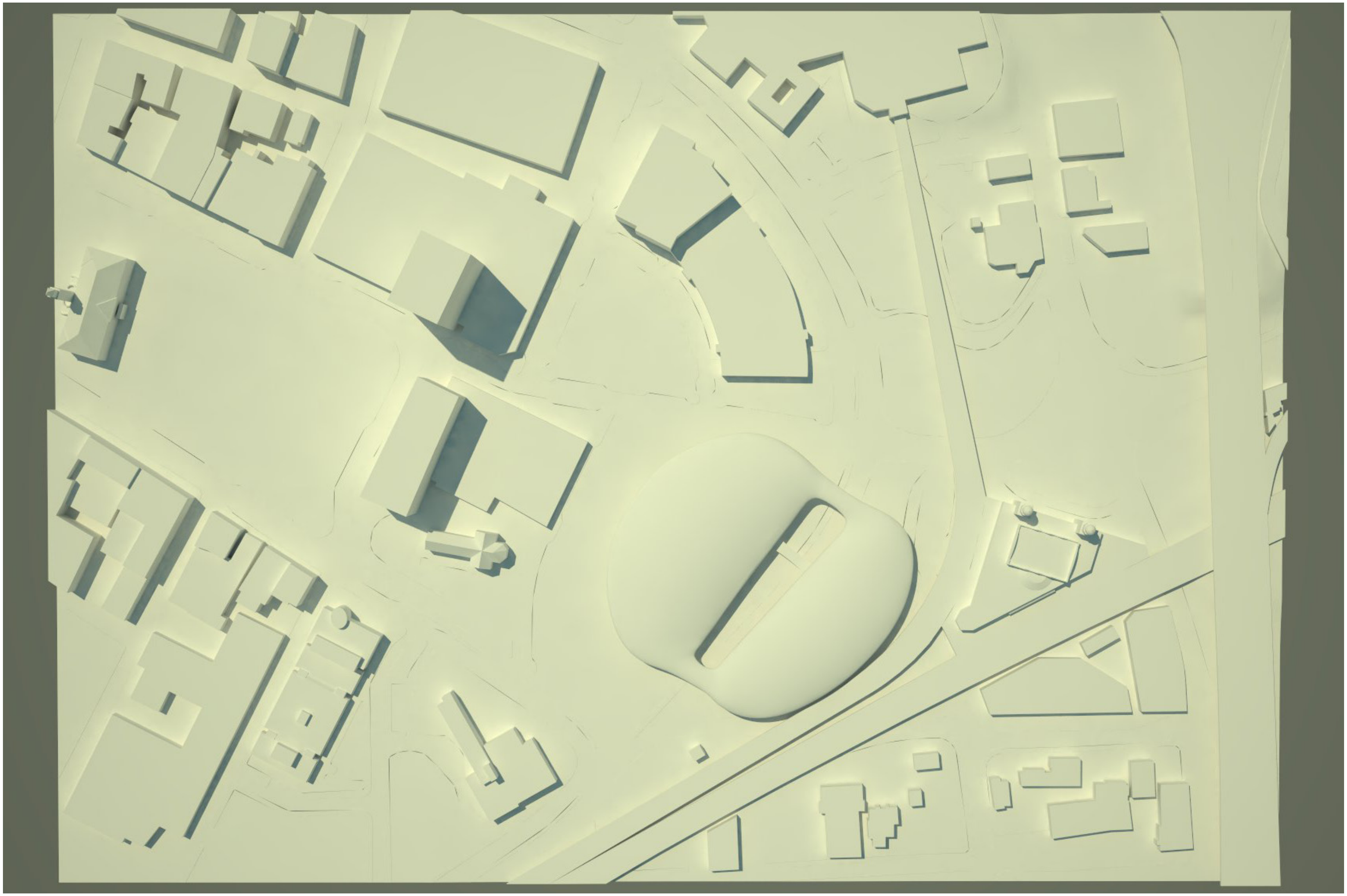
Design

Biomimicry of Nature's Forms (Building Footprint)



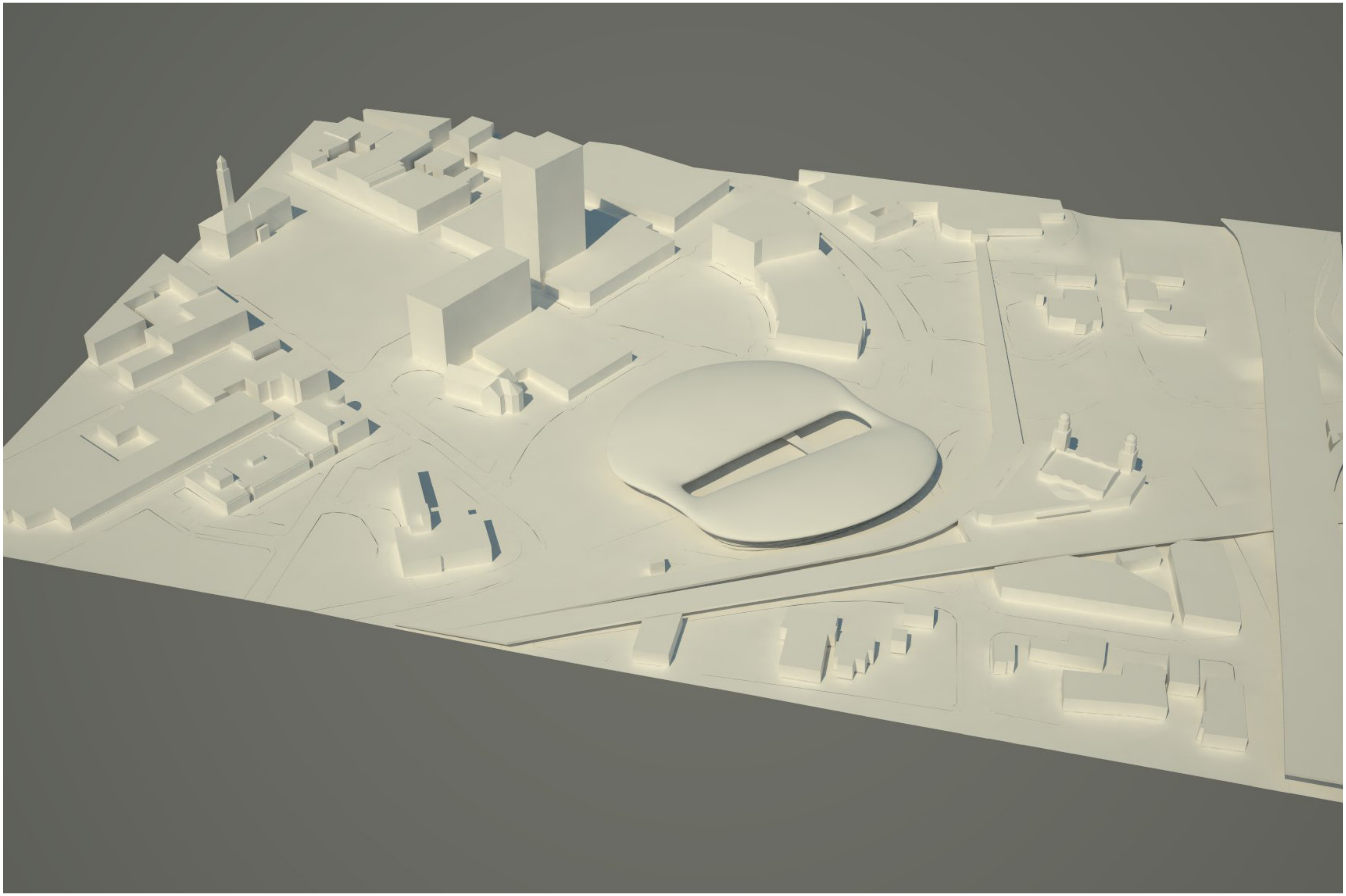
Design

Biomimicry of Nature’s Forms (Massing)



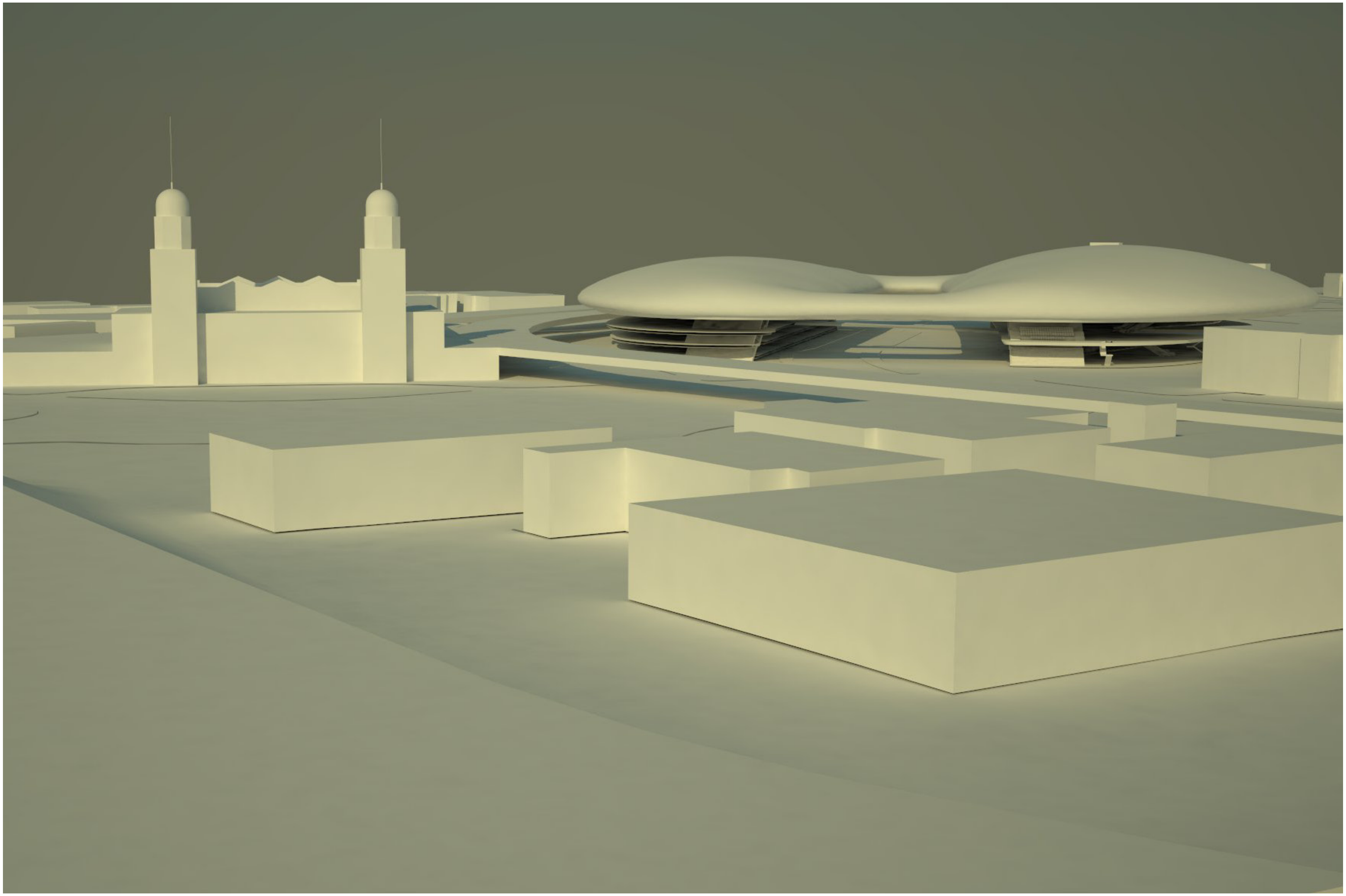
Design

Biomimicry of Nature's Forms (Massing)



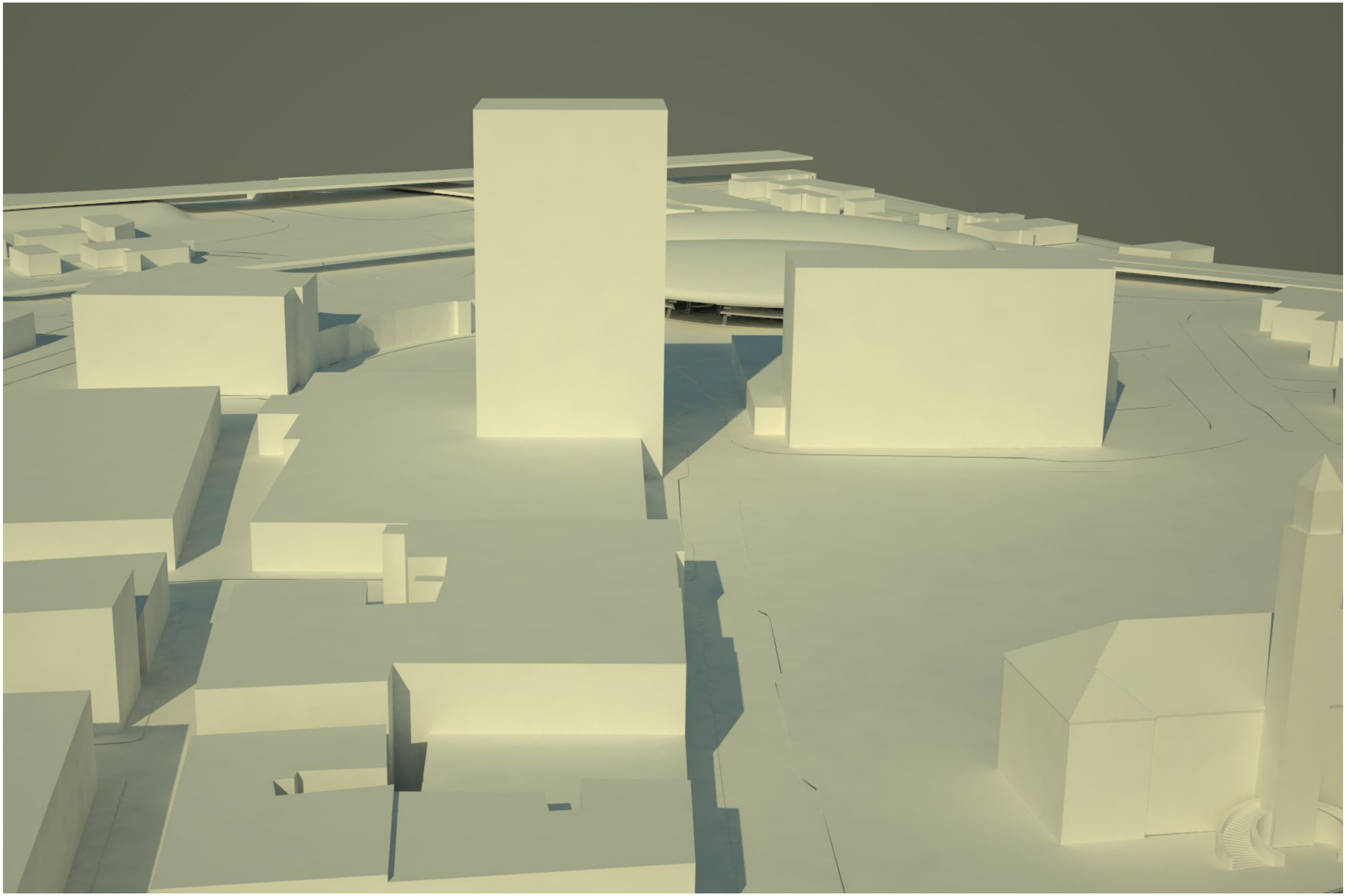
Design

Biomimicry of Nature's Forms (Massing)



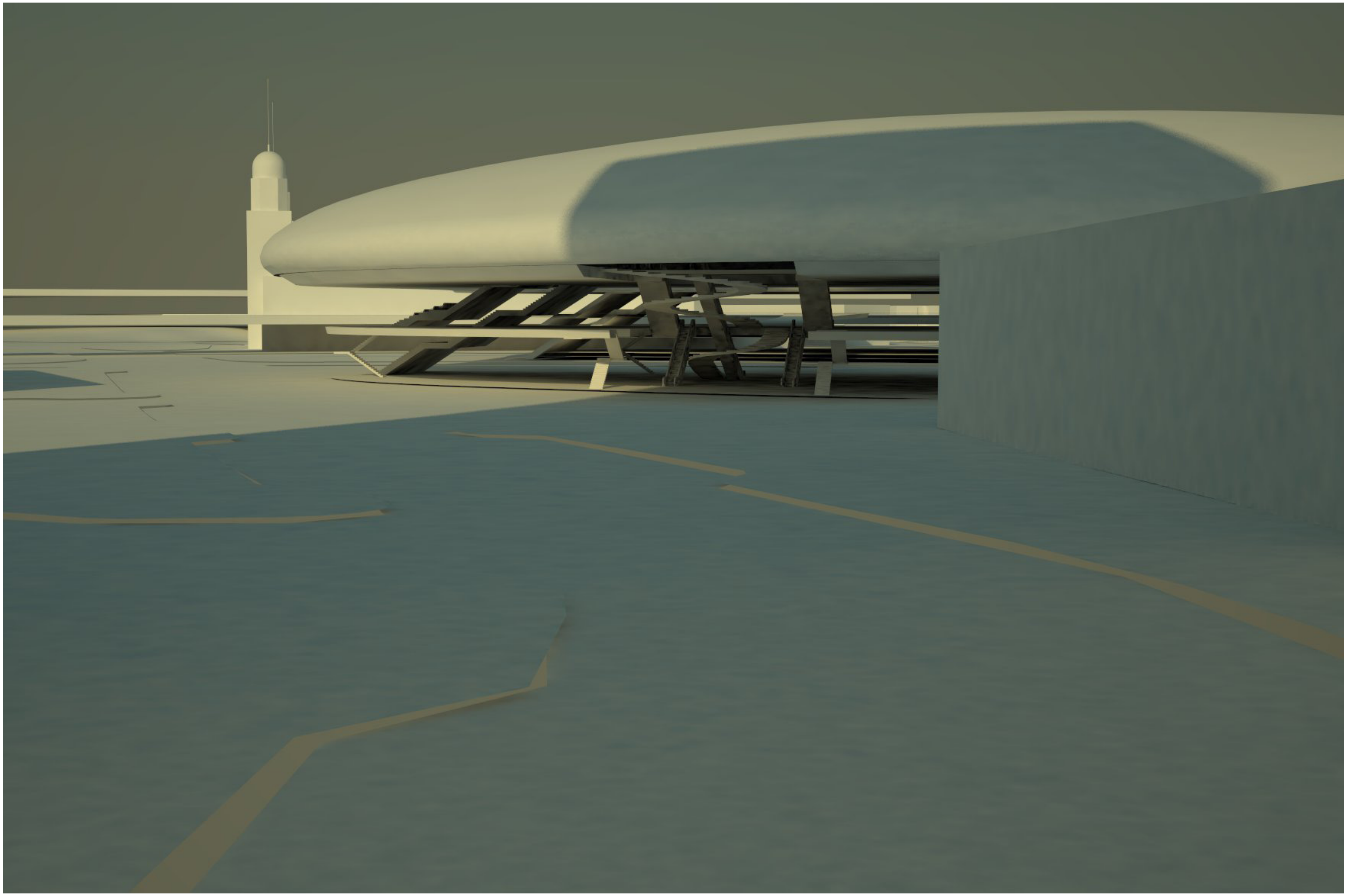
Design

Biomimicry of Nature's Forms (Massing)



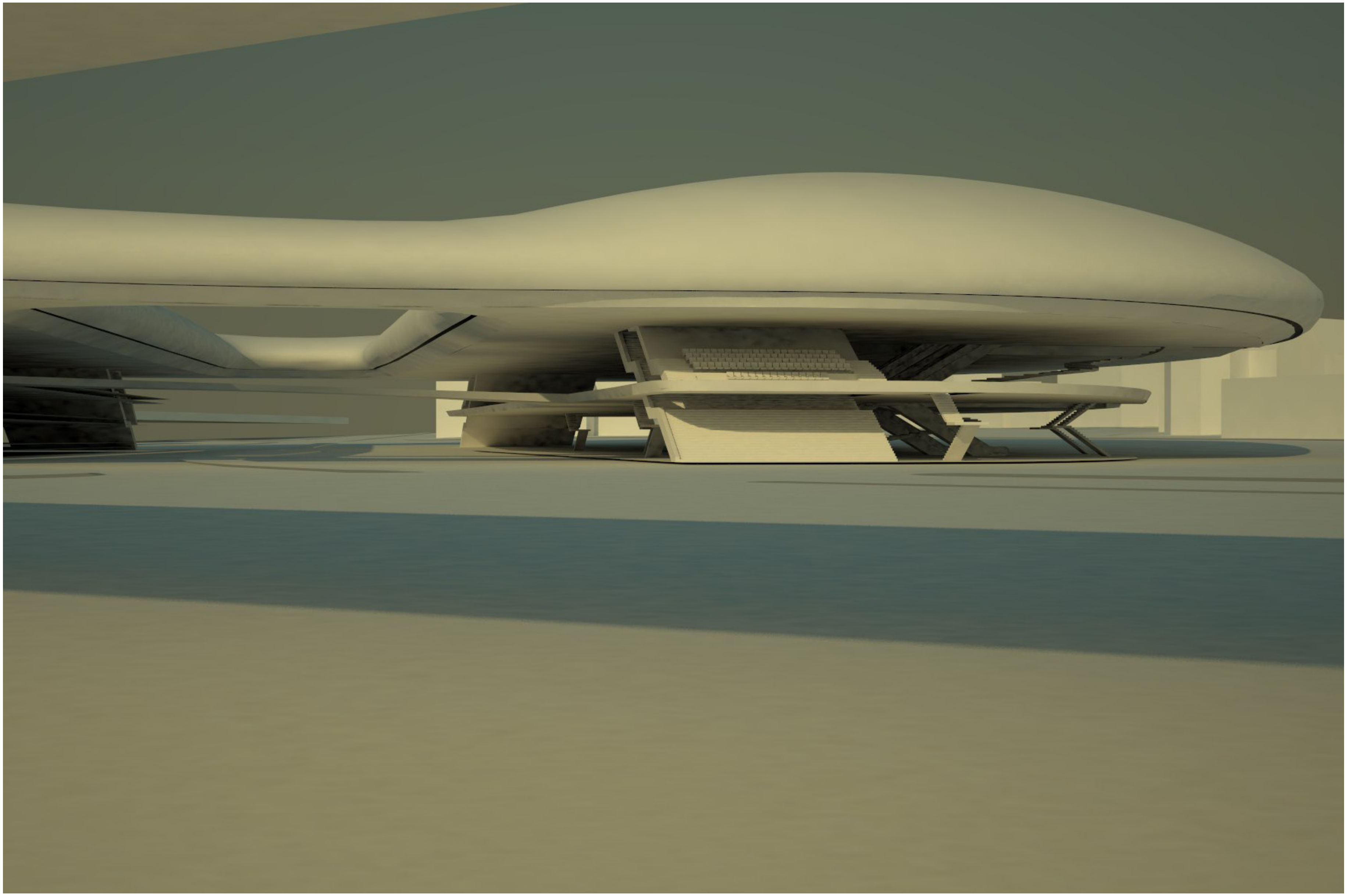
Design

Biomimicry of Nature's Forms (Massing)



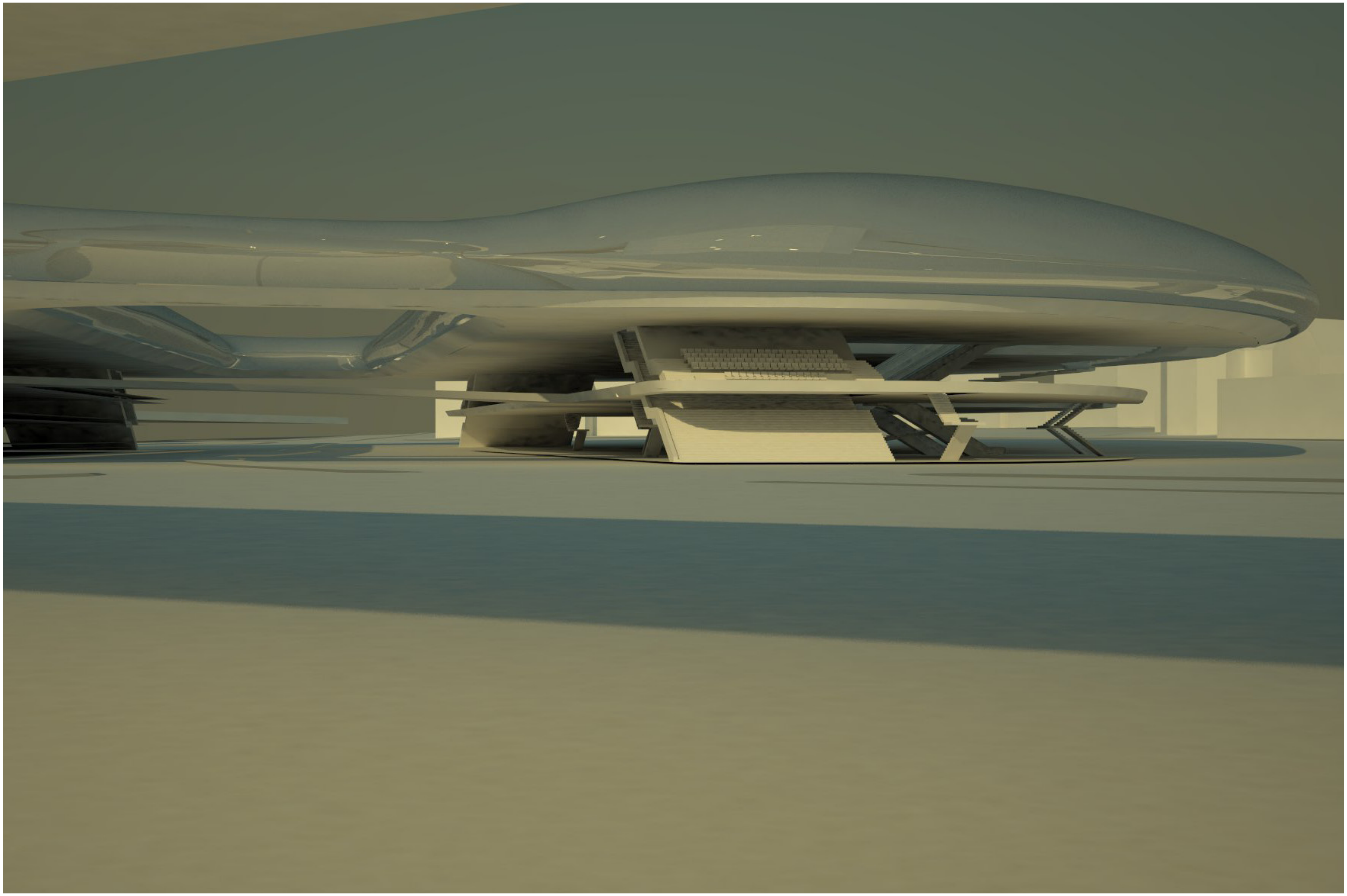
Design

Biomimicry of Nature's Forms (Massing)



Design

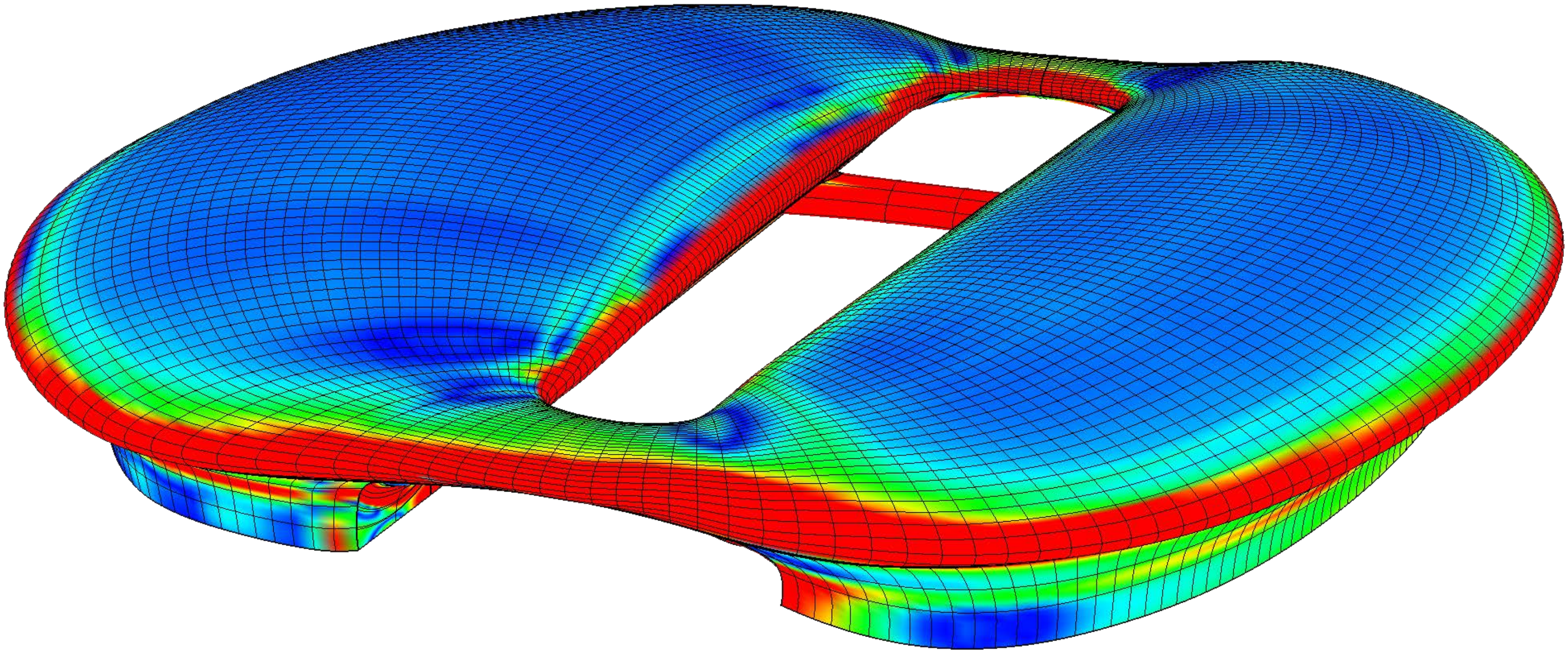
Biomimicry of Nature’s Forms (Transparency)



Design

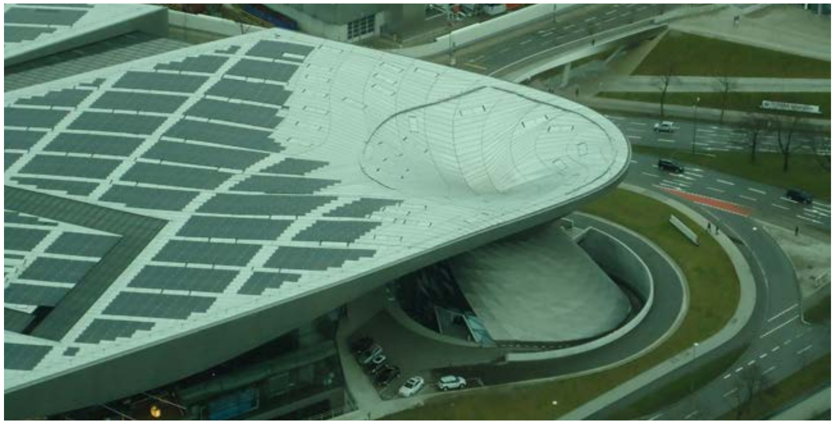
Biomimicry of Nature's Forms

The entire structure comes together from two parts. The upper portion (exhibition space) has a shell-like structure, which takes compressive and tensile forces. These forces are utilized to allow the skin to form bridges; an idea that emerged through observing cell divisions, spider web (close-ups) and other natural membranes.



Design

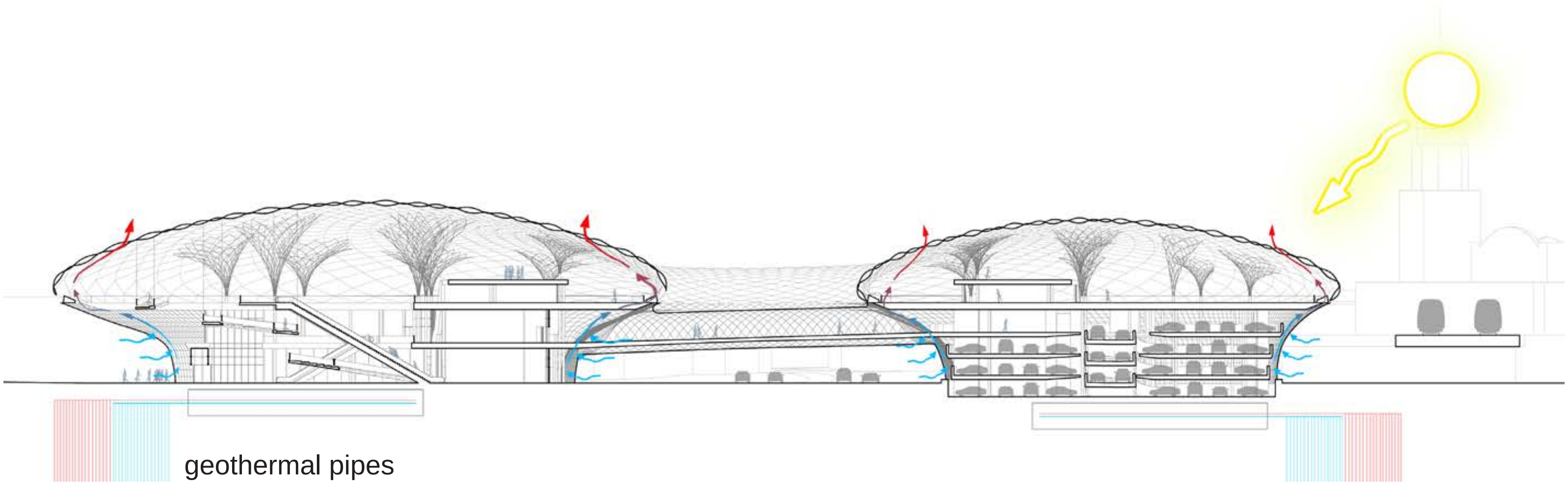
Biomimicry of Nature's Forms



The above images are of BMW World, in Munich by Coop Himmelb(l)au, which I photographed while I was in Munich. This building underlines an example of using the skin of the building as structure. It achieves this through what apears as a giant tube that twists, therefore the iterior space within such tube remains free of columns. The twisting gesture balances compressive forces caused by the roof with tensile ones undertaken by the members of the twisting tube.

Design

Biomimicry of Nature's Forms



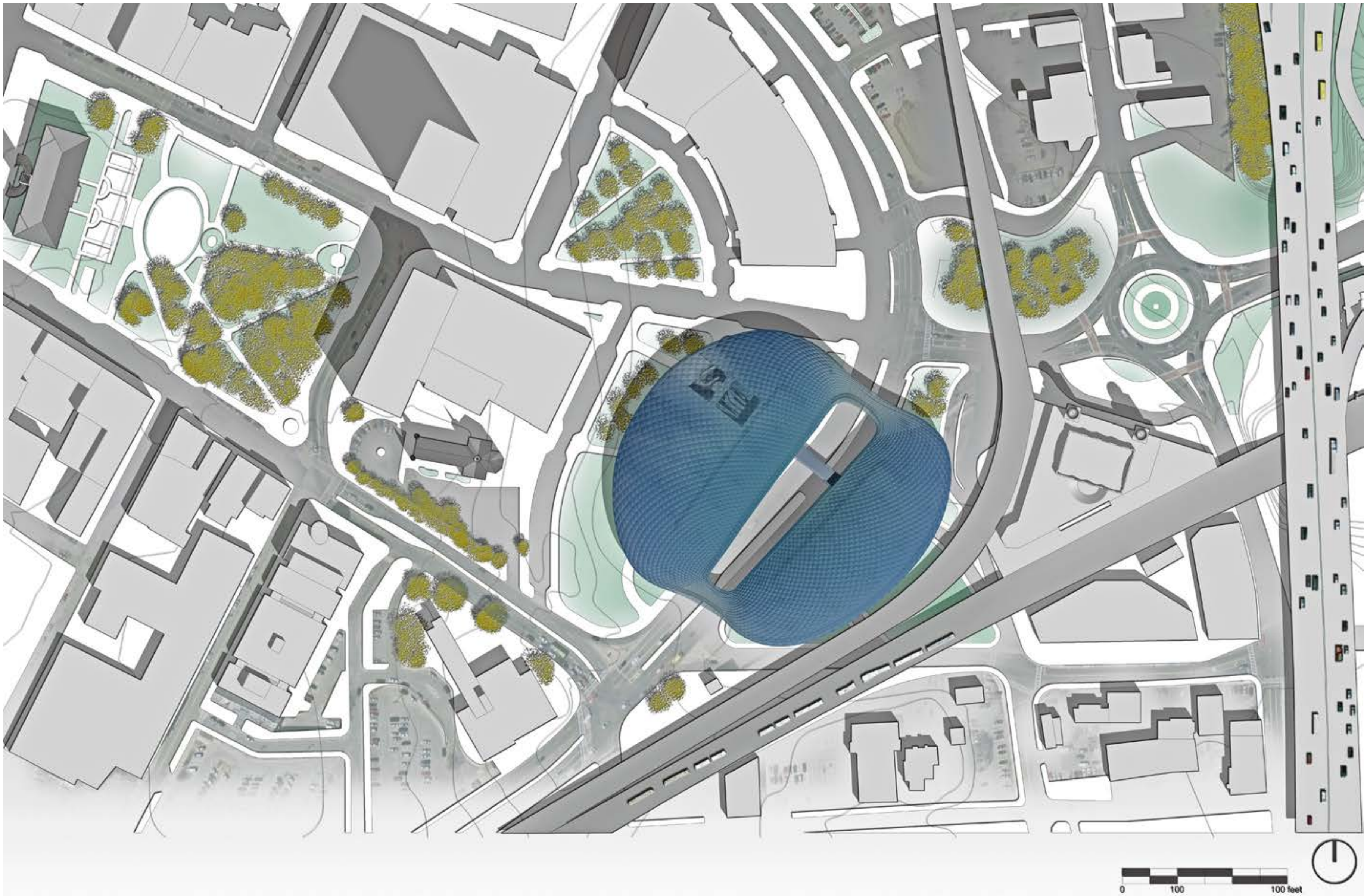
Branch-like columns keep the upper structure suspended from the ground, while the lower structure demonstrates a faceted curtain wall. The upper structure is curved since the ETFE pockets are easily applied due to their flexibility, and with today's digital fabrication such calculus-based design can become a reality. In certain areas of the upper structure, custom energy recovery units are placed instead of the ETFE pockets so that the exhibition spaces breathe. The semi-translucent photovoltaic membranes provide a level of shade at the exhibition level, while the lower areas are shaded from the form of the far-reaching edges of the upper structure. The faceted lower structure makes it easier for operable windows which allow natural air in and out the building. A buffer zone is created in the lower portion of the building between the skin and the walls of the inner programs, while the air inside the cushions serves as insulation for the top portion.

Design

View From the Road

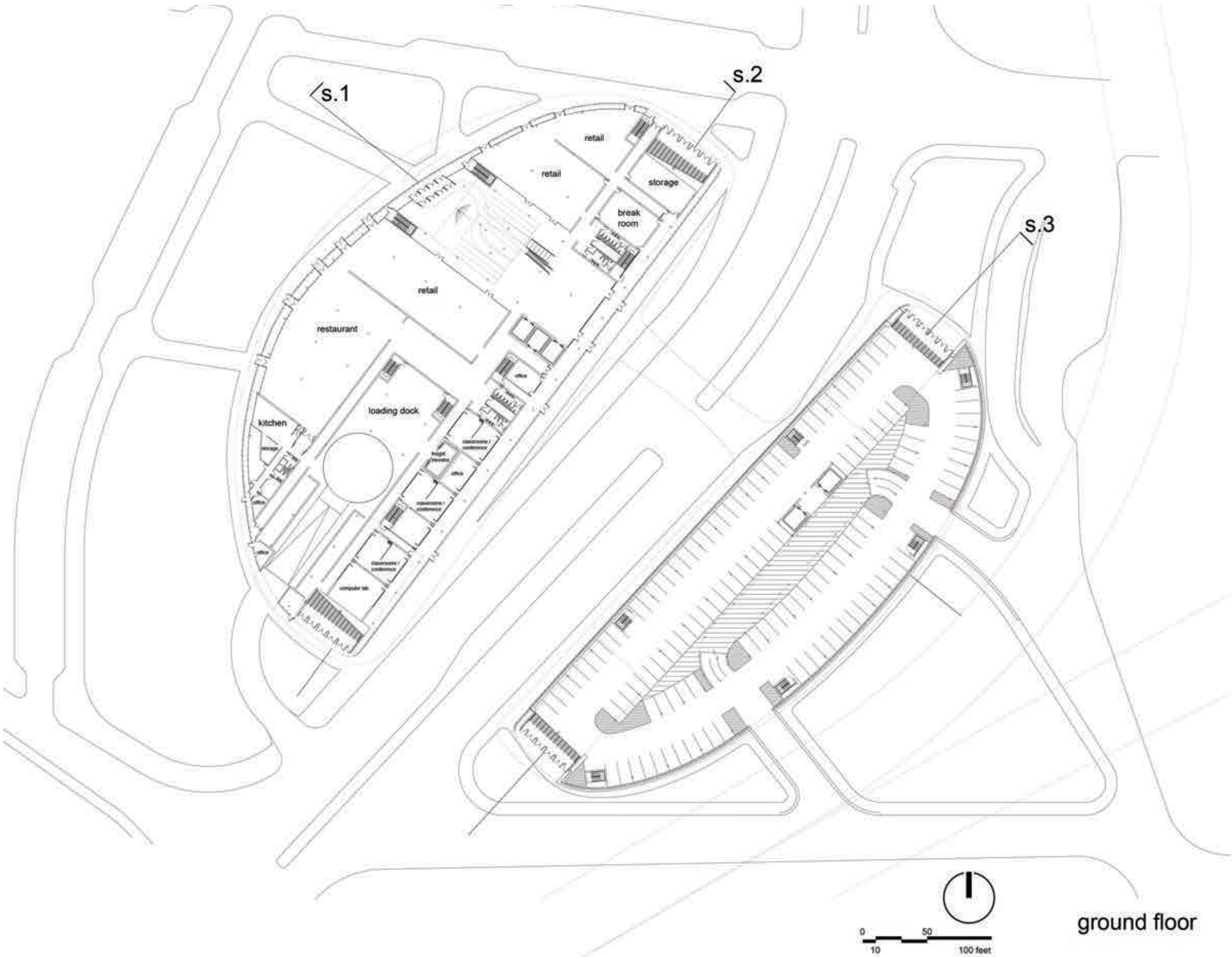
Design

Site Plan



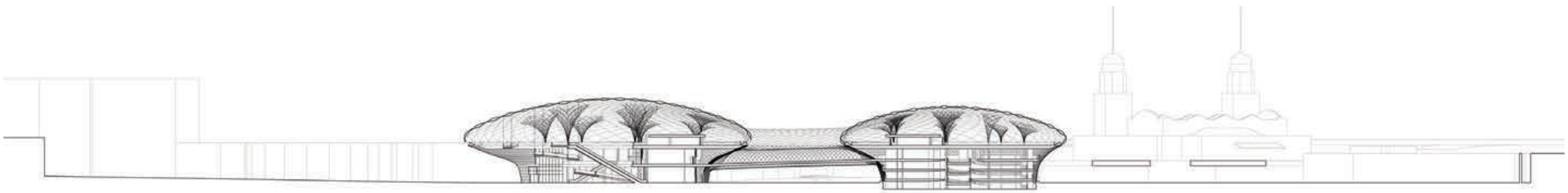
Design

Ground Plan

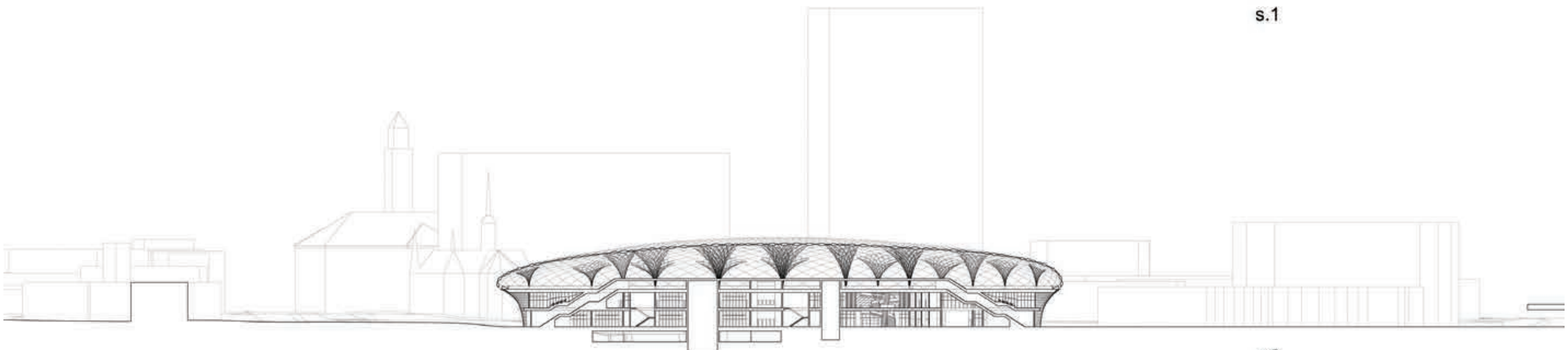


Design

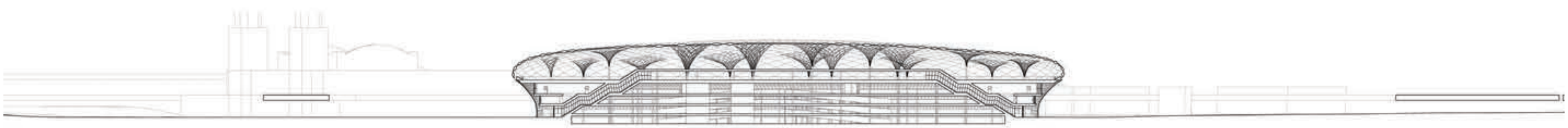
Sections



s.1



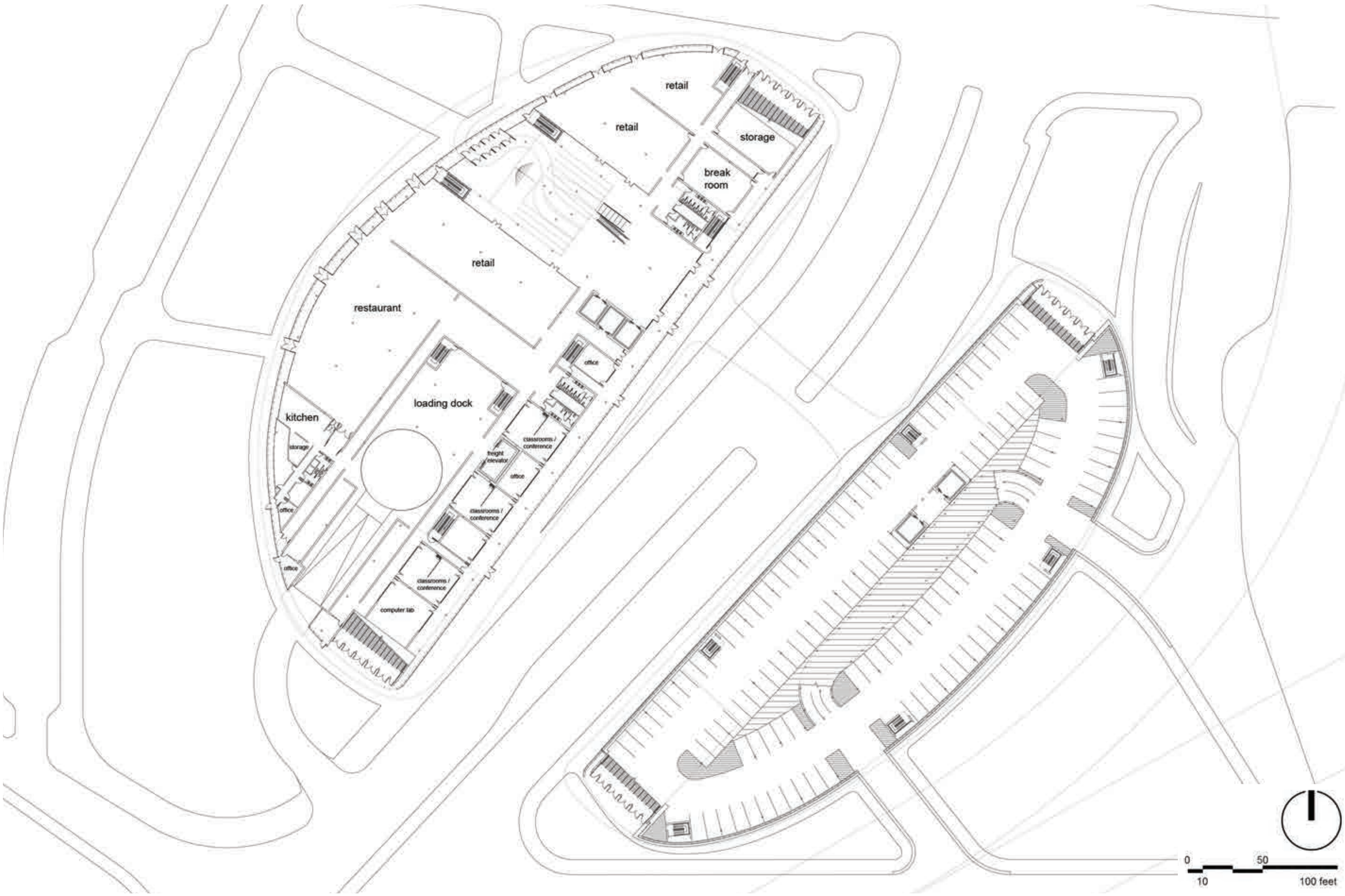
s.2



s.3

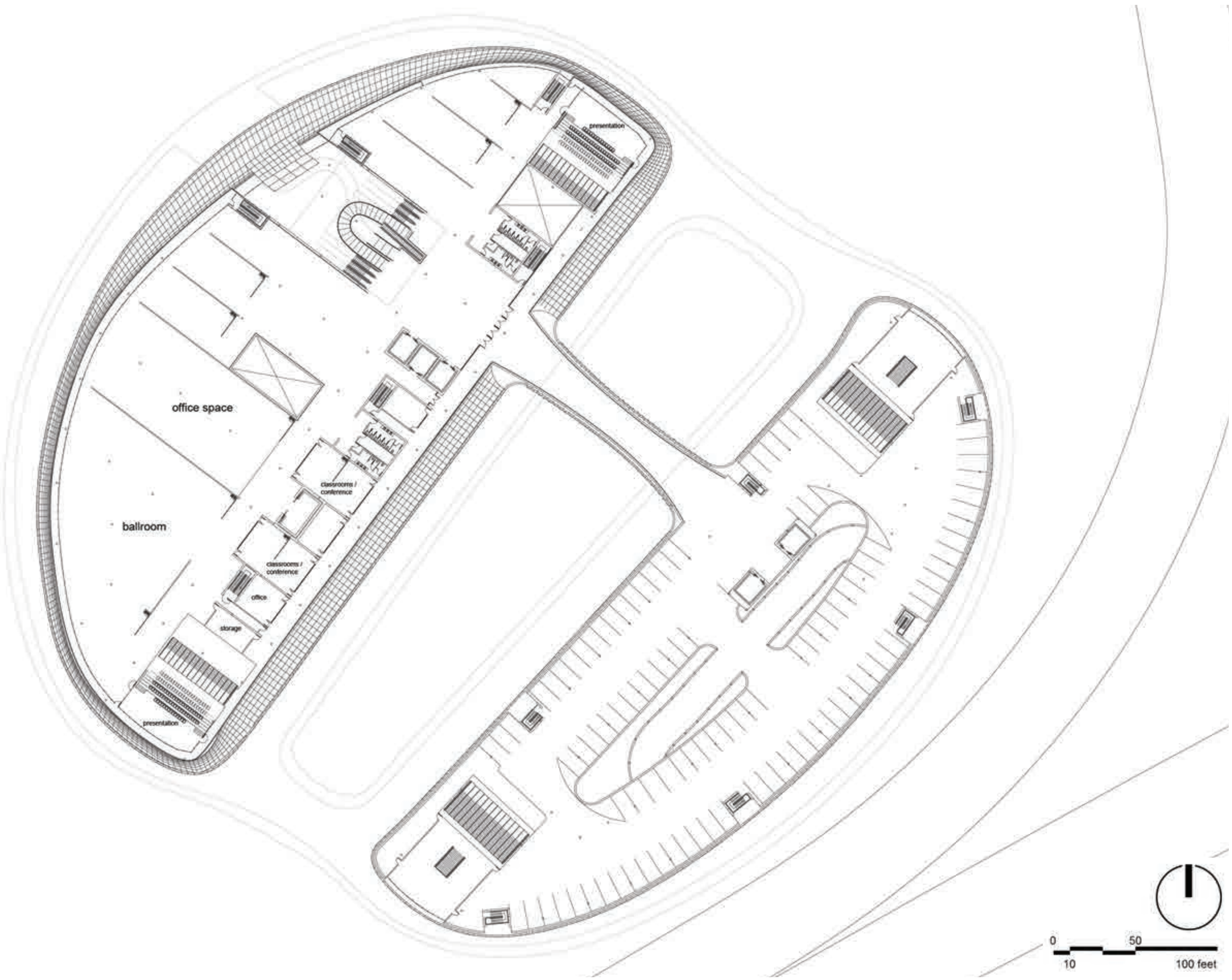
Design

Ground Plan



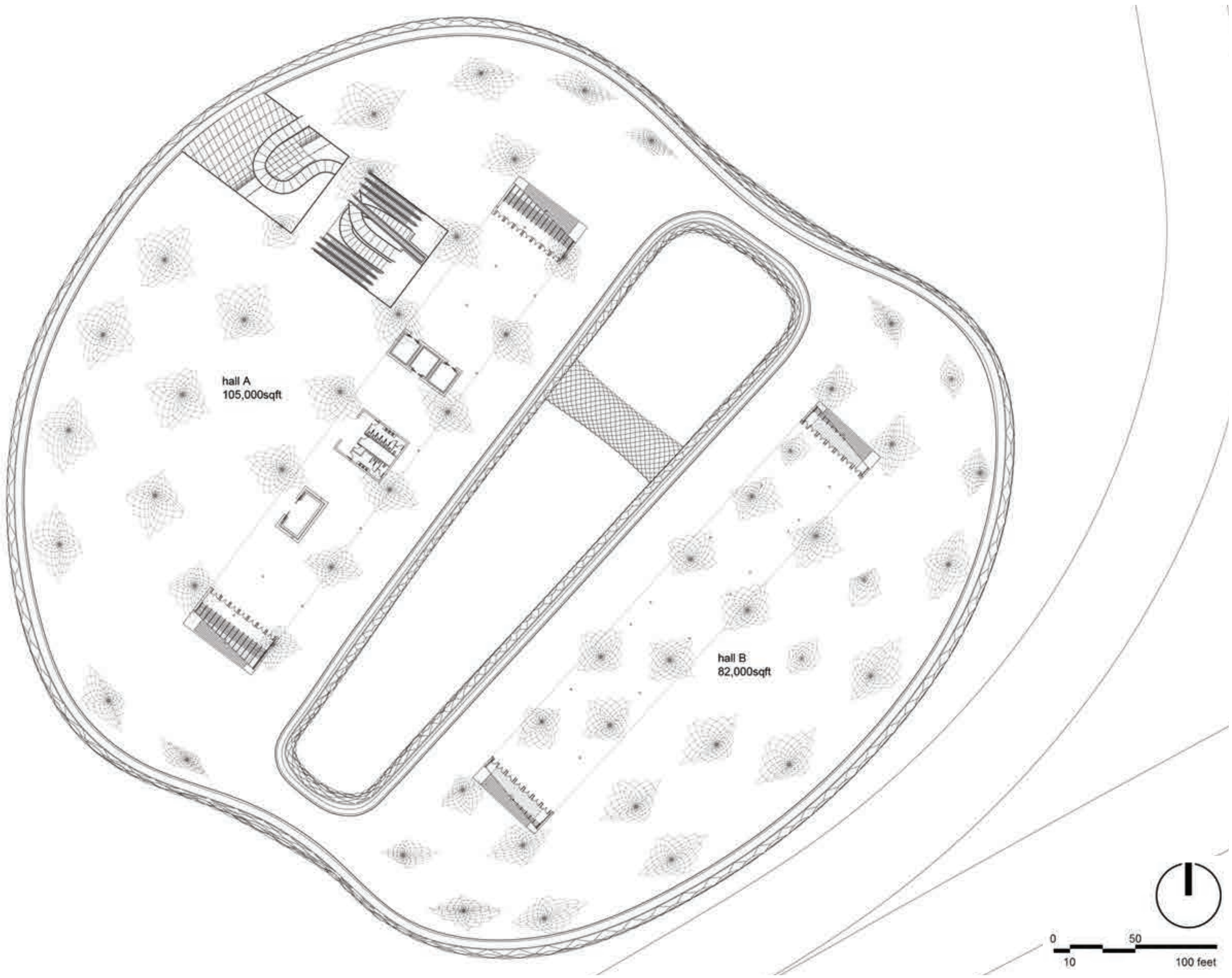
Design

Level 2 Plan (right side: parking: level 3)



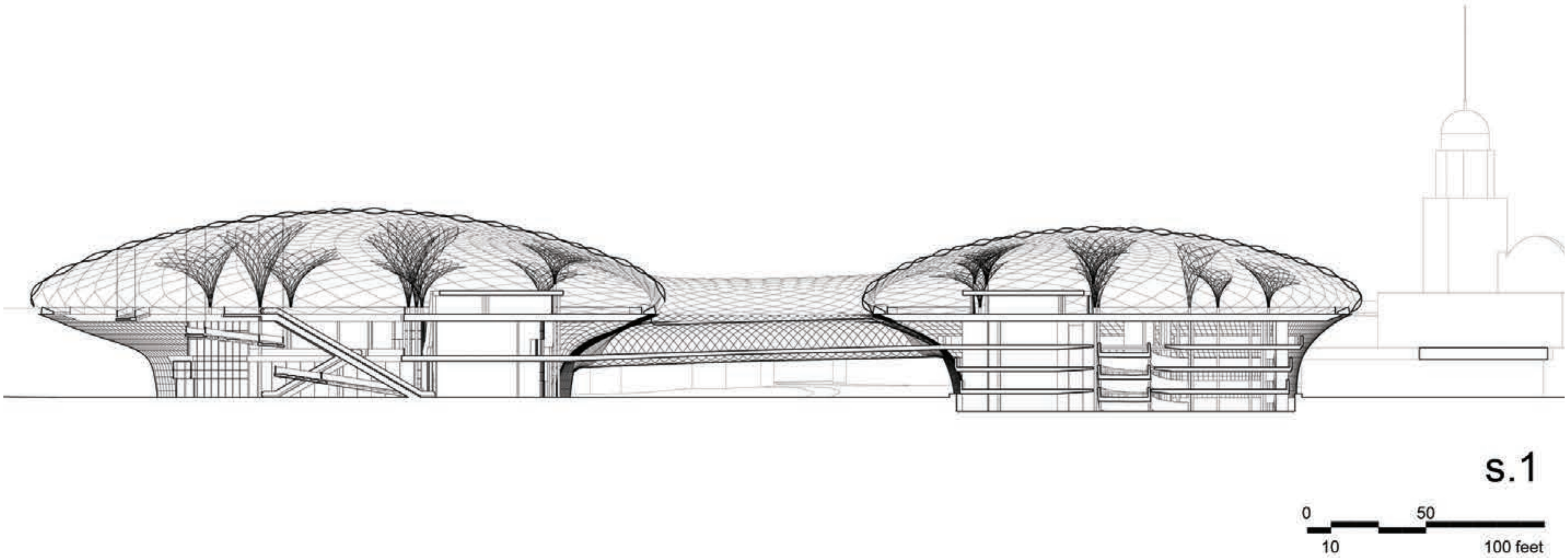
Design

Exhibition Level Plan



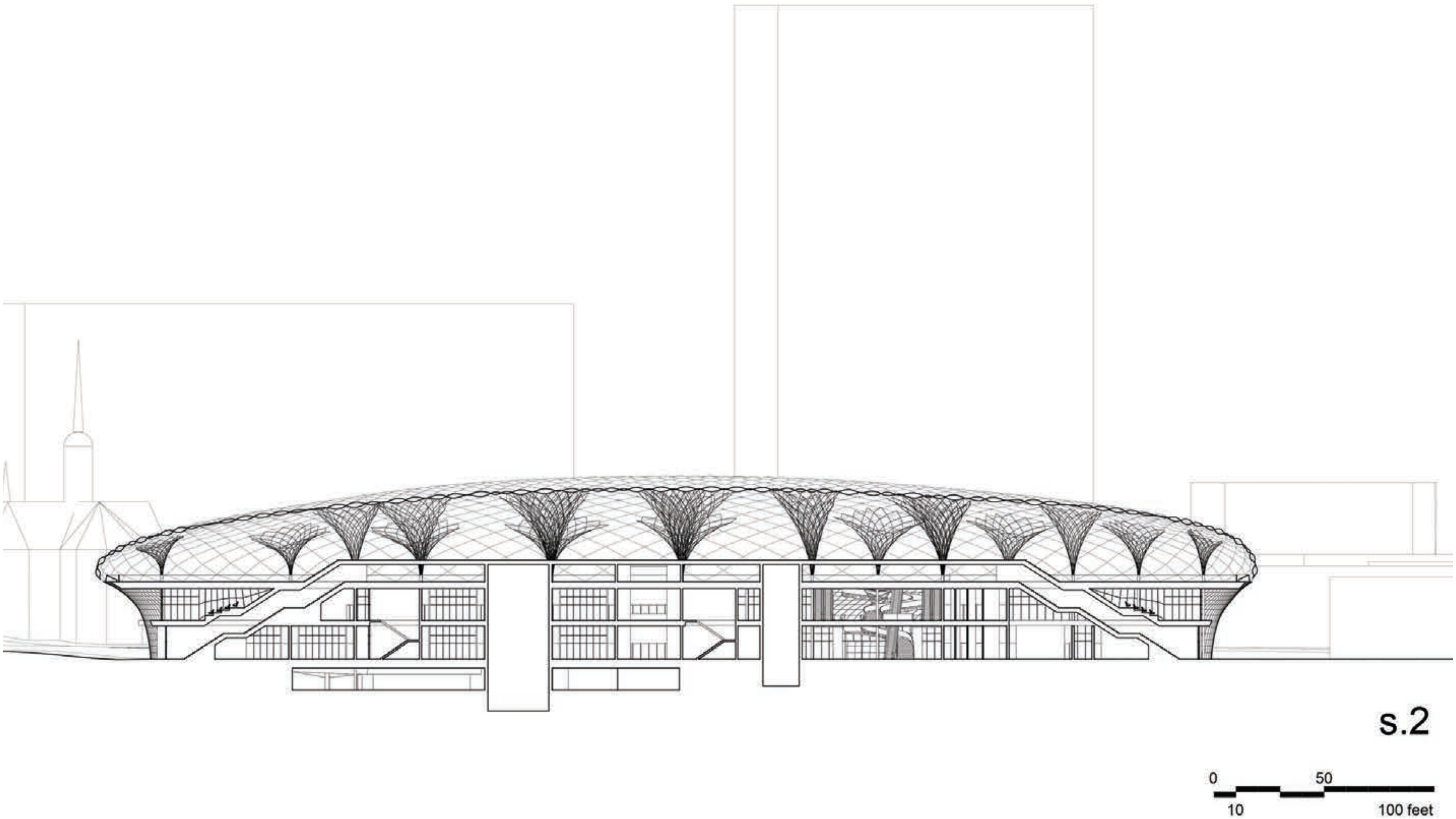
Design

Lateral Section s.1



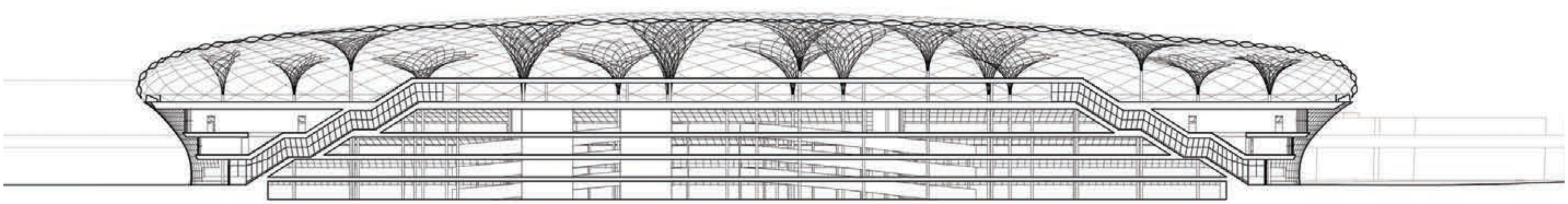
Design

Longitudinal Section s.2 (left wing)



Design

Longitudinal Section s.3 (right wing)

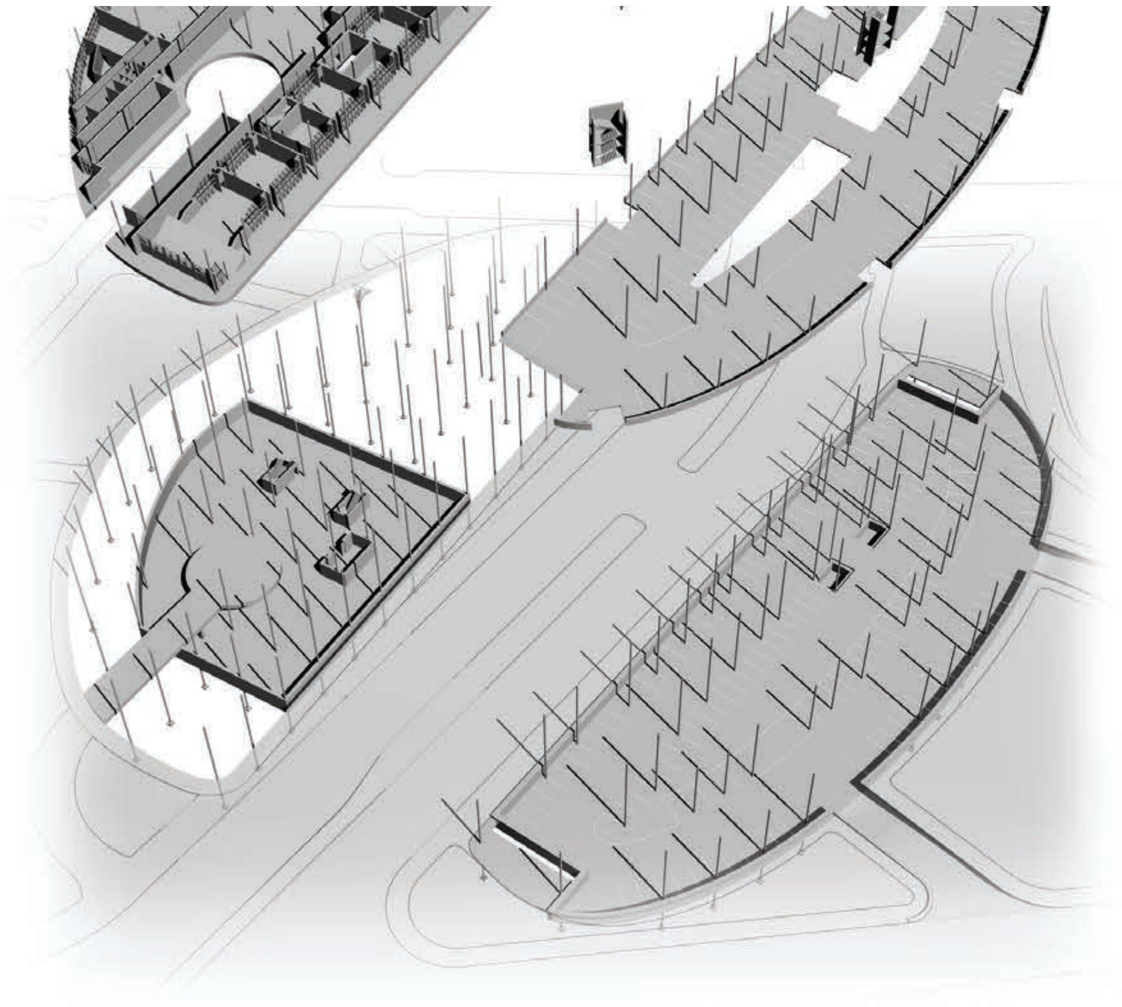


s.3

0 10 50 100 feet

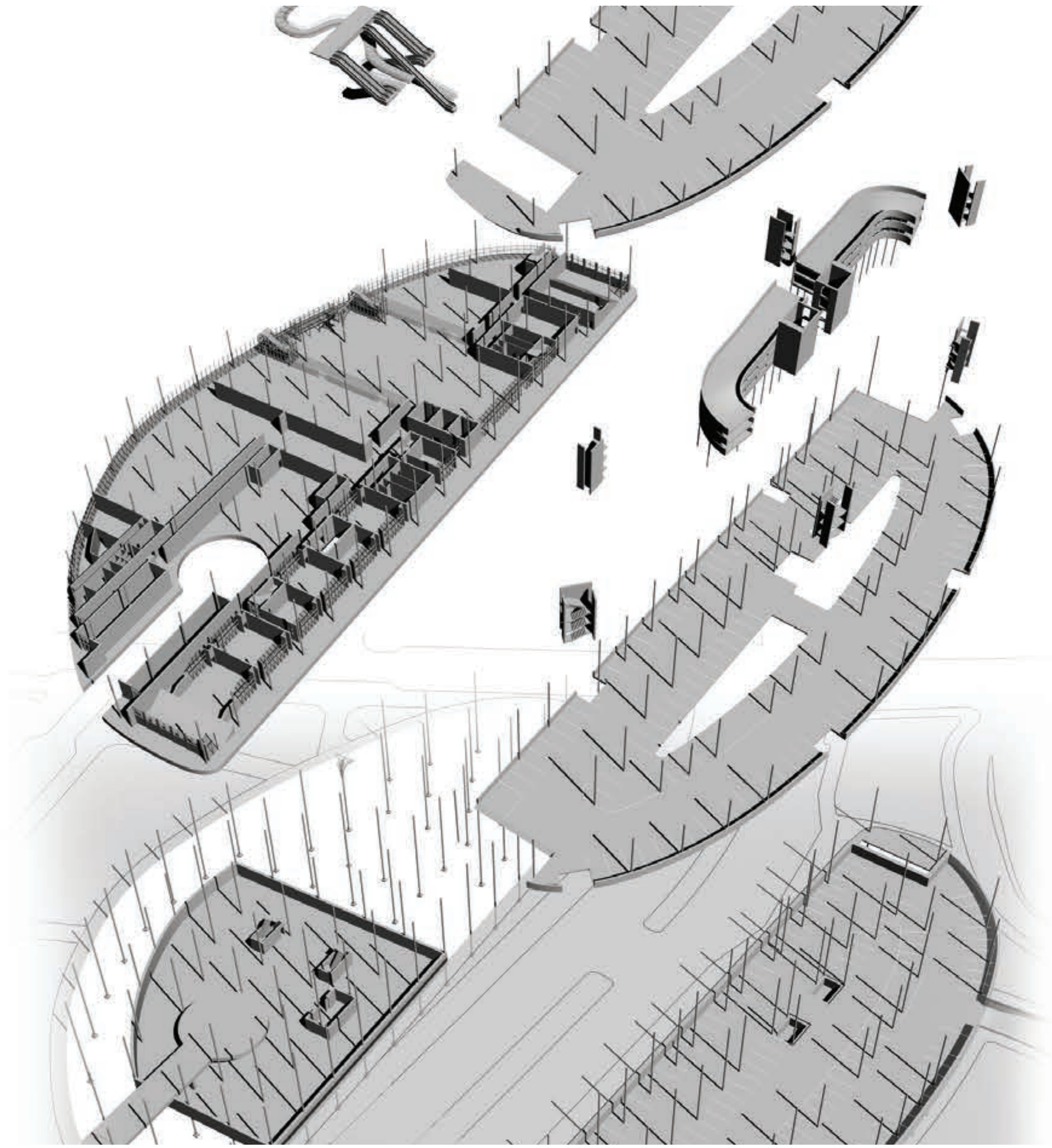
Design

Exploded Axon



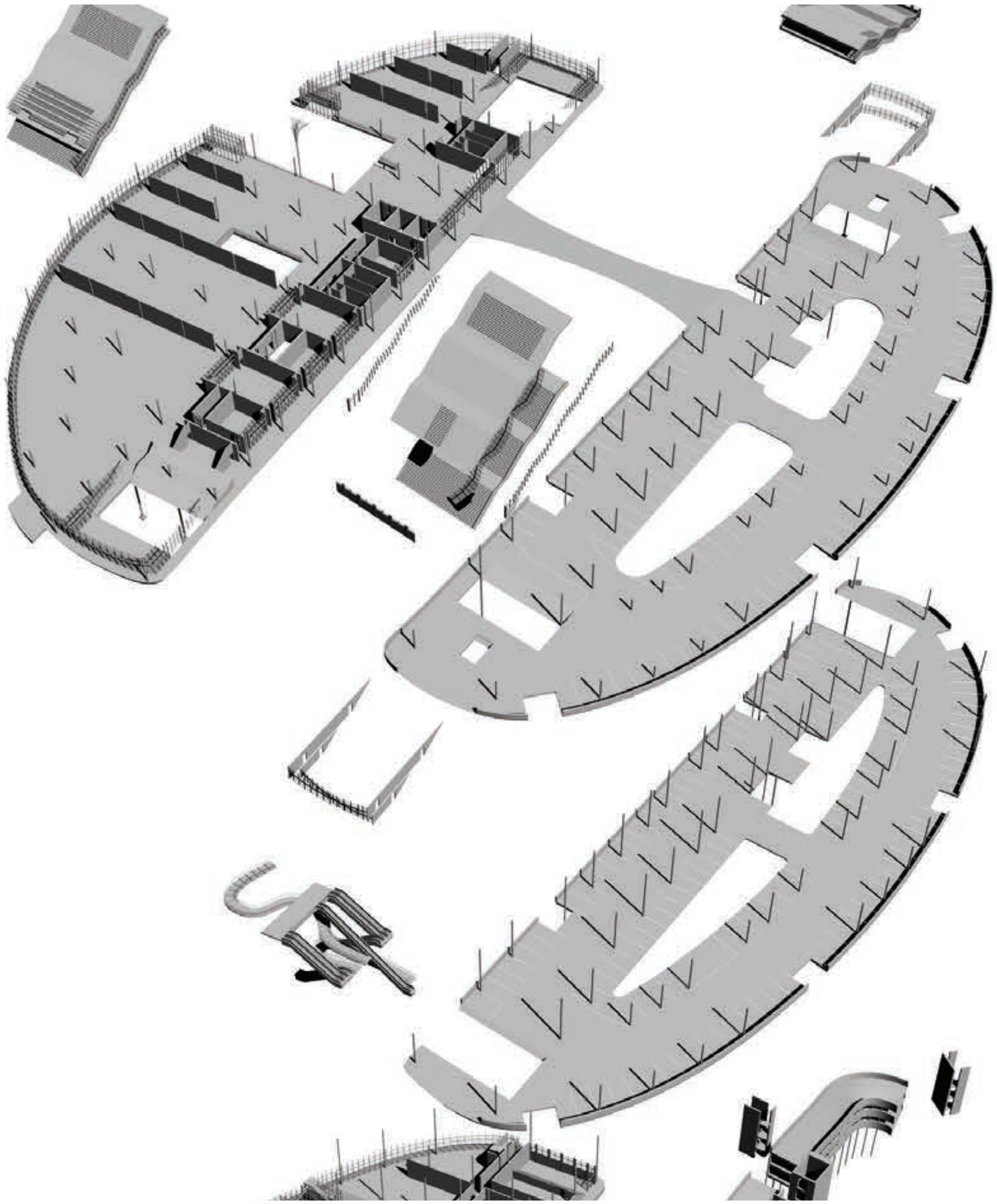
Design

Exploded Axon



Design

Exploded Axon

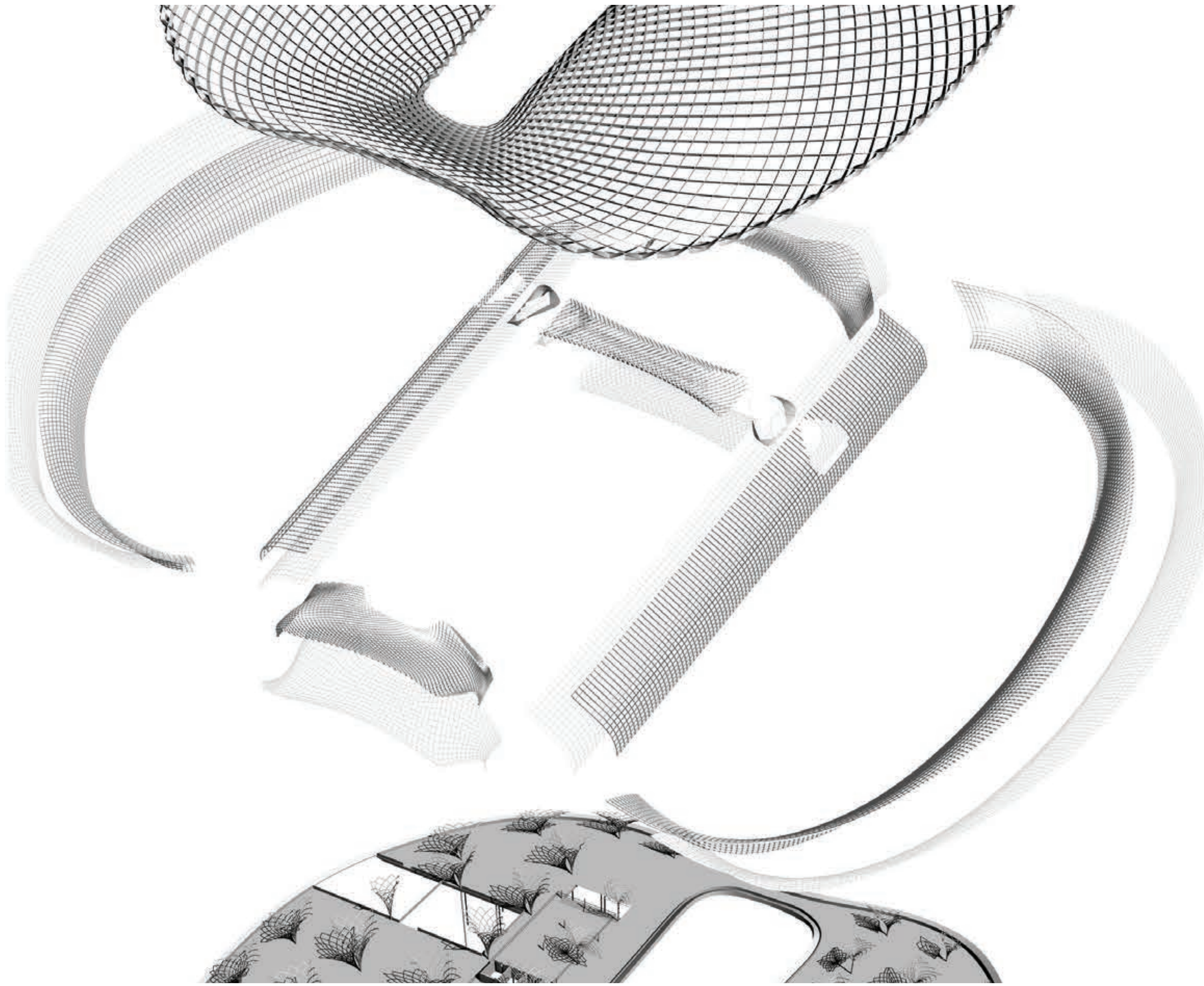


Design

Exploded Axon

Design

Exploded Axon

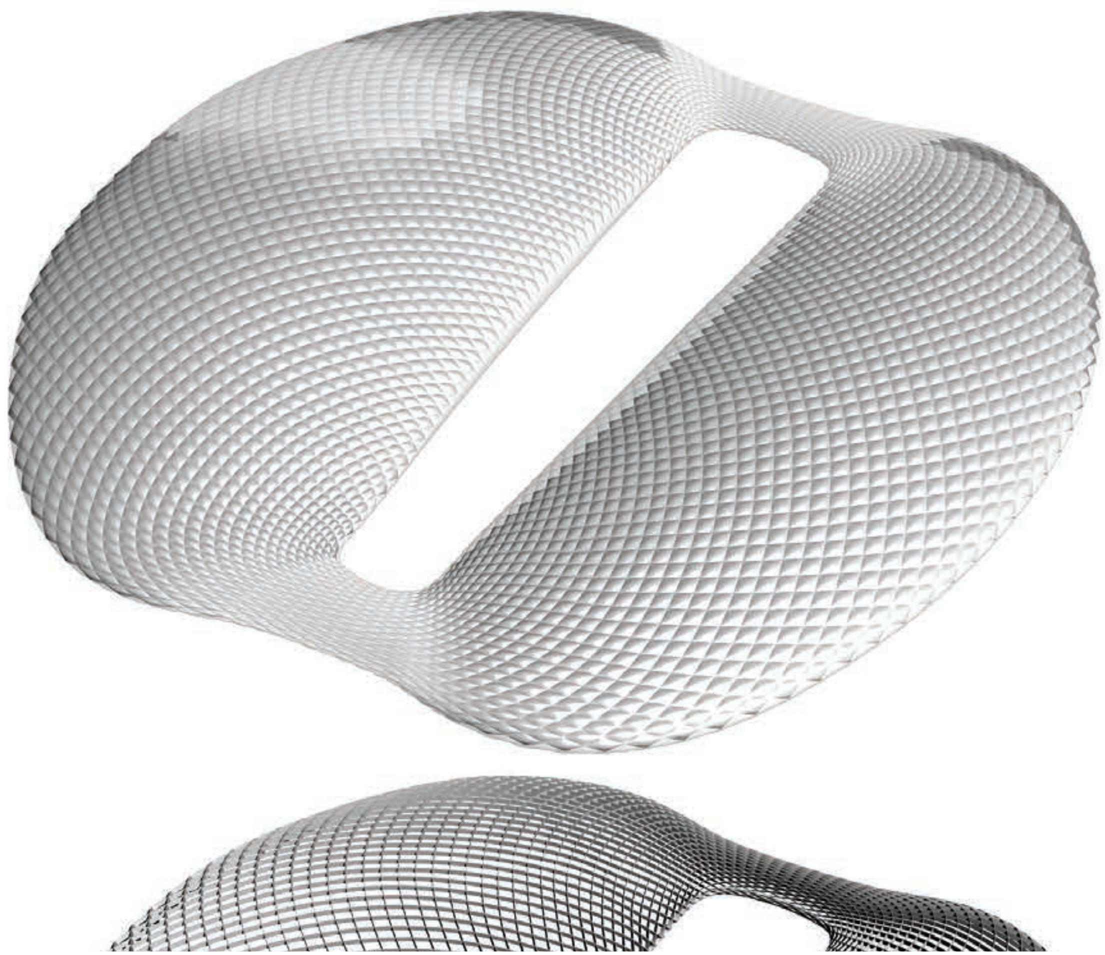


Design

Exploded Axon

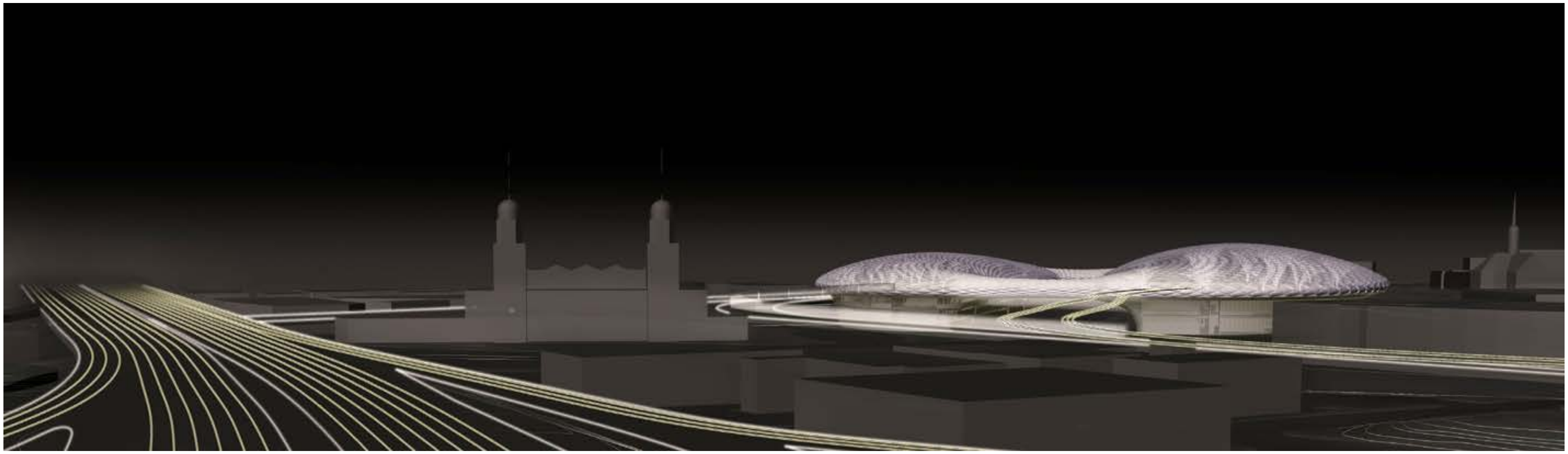
Design

Exploded Axon



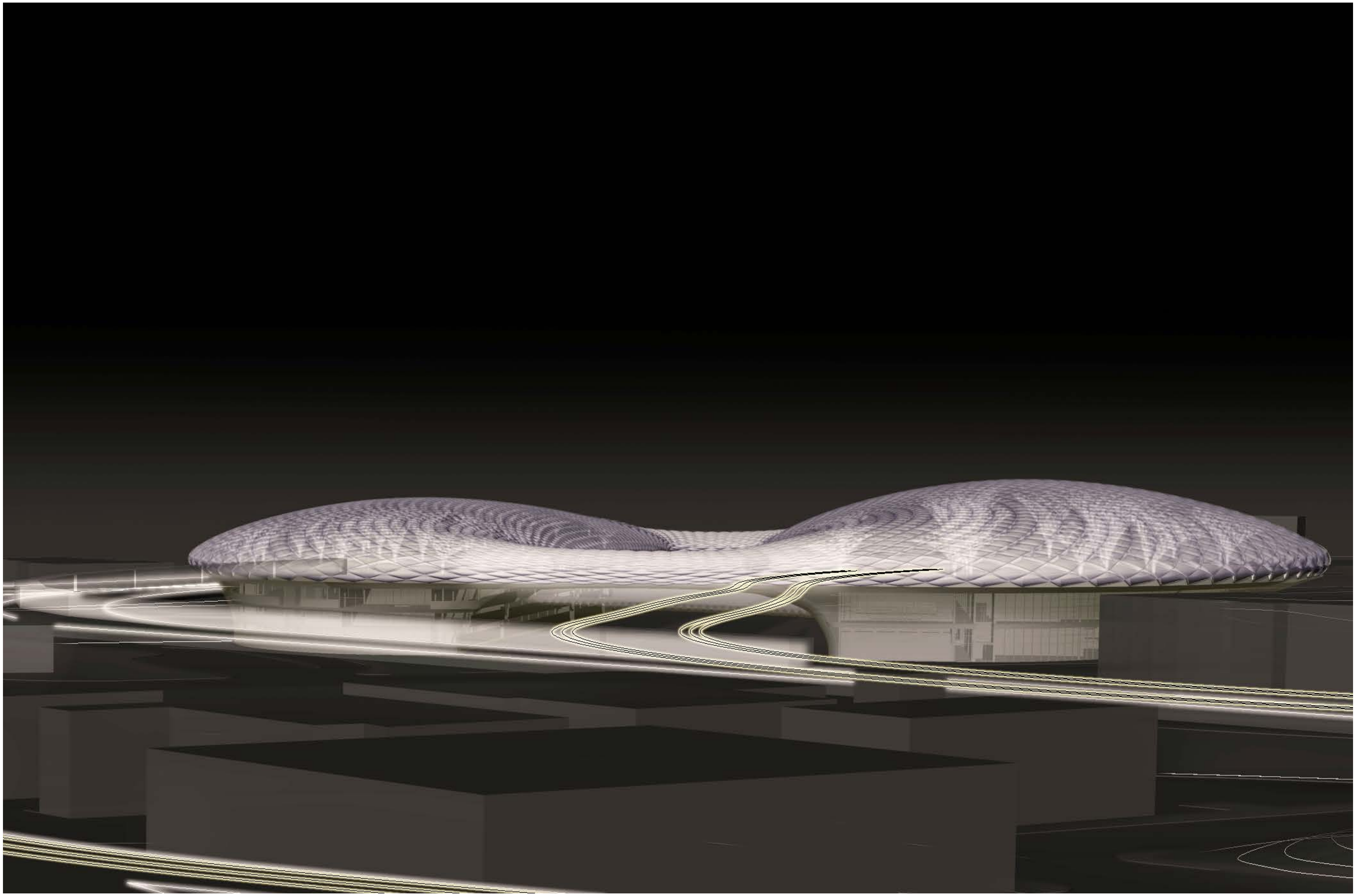
Design

View From the Highway



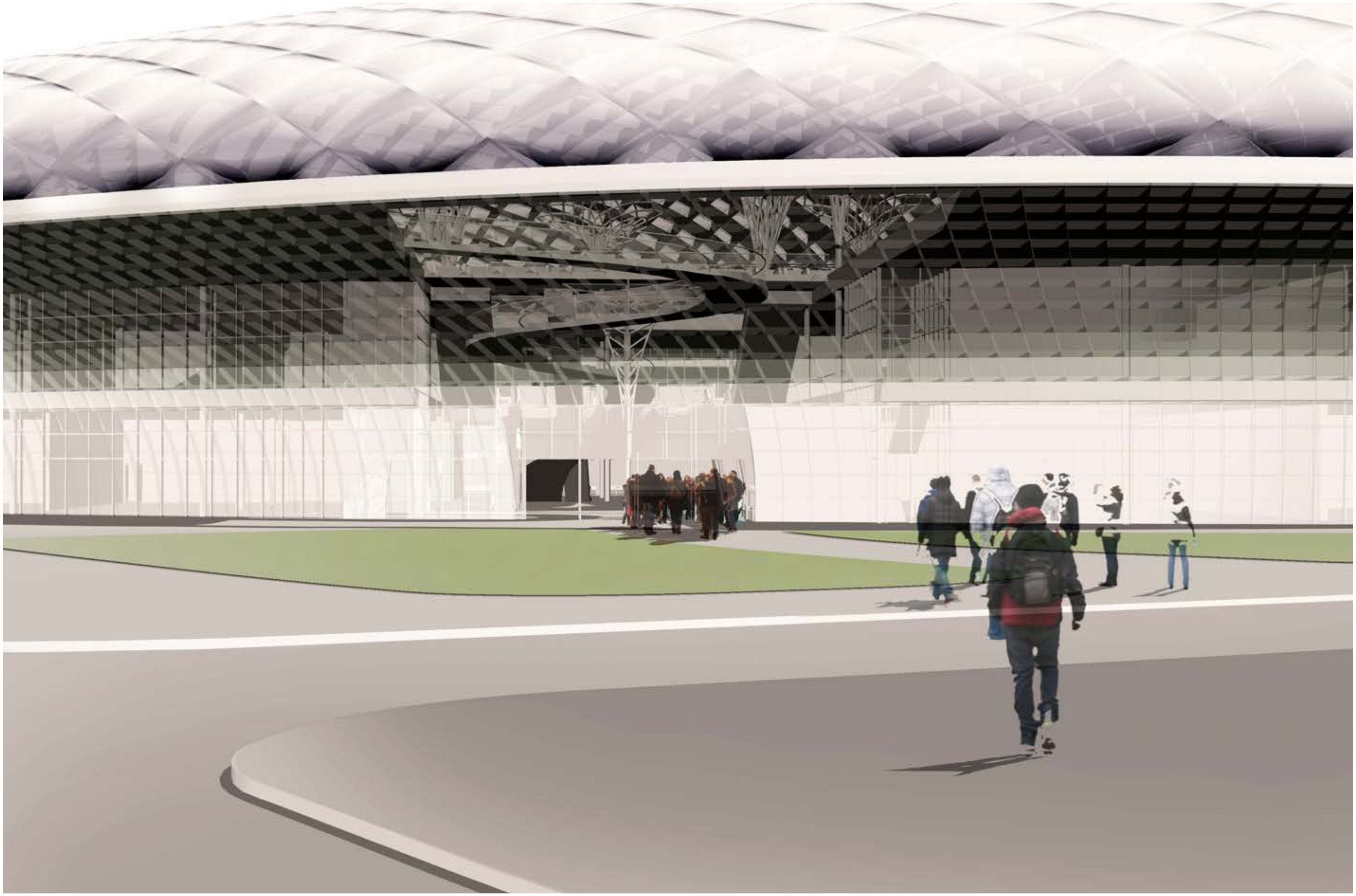
Design

View From the Highway (close-up)



Design

Main Entrance (left wing)



Design

Exhibition Level (looking down the main entrance)

Model Photos

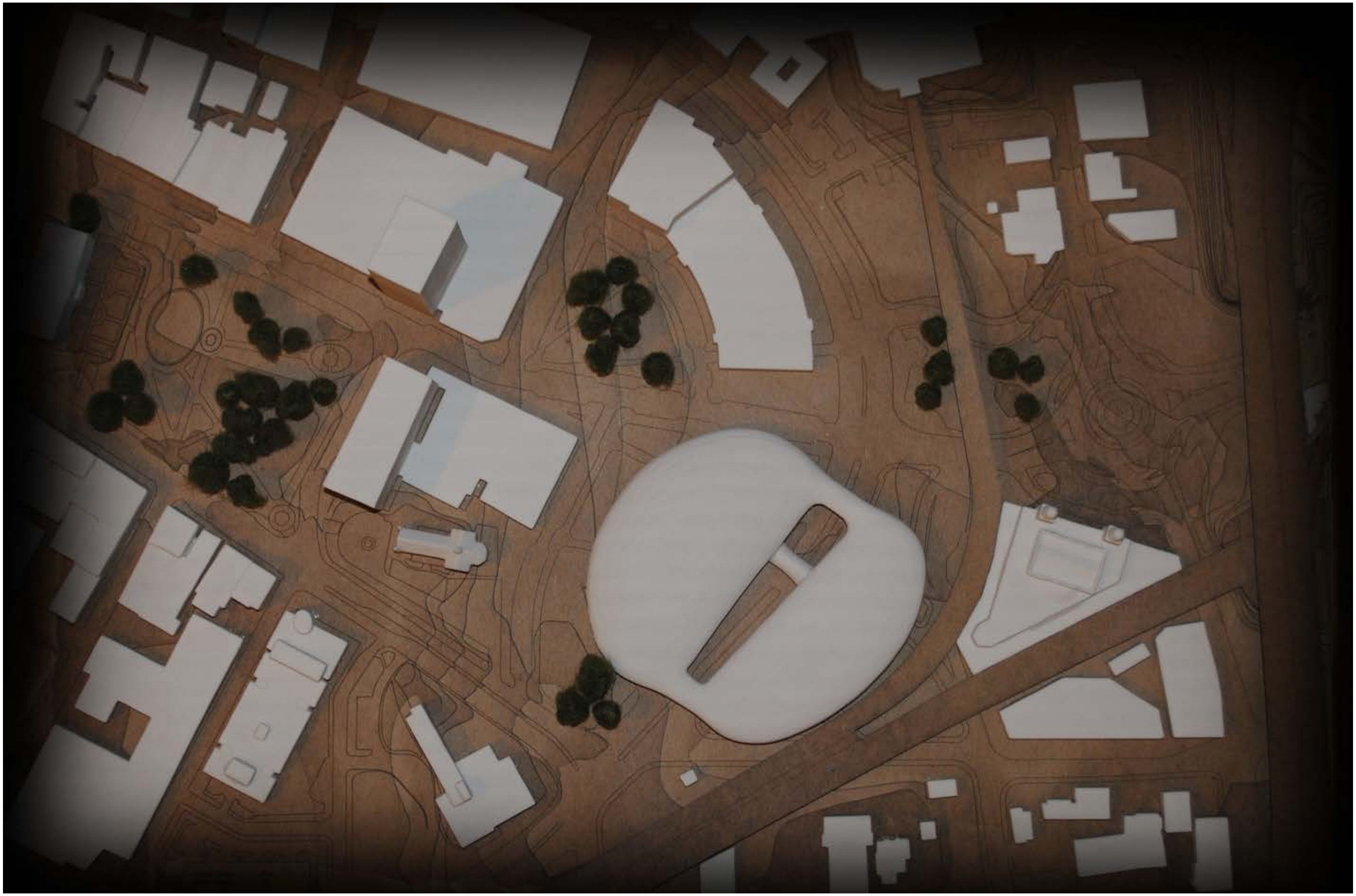
3D Printed: ZPrinter® 310 Plus: Roger Williams University: Digital Manufacturing Lab

Model Photos

3D Printed: ZPrinter® 310 Plus: Roger Williams University: Digital Manufacturing Lab

Model Photos

3D Printed: ZPrinter® 310 Plus: Roger Williams University: Digital Manufacturing Lab



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Model Photos

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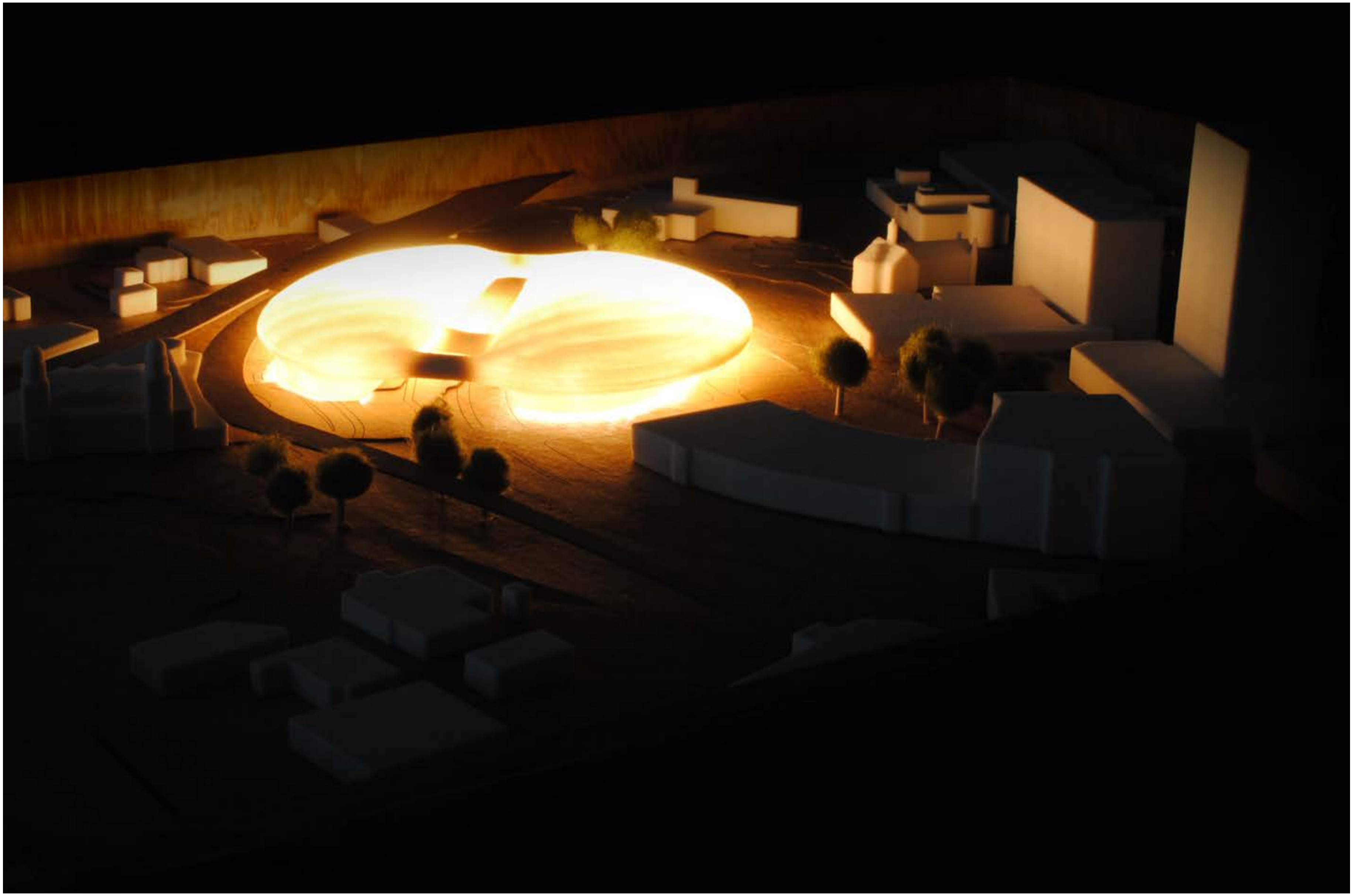

Model Photos

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Model Photos

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During the design process and the production of final material, I used the following software and hardware:

Form Z Render Zone Plus
Bonzai 3D
Rhino
Autocad
Photoshop
Illustrator
InDesign
Laser Cutter
3D Printer (ZPrinter® 310 Plus)