OUTWARD BOUND:
DEVELOPING STRATEGIES FOR THE FUTURE OF SPACEPORTS

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by

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by

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and

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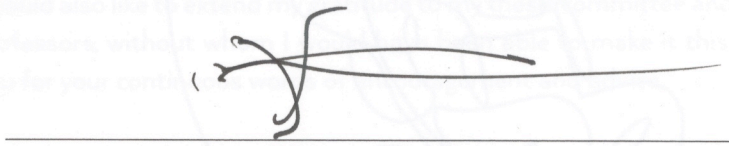

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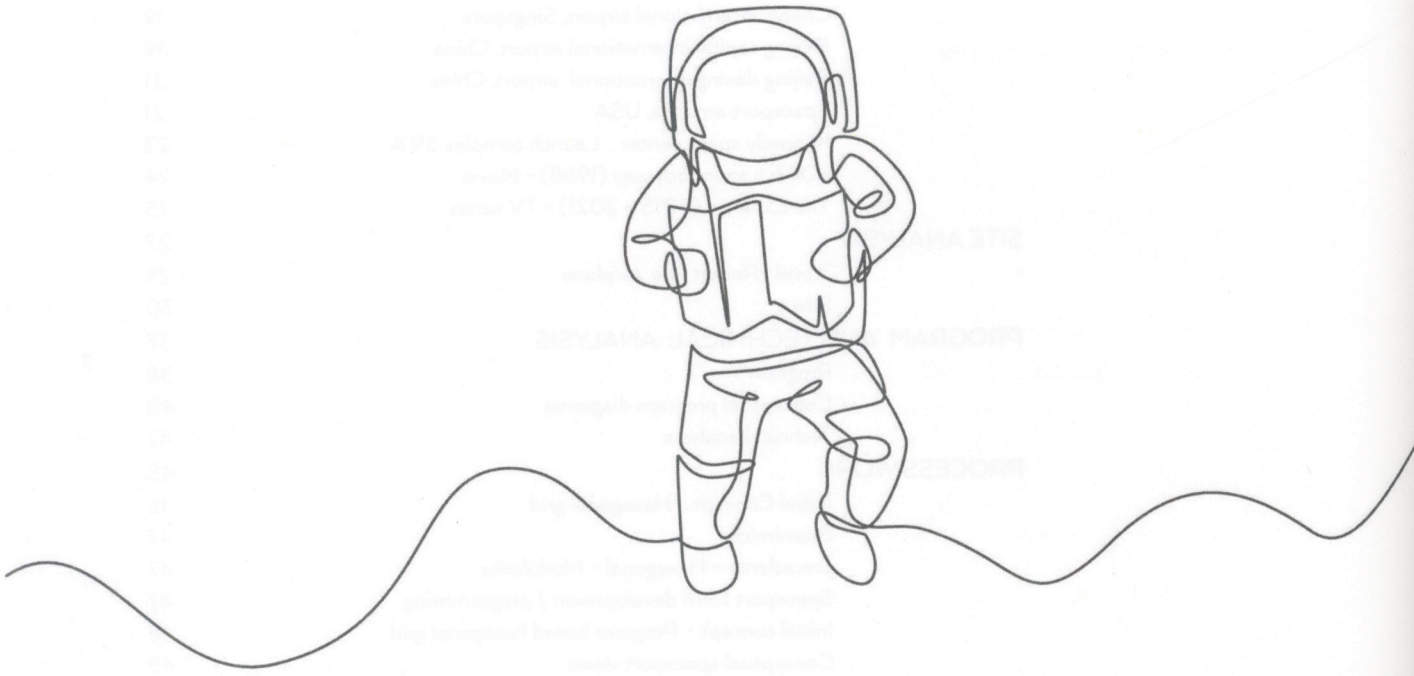
DEDICATION

I would like to thank my family and friends, who have supported and believed in me throughout the last year and a half. Thank you for the words of encouragement and for cheering the aspiring astronaut inside me.

I would also like to extend my gratitude to my thesis committee and my studio professors, without whom I would have been able to make it this far. Thank you for your continuous words of encouragement and advice.



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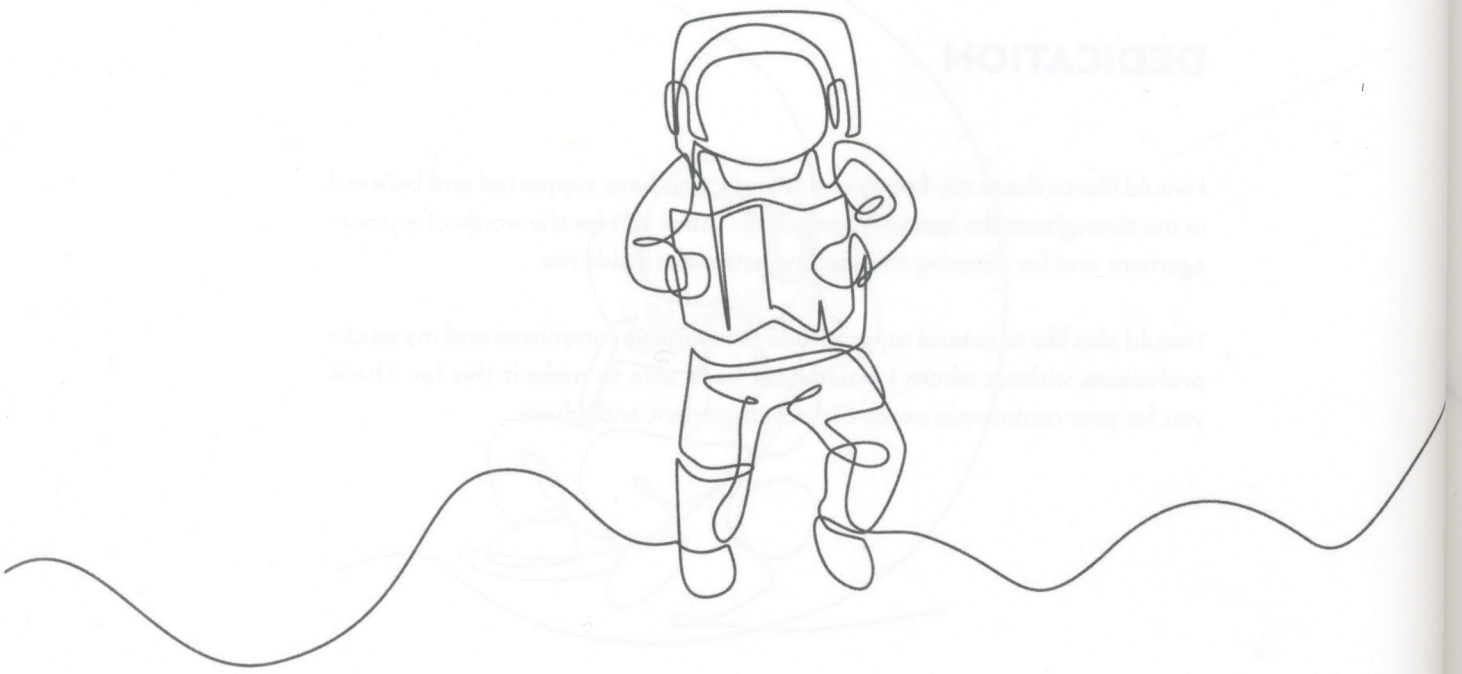

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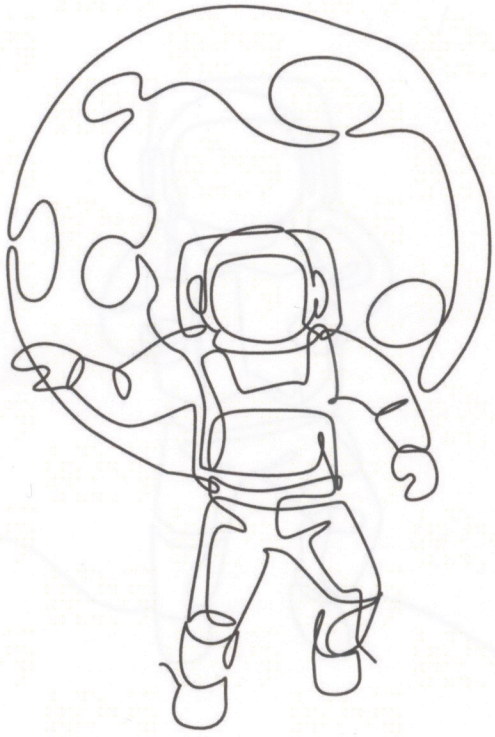

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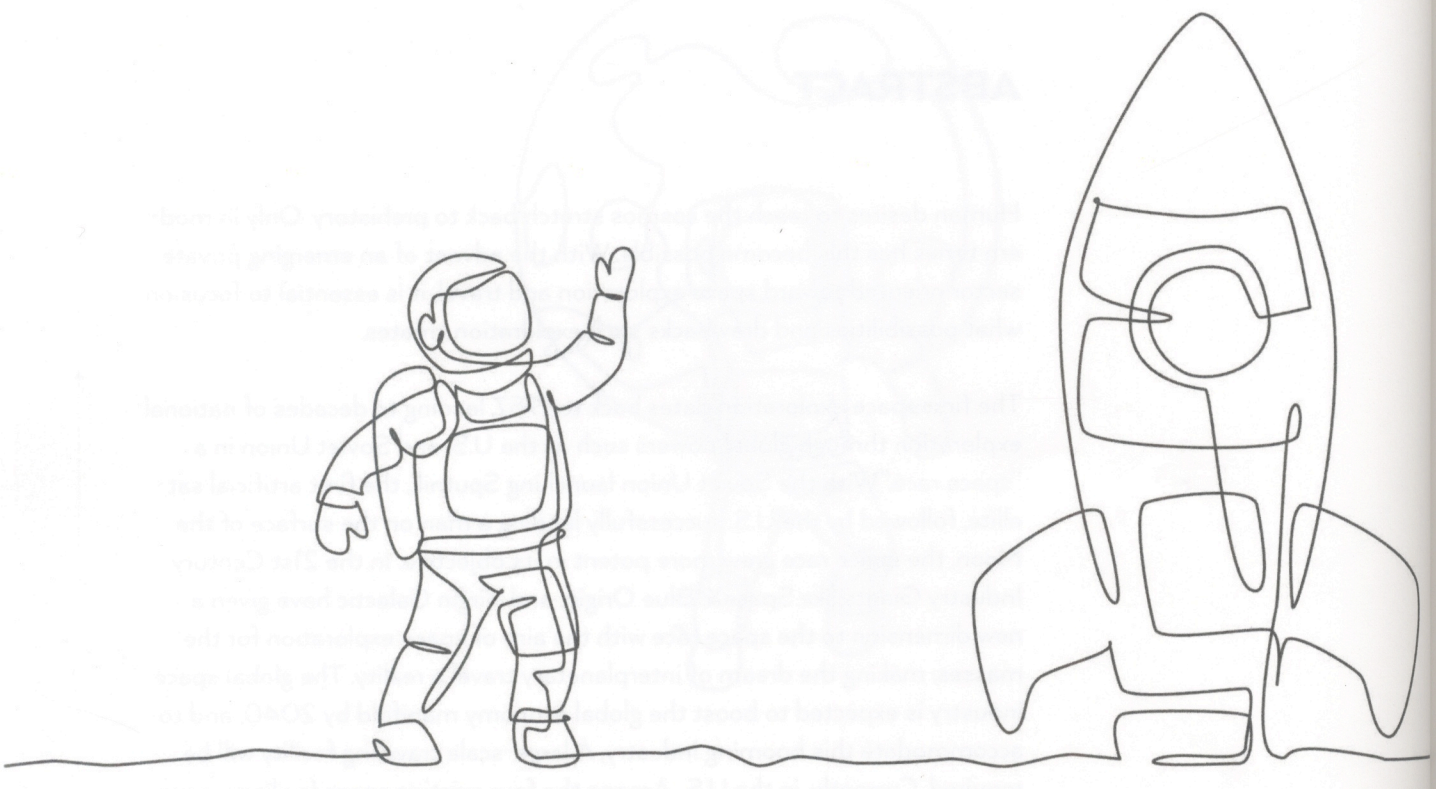
OUTWARD BOUND : DEVELOPING STRATEGIES FOR THE FUTURE OF SPACEPORTS

ABSTRACT

Human desires to reach the cosmos stretch back to prehistory. Only in modern times has this become possible. With the advent of an emerging private sector oriented toward space exploration and travel, it is essential to focus on what possibilities and drawbacks such exploration creates.

The first space exploration dates back to 1957, leading to decades of national exploration through global powers such as the U.S. and Soviet Union in a "space race."With the Soviet Union launching Sputnik, the first artificial satellite, followed by the U.S. successfully landing a man on the surface of the Moon, the space race grew more potent in its objective. In the 21st Century, Industry Giants like SpaceX, Blue Origin, and Virgin Galactic have given a new dimension to the space race with the aim of space exploration for the masses, making the dream of interplanetary travel a reality. The global space industry is expected to boost the global economy manifold by 2040, and to accommodate this booming industry, A large-scale traveling facility will be required. Currently, in the U.S., Among the four existing space facilities, none of them are capable of supporting large-scale transportation when space travel scales up. By looking at the examples of major transportation hubs like Shanghai and Singapore airports, I assess the spaceport's abilities to adapt over time and ensure an enjoyable user experience while accommodating growing needs.

From these analyses, I look at How to Consider Multiple Design Strategies for the Development of Spaceport with a focus on accommodating the Technical Aspects of a large scale Transit Hub as well as Heightening the experience of Space Travelers and its Users.



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INTRODUCTION

In 1903, the Wright brothers took the very first flight in the air. A few years later, The very first airport was made for the Edwardian air show in the early 1900s in California[6], A tented space that separated the Place for arrival for the public from that of the aircraft. 100 yrs later the airports have significantly sized and have become mega structures themselves. Even though there is a lot of progress made by companies for space tourism we are in a very early stage where Right Now the Space travel industry is in its early stages ie 1920's of the Aviation industry. My thesis project takes place 80 - 100 yrs in the future, where using rockets to travel has become as normal as flying in an airplane from one continent to another. SpaceX proposed a plan of using starships to travel around the globe, where it would be possible to travel anywhere around the planet in under 1 hr. Thus emphasizing the aphorism "Time is Money" that first appeared in the year 1748.

My thesis focuses on exploring the pre-departure journey of travelers both international and domestic. The Journey is the view through the lenses of time in architecture, where the journey for the domestic (around the earth) travelers would be limited to a few hrs, whereas the journey for the international (interspace) travelers would be somewhere between 10 - 14 days. Thus making time a key factor in terms of how architecture would take shape around the tenure of the travelers staying at the spaceport allowing them to enjoy their journey.

THESIS QUESTION

How can we consider multiple time scales when designing spaceports to accommodate both technical challenges as well as heighten the experience of space travelers?

I define time scales in terms of

The spaceport as architecture itself: expansion over time due to increasing traffic of passengers, the flow of people through spaces, and the experience of waiting.
Human experience that would take place within the spaceport, waiting for liftoff, transitions through spaces, and the journey to the launchpad before liftoff.

KEY TERMS

Space, Space Travel, Space Race, Space Colonization, Cosmos, Time, Transportation, Interplanetary living, Tourism, Airports, Launchpads, Mars

LITERATURE REVIEW

20TH AND 21ST CENTURY - SPACE RACE

The term "Space race" grew out after the cold war between the United States and the soviet union. For almost 50 yrs the two nations competed against each other to show their superpower. On October 4, 1957, the soviet union surprised the world by launching the very first satellite named "Sputnik" in space. This successful launch ignited the tension between the two nations.[7]

"Finally, if we are to win the battle that is now going on around the world between freedom and tyranny, the dramatic achievements in space which occurred in recent weeks should have made clear to us all, as did the Sputnik in 1957, the impact of this adventure on the minds of men everywhere...."

President John F. Kennedy, 1961[8]

"I believe that this nation should commit itself to achieve the goal, before this decade is out, of landing a man on the Moon and returning him safely to the Earth. No single space project...will be more exciting, or more impressive to humankind, or more important...and none will be so difficult or expensive to accomplish...."

President John F. Kennedy, May 25th, 1961[9]

After this declaration by President Kennedy, the space race had a clear goal of landing an American on the surface of the Moon before the soviets. Before this, there were no set rules for the goal or what would be counted as a win in the space race? On April 12, 1961 Soviets stunned the world by sending Astronaut Yuri Gagarin into space, making him the first human to ever be in space. Ten months later, the USA sent the first astronaut Alan Shepard into space to orbit the Earth. 8 yrs later, on July 21, 1969, the USA was able to land Apollo 11 with the first Man Neil Armstrong to land on the Moon.

"That's one small step for man, one giant leap for mankind."

U.S. astronaut Neil Armstrong, on the Moon, 1969[10]

In the 21st century, The Term "space race" has a new goal: to get humans either to Mmars or to let the general public explore space. But instead of the

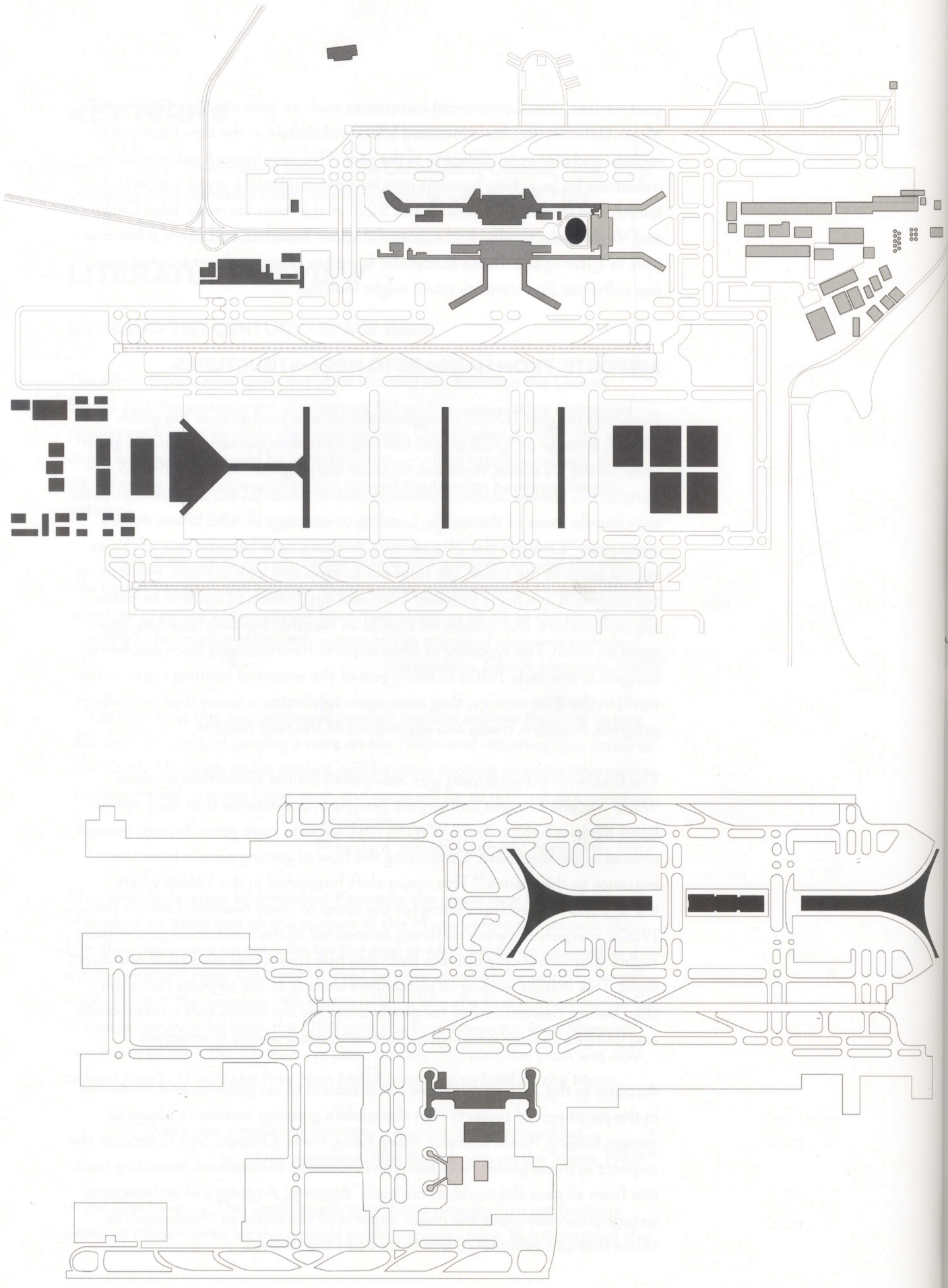
government, now Commercial companies such as SpaceX, Blue Origin and Virgin Galactic, etc., have invested billions of dollars in the development of rockets and planes to compete in the race. This year SpaceX achieved a big milestone by launching humans into International space and a successful launch and landing of Falcon 9 and S20 i.e. the rover for mars. Blue Origin and Virgin Galactic also had successful space launches and spent a few minutes in outer space. These successful launches bring us closer to what one can call what 21st-century travel might look like.

AIRPORTS: FROM HANGARS TO MEGA-STRUCTURES

Every day roughly 1,00,000 flights take off and land all over the globe, with an average of 9,728 planes carrying 1.2 million passengers at any given time.[11]In the Us Alone, there are 45,000 daily flights. There are 19,633 airports in the United States of America, out of which 5,082 are public airports that handle most of the traffic, Leading to earnings of 488 billion dollars every year. [12]Living in the 21st century, Airports have become one of the essential parts of our travel. We tend not to stop and look at them. Perhaps we are too much in a hurry to travel from one destination to another to notice the architecture. But maybe we should as no other building type has developed so much. The typology of what airports have changed from just being hangers in the early 1910s to being one of the essential building types in the world in the 21st century, that once again celebrates a space that symbolizes progress, freedom, trade, and aspirations of the host nations. [13]

The first-ever actual airport was assembled for the Edwardian air show. World war one brought civil airport designs into existence that were speculative designs before. From WWI to now, airports have gone through several phases of development, Optimizing the flow of getting people from the entrance to the planes.[14] This major shift happened in the 1960s where the airports shifted from being for the elites to mass tourism. Later in the 1980s, mergers between different airlines led to the creation of connection flights that would only operate from one hub to another instead of one direct flight. This merger leading to passengers waiting at the airports far longer than before created a need for new businesses like shops, cafes, restaurants, and lounges, making different airports into destinations themselves. [15]

Airports in the 21st century now come second to art galleries and museums in the pantheon of projects that the world's greatest architects aspire to design. Beijing, Kuala Lumpur, Hong Kong, Paris, Chicago, San Francisco: the airports in these places have become landmarks themselves, attracting tourists from all over the world. In his book "Airports: A century of architecture," peter human describes the major airports of the world as Mega airports, those that can genuinely claim to be cities themselves



PRECEDENTS

CHANGI INTERNATIONAL AIRPORT, SINGAPORE[16]

Changi International Airport in Singapore is the busiest airport in Southeast Asia(As of 2019) is located on a 13 square Km site. The airport consists of a total of 5 terminals supporting 68.2 million passengers per year. Like several airports, Changi International airport has grown and evolved rapidly over 37 years, adding new terminals in 1981, 1990, 2008, 2012, and 2017.

The expansion of the airport is a true example of a large-scale urban plan that was designed by keeping growth over time in mind. The Changi Airport authority mainly focused on airport operations until the year 2012, when the authorities decided to add retail in the path of the passengers leading to the construction of Jewel. In 2017, the airport gained a significant amount of popularity after the completion of the jewel designed by Moshe Sadafie. The jewel houses a complex program that includes retail, restaurants, hotel, parking, airport offices, public gardens serving the passengers as well as the citizens of Singapore. Leading to the creation of this bespoke garden/ glass structure covering the entire airport creating a surreal experience.

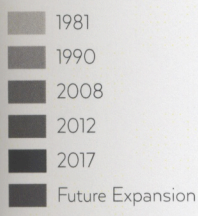


Figure. 1: Changi Intertrnational airport expansion

BEIJING CAPITAL INTERNATIONAL AIRPORT, CHINA[17]

Beijing Capital International Airport is the second busiest airport in the world, handling more than 90 million passengers every year. [18]The drag-on-like layout of the terminals is meant to celebrate the thrill and poetry of flight, while the orange roof evokes the vibrant coloration of the city's famed Forbidden City. and was built to support the traffic for the 2008 Beijing Olympics.[19]

The views along the central axis are marked by discrete red colored columns reminiscent of Traditional Chinese Temples.The airport is designed with the aim of resolving complexities of modern air travel, with spatial clarity around the space under the loop of well-connected services.The Terminal Building is incorporated with multiple passive environmental techniques such as taking into account optimum use of daylight with the help of skylight and the glazing oriented towards the south east to maximize heat gain from early morning sun,and an integrated environmental system aimed towards reducing energy consumption.For its construction, the Airport used locally sourced materials and application of Local skills, for creating a sense of belongingness to the site.[20]

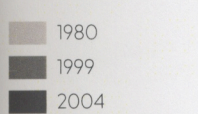
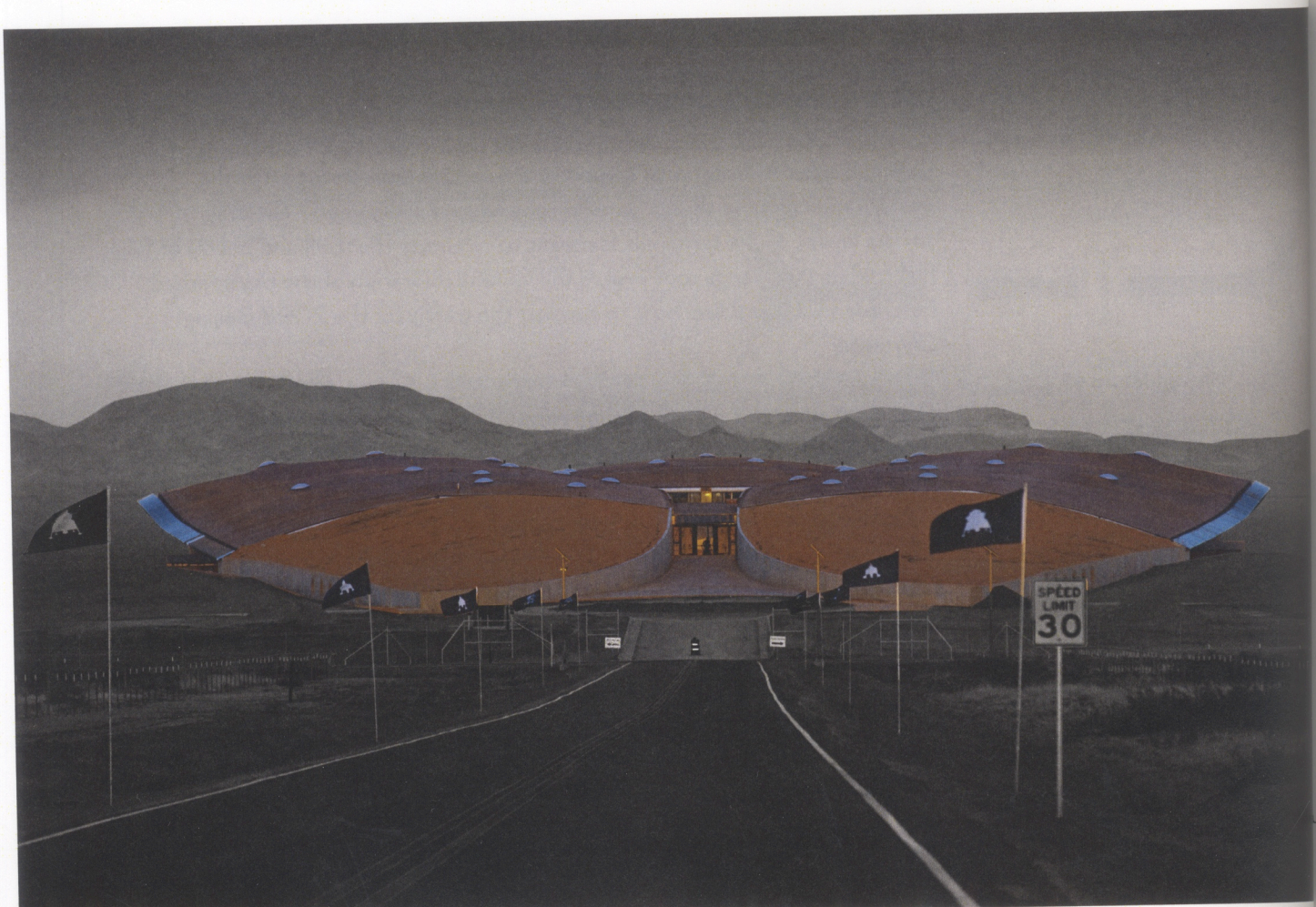


Figure. 2: Beijing Capital Intertrnation Airport expansion


SPEED
LIMIT
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BEIJING DAXING INTERNATIONAL AIRPORT, CHINA

Beijing Daxing International Airport is a comprehensive transportation Facility designed by Zaha Hadid Architects in 2019[21]. It can cater to up to 100 million passengers annually, making it the biggest Airport in the world.[22]

The design for the Airport is based on traditional Architecture featuring a central courtyard that branches out to other connected spaces. The Airport has a large, naturally lit main Atrium space at the heart of the structure, with all amenities being accessible at different levels. Among the six arms mimicking the Starfish concept, five serve as the airport piers, whereas the sixth one houses offices, a hotel, and an internal ground Transportation system. The structure shows the concept of fluidity in a built space which symbolizes movement and easy flow of people, factors essential for a Transit Hub. The different zones within the Airport seem to connect, which enhances the experience of its users seamlessly.

Apart from being a visually appealing space, the Airport incorporates sustainable energy measures with an approach toward reducing carbon footprint by adding strategies such as solar panels, rainwater collection, and waste and water management systems.

igure. 3: Beijing daxing International Airport Aerial iew[26]

SPACEPORT AMERICA, USA[23]

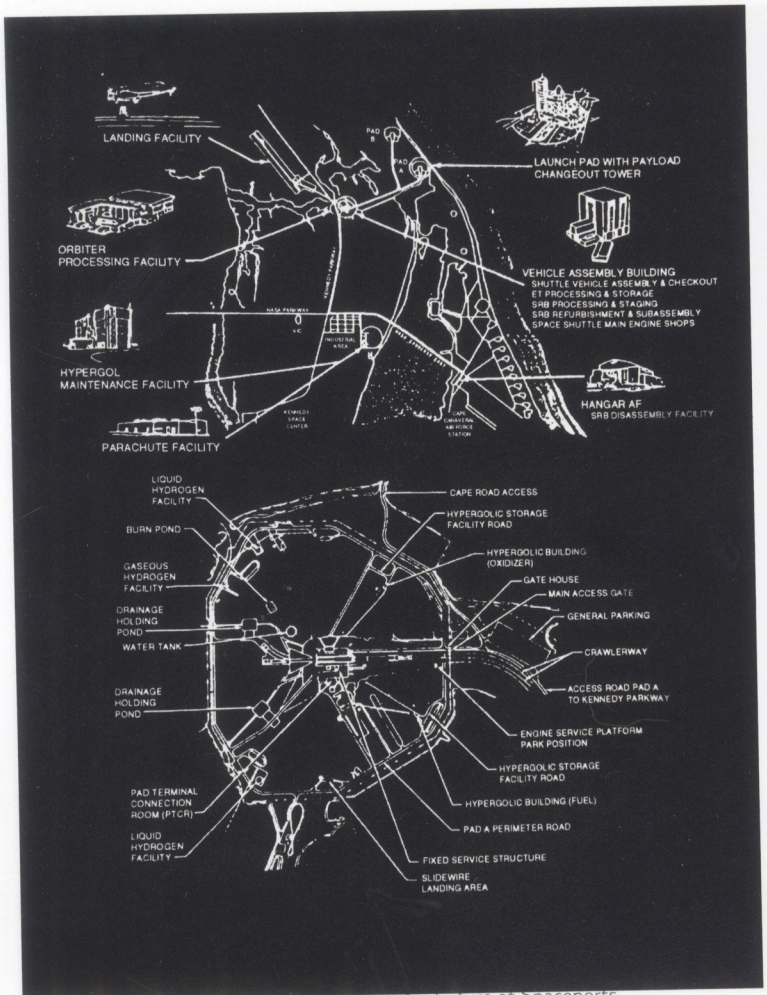
Spaceport America, formerly the Southwest Regional Spaceport, is an FAA Licensed Spaceport facility located in New Mexico. It is designed by Foster+Partners and URS Corporation and operated by New Mexico Spaceport Authority. It is the world's first purpose-built commercial Spaceport. It is the first of its kind Rocket launching facility for only commercial purposes. It is currently leased out to 5 companies for operational purposes. It is built to accommodate Vertical and Horizontal launches, with over 300 launches since 2006.[24]

The Spaceport sits on a massive site of 15.38 acres. It boasts multiple facilities like two hangers, a training area, a departure lounge, a restaurant, spacesuit dressing rooms, a celebration area, and a runway. The Western Zone of the facility accommodates administrative and other support facilities for Virgin Galactic and the New Mexico Spaceport Authority. The eastern zone comprises of principal operational training area, departure lounge, spacesuit dressing rooms, and celebration areas.

The Building was accredited with LEED Gold Certification upon its completion in 2014 for its incorporation of environmentally sustainable techniques such as Solar thermal panels, Earth Tubes and underfloor Radiant Cooling, and Natural Ventilation.[25]

igure. 4: View of Spaceport America, New Mexico[27]

NASA


LANDING FACILITY
LAUNCH PAD WITH PAYLOAD CHANGEOUT TOWER
ORBITER PROCESSING FACILITY
VEHICLE ASSEMBLY BUILDING
SHUTTLE VEHICLE ASSEMBLY & CHECKOUT
ET PROCESSING & STORAGE
SRB PROCESSING & STAGING
SRB REFURBISHMENT & SUBASSEMBLY
SPACE SHUTTLE MAIN ENGINE SHOPS
HYPERGOL MAINTENANCE FACILITY
HANGAR AF
SRB DISASSEMBLY FACILITY
PARACHUTE FACILITY
LIQUID HYDROGEN FACILITY
CAPE ROAD ACCESS
HYPERGOLIC STORAGE FACILITY ROAD
BURN POND
HYPERGOLIC BUILDING (OXIDIZER)
GASEOUS HYDROGEN FACILITY
GATE HOUSE
MAIN ACCESS GATE
DRAINAGE HOLDING POND
GENERAL PARKING
WATER TANK
CRAWLERWAY
DRAINAGE HOLDING POND
ACCESS ROAD PAD A TO KENNEDY PARKWAY
ENGINE SERVICE PLATFORM PARK POSITION
HYPERGOLIC STORAGE FACILITY ROAD
PAD TERMINAL CONNECTION ROOM (PTCR)
HYPERGOLIC BUILDING (FUEL)
LIQUID HYDROGEN FACILITY
PAD A PERIMETER ROAD
FIXED SERVICE STRUCTURE
SLIDEWIRE LANDING AREA

KENNEDY SPACE CENTER: LAUNCH COMPLEX 39 A

This document was prepared by Nation Aeronautics and Space Administration(NASA), highlighting the Key Features of the two launch pads designed at the Kennedy space center that served as one of the essential parts for the manned space flight endeavors. Both the pads are octagonal shaped and cover a quarter-square mile of land. The launches are conducted on top of 390 feet by 325 feet concrete hardstand. The main components of a launching pad are as follows:[28]

Fixed Service Structure [29]

It is one of the most prominent features and stands 347 ft from ground level. The Fixed service structure contains 12 floors positioned at 20 ft intervals and is equipped with three swing arms, also known as umbilicals, that provide access to the rocket.

- Orbiter Access Arm
- External tank hydrogen vents umbilical and inter-tank arm.
- Outer tank gaseous oxygen vent arm
- It also consists of a rope line used as an emergency egress system.

Rotating Service structure[30]

The RSS provides secure access (Contaminant free and vacuumed space) to the rocket for installation and service of the payloads. The majority of the payloads are installed to a rocket when it is in a vertical position. It is partly because of the design and partially because it can occur later during the launching process. The RSS is later retracted from the rocket right before the launch. It consists of:

- Payload changeout room
- Payload ground handling mechanism (5 platforms)
- Liquid oxygen and hydrogen lines
- Hypergolic fuel and oxidizer lines

Flame trench Deflector System to guide the flame from the rocket fuel engine.[31]

Liquid Hydrogen and Liquid hydrogen tanks are located ⅛ mile in the northeast and west direction, respectively.[32]

Hypergolic Storage is located on the south of the launch pad.[33]

Pad terminal connection room [34]

Sound suppression system consisting of 300,000 gallons of water on the northeast of the pad.[35]

Figure. 5: Kenndey Space Center Aerial View [36]
Figure. 6: Launch Pad 39 A - Technical Diagram [37]
Figure. 7: Launch Pad 39 A - 2010's[38]
Figure. 8: Launch Pad 39 A - 2020[39]

2001:A SPACE ODYSSEY (1968) - MOVIE

40

2001: A space odyssey is a 1968 Science fiction movie directed by Stanley Kubrick. The movie is based on a short story, "The Sentinel," written by Kubrick and Arthur C. Clarke in 1951. It incorporates three short stories about Human Evolution, Life in space and Extraterrestrial Life, and artificial intelligence tied together by a giant Extraterrestrial object.

The Film Begins with a prehistoric setting taking the viewers to the Early days of human evolution by displaying a herd of man-apes living their lives in a deserted location, Living their lives by surviving on the scarcely available food. The next day a giant Monolith appears in the middle of their shelter in the rocky area, confusing the man-apes and developing a curiosity among them to touch it and discover what it was. Bring attention to the early days of curiosity among living beings to find out and explore things. Later, as the man-ape started to develop cognitive skills as his brain grew, it led him to develop weapons to protect his herd/ community from others. Humans have been part of herds/ groups/ communities since the beginning of time and have thus grown.

In a blink, the movie transfers into the scene from early civilization to 2001, i.e., 49 yrs into the future from when the movie was built. Dr. Haywood Floyd, a scientist, is shown traveling to the moon in a spaceplane. The plane eventually lands into a space station where he checks in with and immigration and then lounges. Later on, when he lands at the moon in one of the orbiters, he is aware that the monolith has been found on the moon's surface that predates human civilization. The team later that day when Dr. Flyod and his team of scientists drive across the moon to view the monolith. As they uncover the giant monolith, the sunlight hits upon it for the first time and sends a piercing sound signal to the far reaches of the universe.[41]

The detail in design in the movie makes one understand what a space-trav-

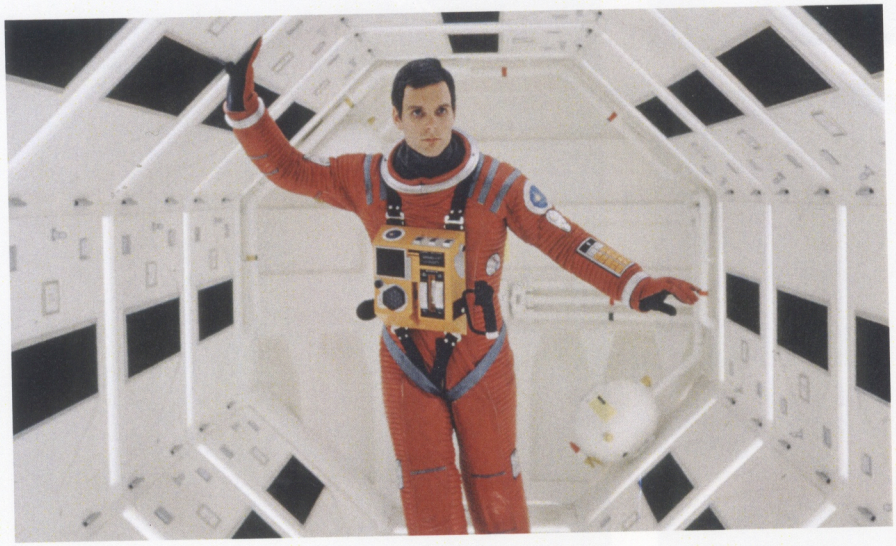


Figure. 9: 2001 : A Space Odyssey poster[44]

eling in the future might look like. Some of the critical design details that stood out were:

- Anti Gravity Planes,
- Sipping food in a flight instead of eating,
- The rotating immigration center, Hotel, Digital shop, and lounge space are located in a giant circular space station.
- The artificial intelligence controlling the missions and mostly everything. (Alexa, Siri, or Google didn't exist in 1958)
- Whole research colonies with families living in it.
- All these details thus help one imagine where we were 3 million years ago to what the future of traveling/ living in outer space would look like.

THE EXPANSE (2015 - 2021) - TV SERIES[42]

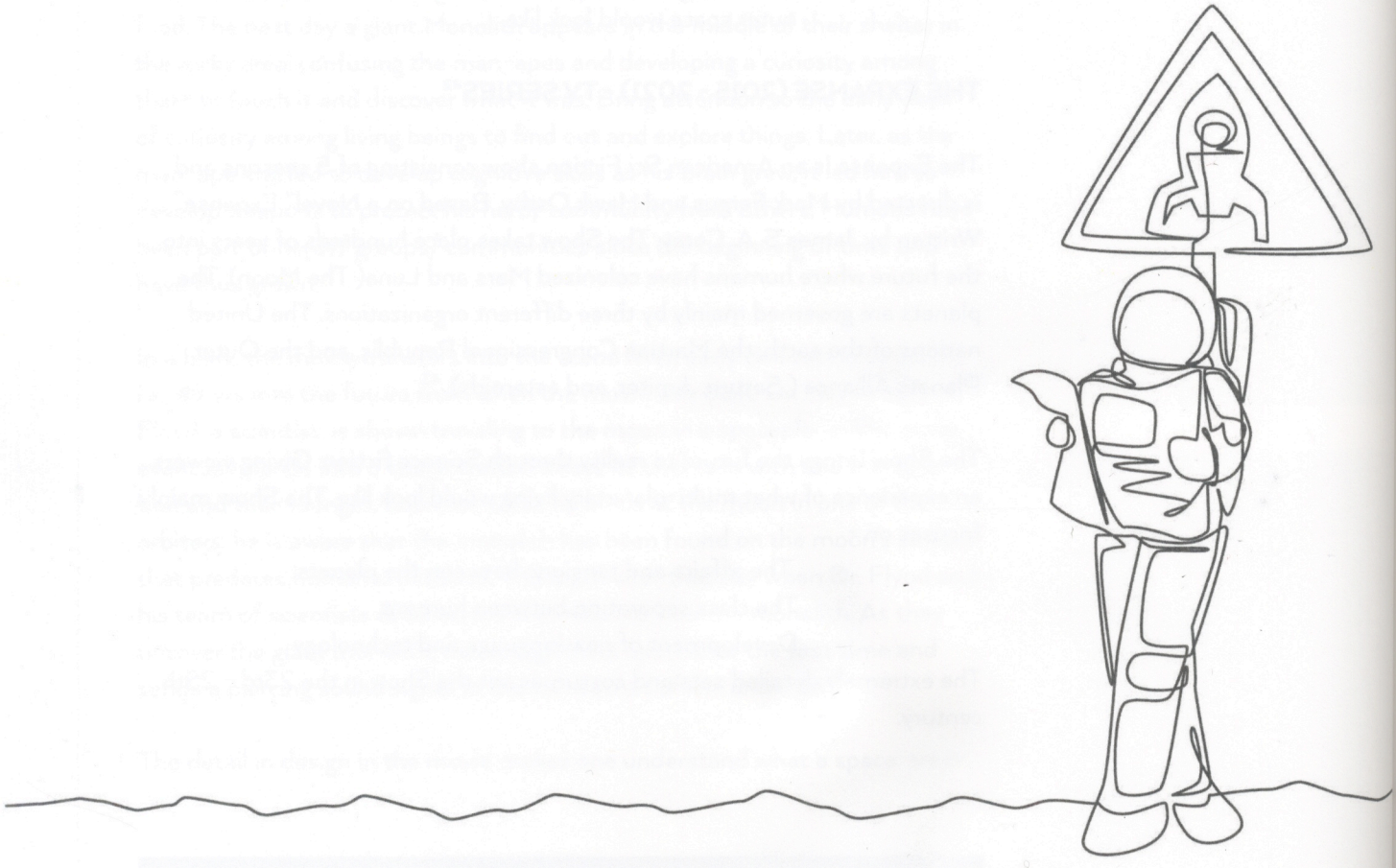
The Expanse is an American Sci Fiction show consisting of 5 seasons and is directed by Mark Fergus and Hawk Ostby. Based on a Novel" Expanse" Written by James S. A. Corey. The Show takes place hundreds of years into the future where humans have colonized Mars and Luna(The Moon). The planets are governed mainly by three different organizations, The United nations of the earth, the Martian Congressional Republic, and the Outer Planets Alliance (Saturn, Jupiter, and asteroids). [43]

The Show brings the future to reality through Science fiction, Giving viewers an experience of what multi-planetary living would look like. The Show mainly focuses on -

- The affairs and tensions between the planets.
- The class separation between humans
- Development of new language and technology

The extremely detailed sets and costumes set the Show in the 23rd - 25th century.

Figure. 10: Expanse Season 5 Poster[45]



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SITE ANALYSIS

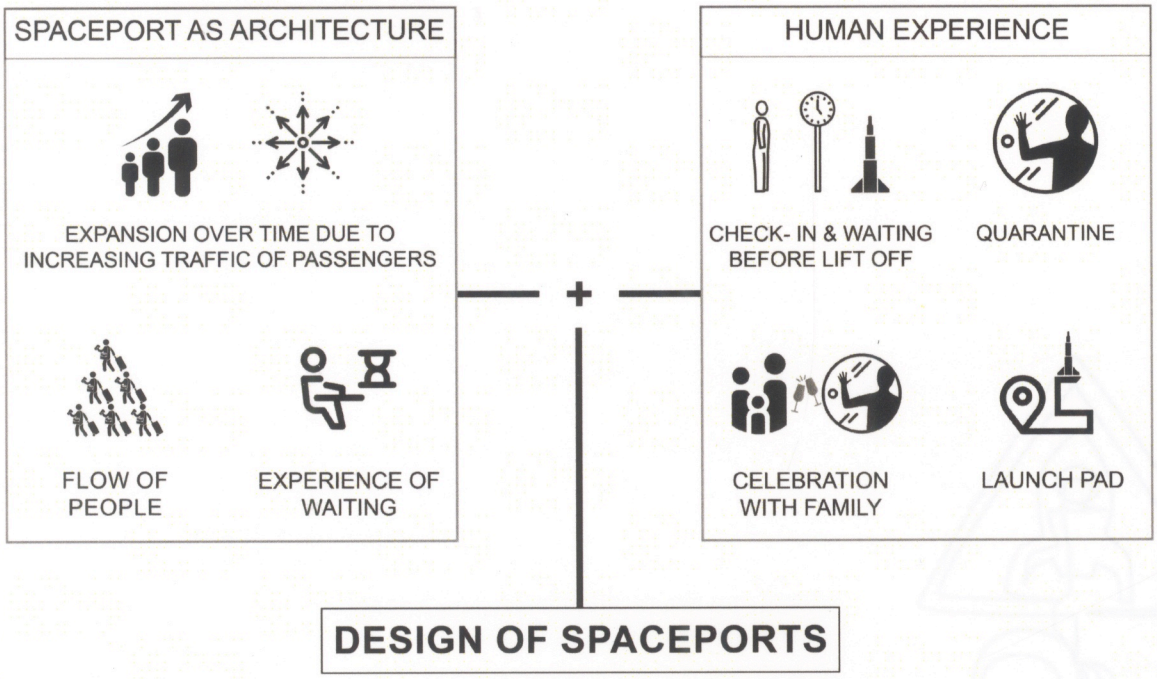


Figure. 11: Time Scales for design and expansion of Spaceport

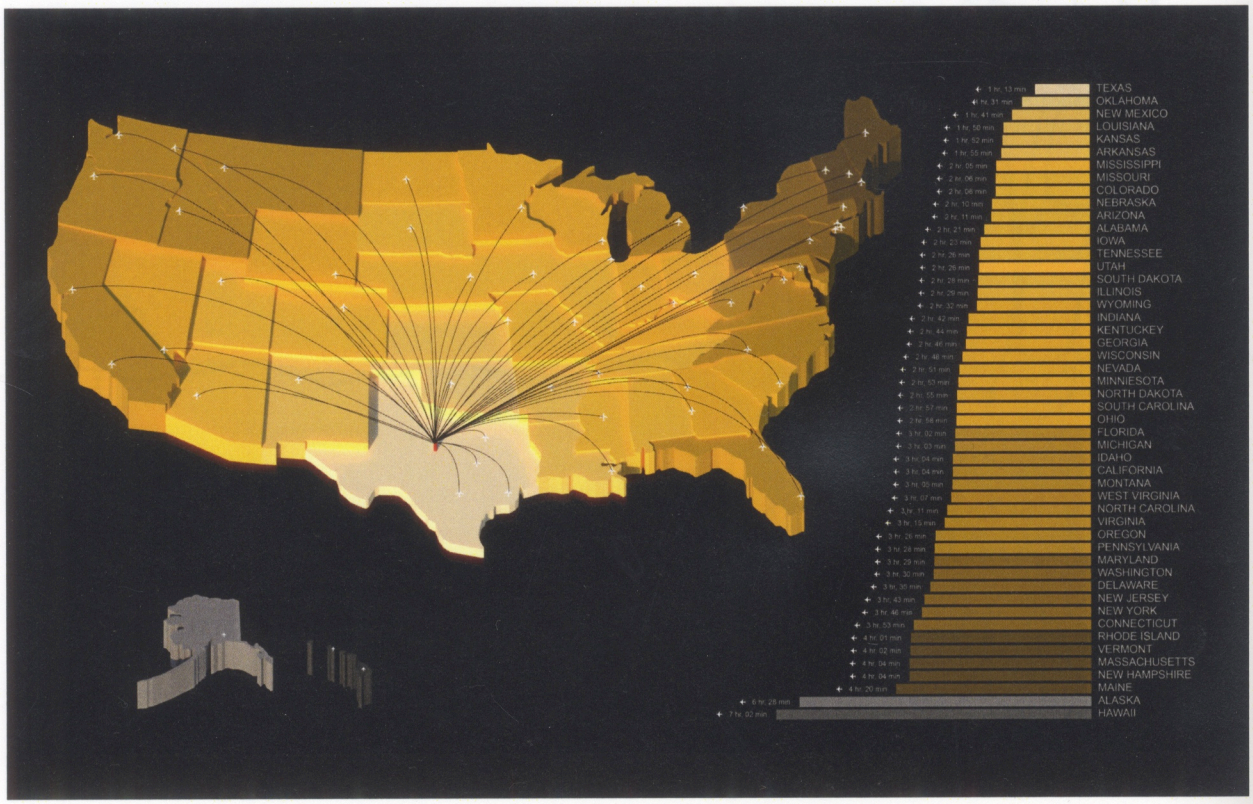


Figure. 12: Flight Connection time to site from major Airports around the United States of America

TRAVEL : ROCKET V/S AIRPLANE

The program divides the travelers into two distinct categories, namely Inter-Galactic and Inter-Continental, respective of their travel destination. Intergalactic travel refers to travel from Earth to a different celestial body or a planet, and Intercontinental travel refers to travel to various destinations within the Earth.

The chart below shows a comparative analysis of the current duration of travel completed through Airplanes from the US domestically and internationally and the projected time a rocket takes to achieve the same journey. With comparable time for pre-departure procedures that include check-in, boarding, and check-out, the total time for the trip between the two modes of transportation is very prominent. For instance, The typical journey from new york to Paris is 3643 miles, and traveling in an airplane takes about 7hrs and 20 mins. This time will shorten to only 30 min when traveled by rocket.[48]

The right part of the chart shows the time taken for Interplanetary travel, from Earth to other celestial bodies, based on the numbers provided by

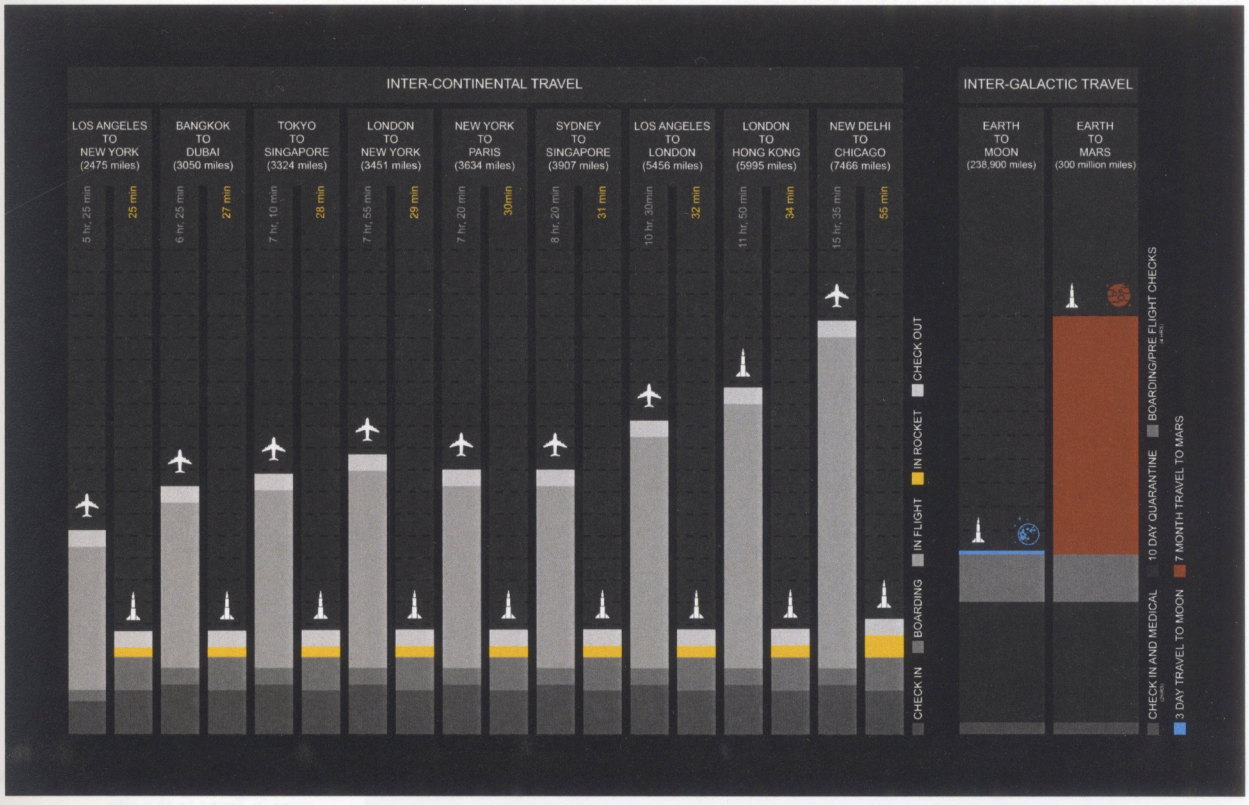


Figure. 13: The chart above displays two things - Types of travelers for spaceport and Airplane v/s Rocket traveling time

Information source[47]

SITE

The chosen site is located in the heart of Texas, which is within 2 hours of Flight Range and 1 hour of Hyperloop projected as Connections to the Spaceport. The site also offers excellent connectivity, being within a nominal distance from Major cities like Houston, San Antonio, and Austin. To decide on the site to construct this large-scale project, the following factors[50] were taken into consideration :

- Year-round nominal weather.
- Proximity to water
- Closest to the equator for efficient orbital launch.
- Proximity to existing Space center facilities.
- Availability of a 10-15 sq Mile land
- Availability of a Minimum of 2.5-mile distance from the civilization for safe launch.

The site is further divided into two zones: the North Zone, which would house the infrastructure of the Spaceport, and The South Zone, which would be used as a Launch Site for the rockets.

The south side also has a 2.5-mile perimeter setback as specified in Federal Aviation Industry Faa guidelines. The Colorado River and OH Ivie Lake flow through the site, and thus a 3-mile radius of setback is set to protect the Natural resource.

To accommodate the facility's future expansion, A buffer zone has been established on the southwest of the site, which can act as future cargo terminals.

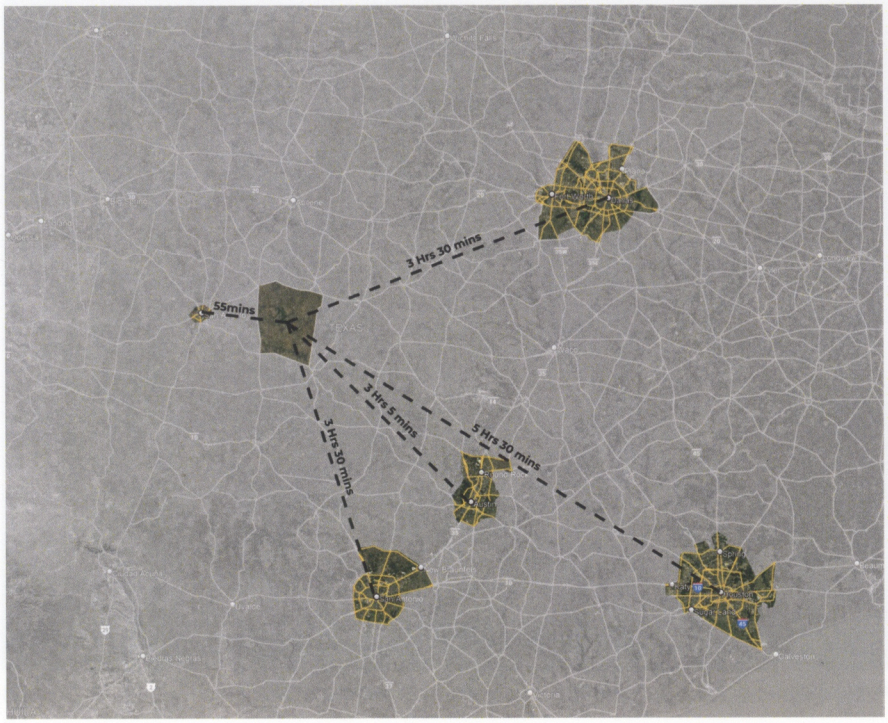


Figure. 14: Time taken to travel by road from m
cities in Texas to the site

Base

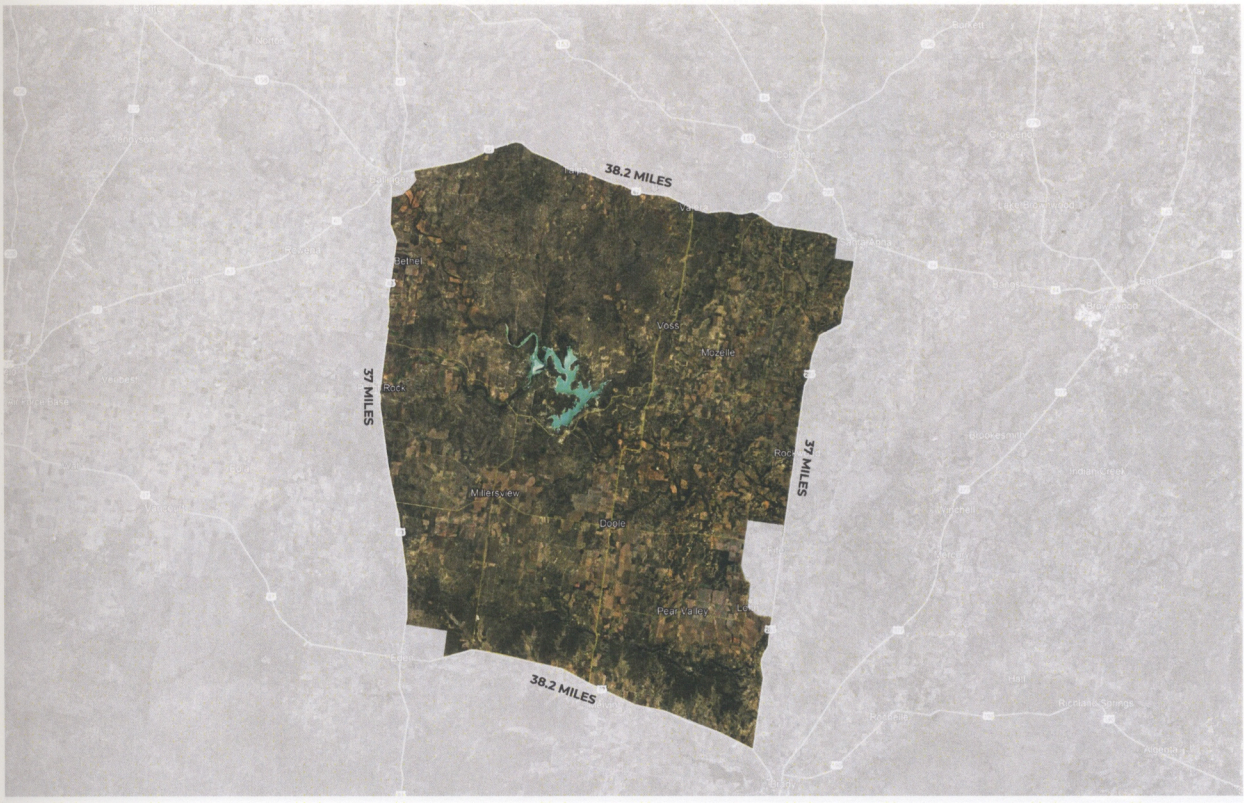


Figure. 15: Satellite view of site and perimeter lengths

Base Image[51]

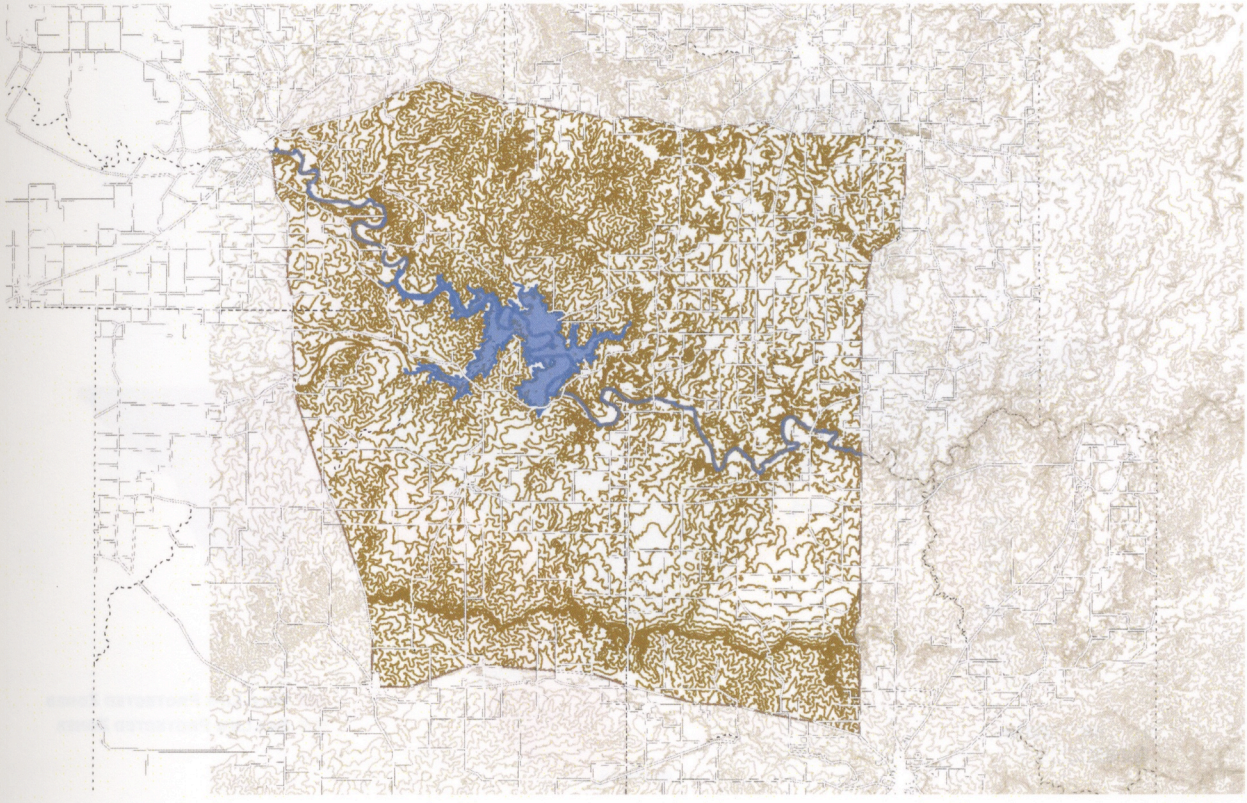


Figure. 16: QGIS map - Site topography

Data[52]

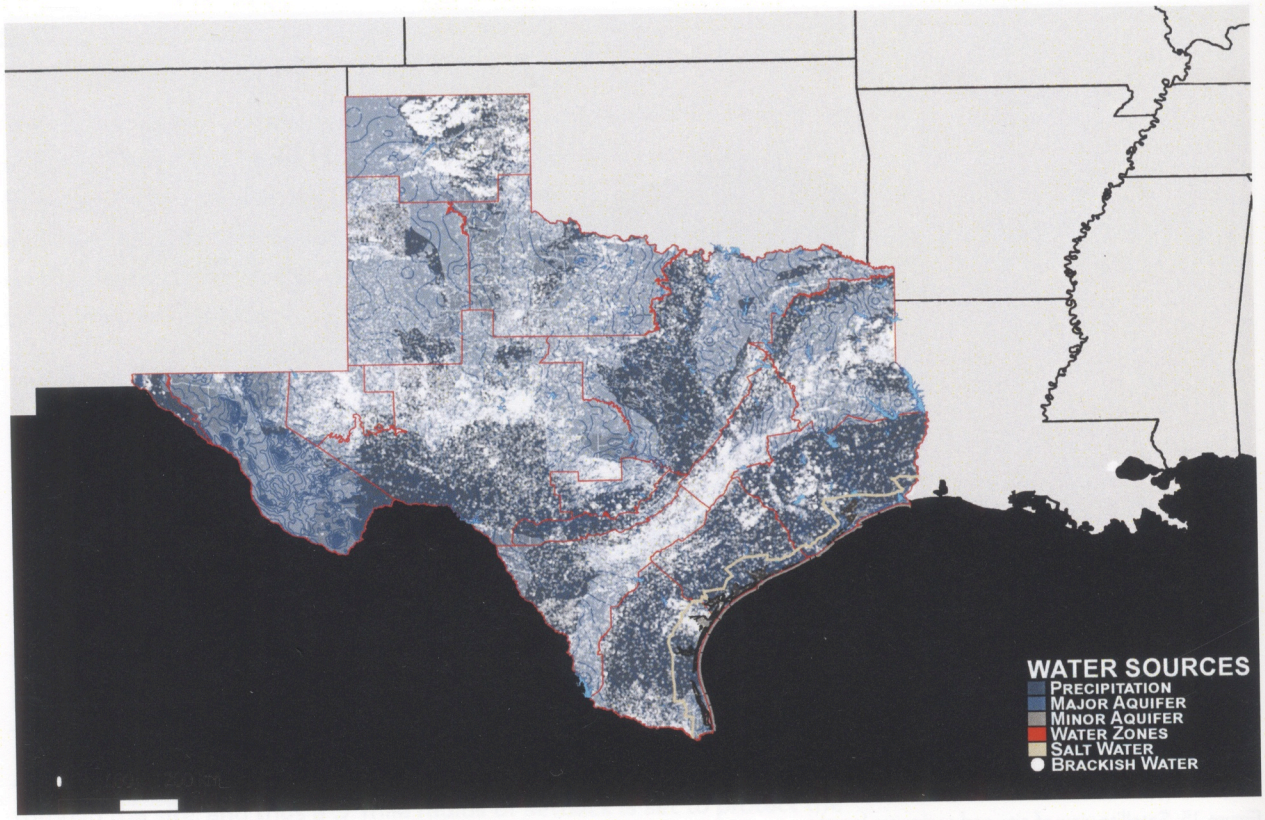


Figure. 17: QGIS map - Natural water resources in Texas

Data[53]

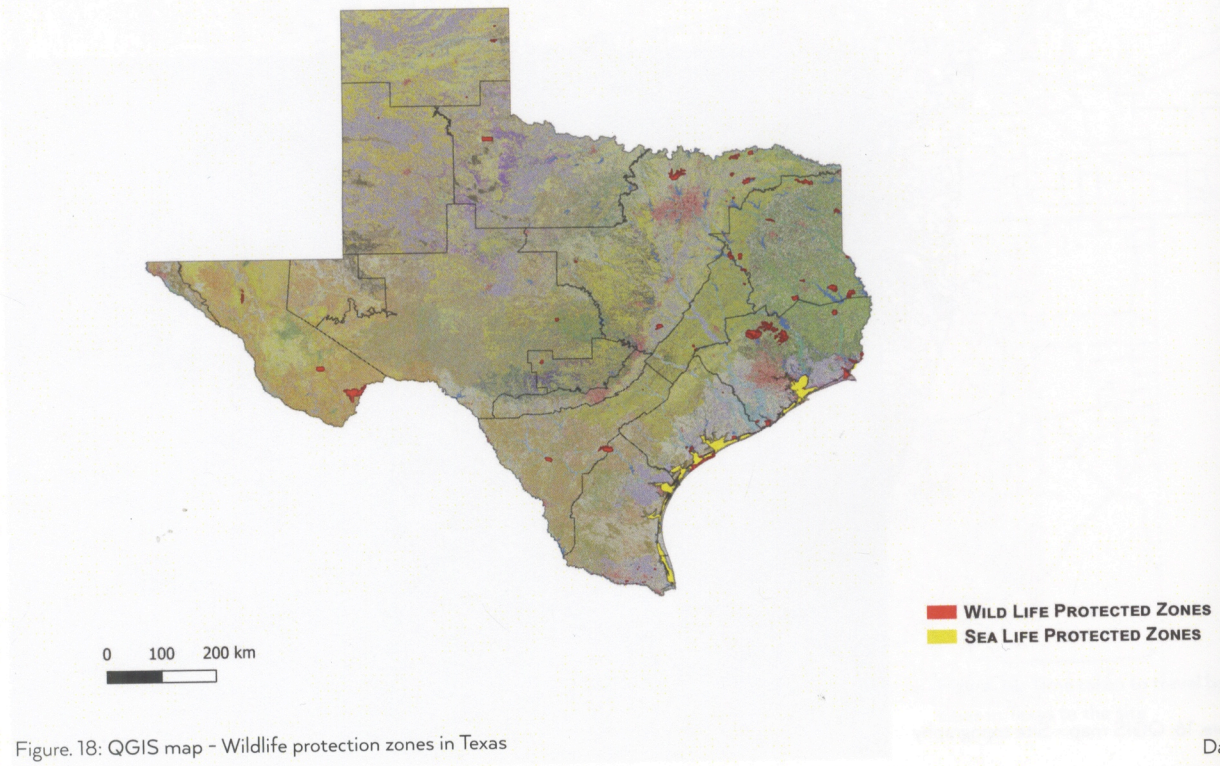


Figure. 18: QGIS map - Wildlife protection zones in Texas

Data[54]

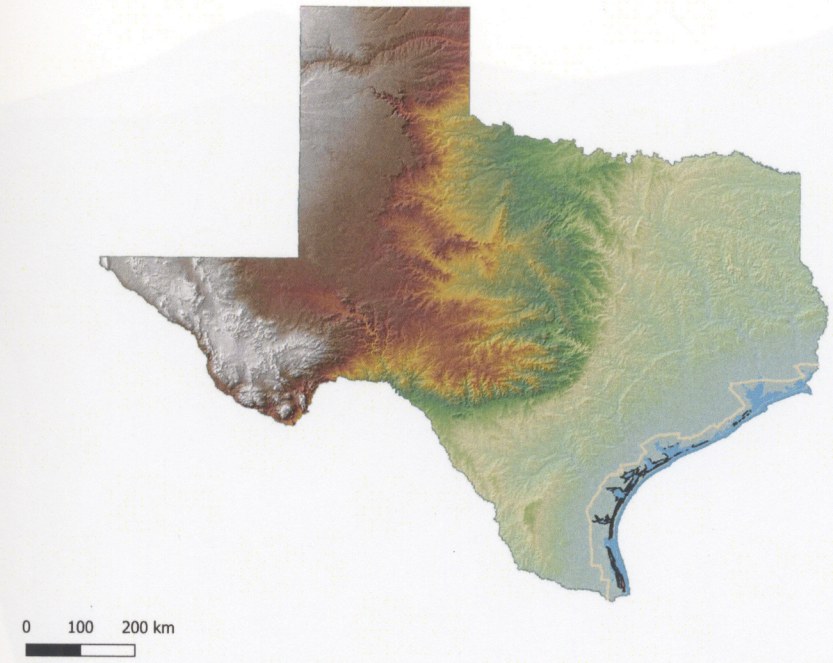


Figure. 19: QGIS map - Texas terrain

Data[55]

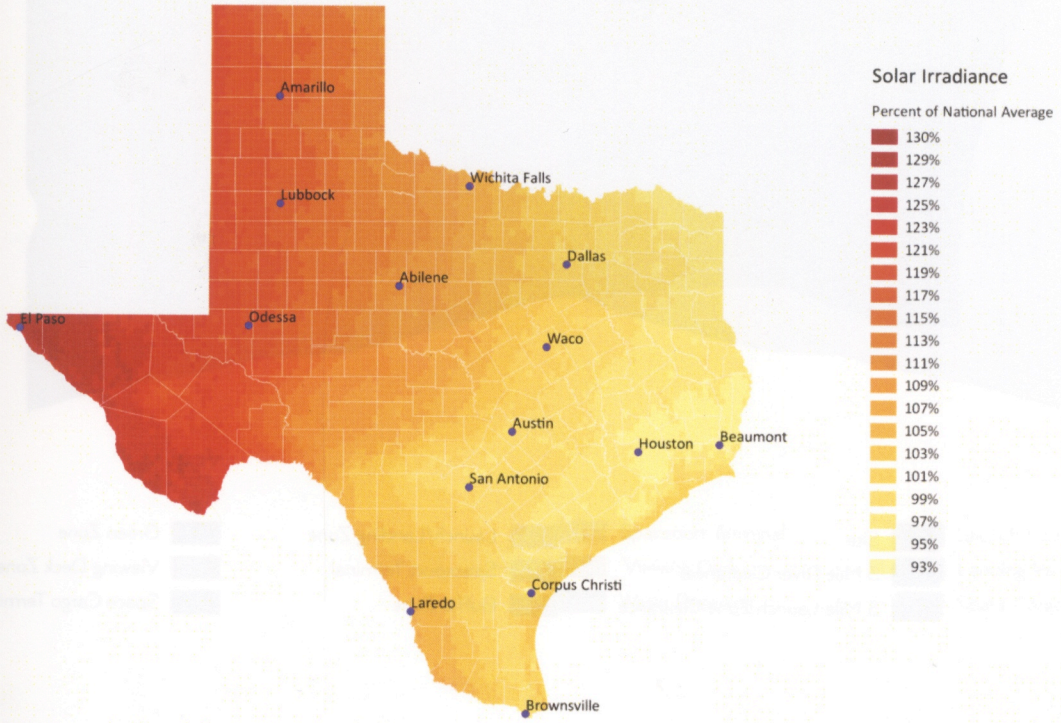


Figure. 20: Texas solar resource - Average annual irradiance map [56]

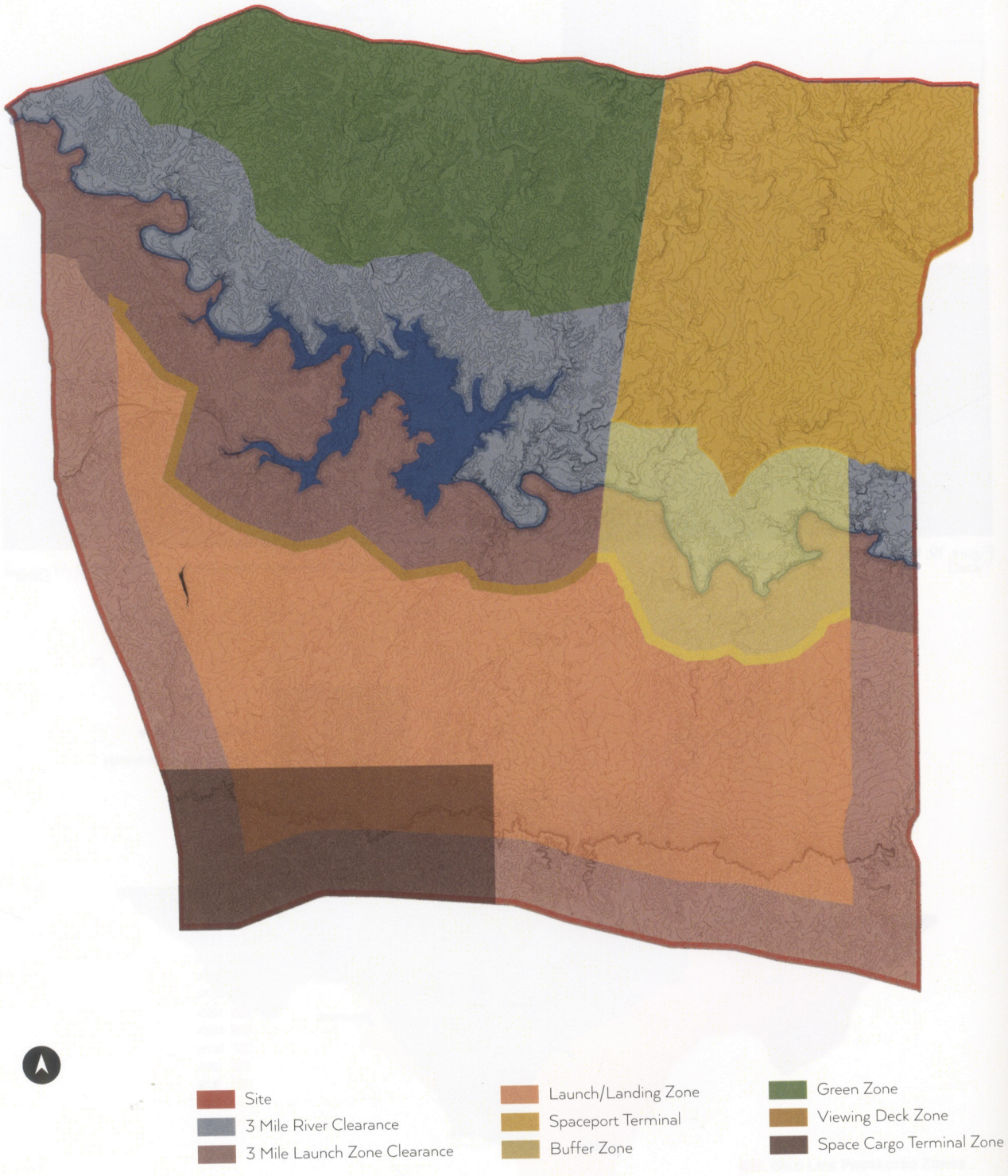


Figure. 21: Site zoning map based on FAA regulations

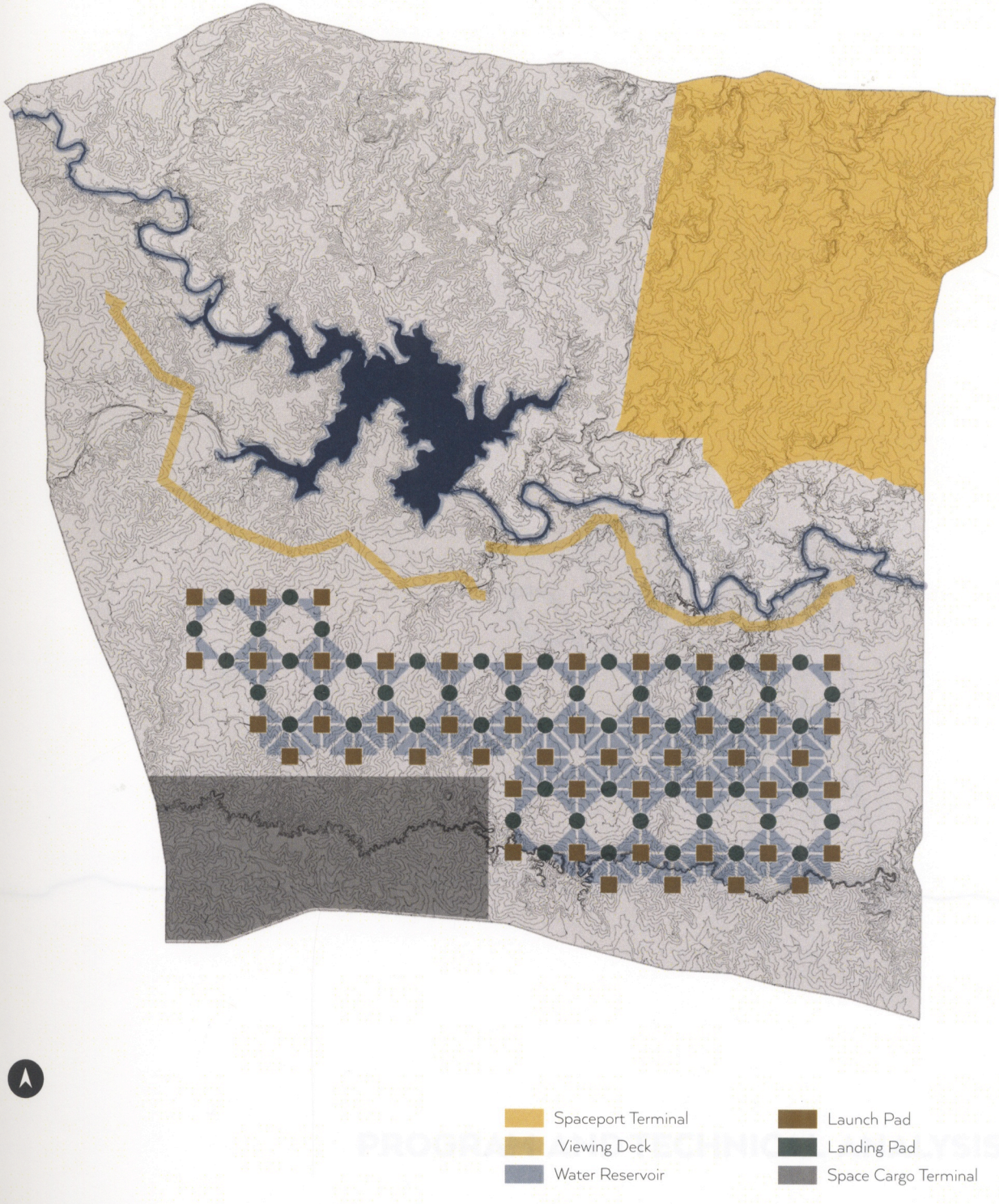


Figure. 22: Spaceport Program Zones

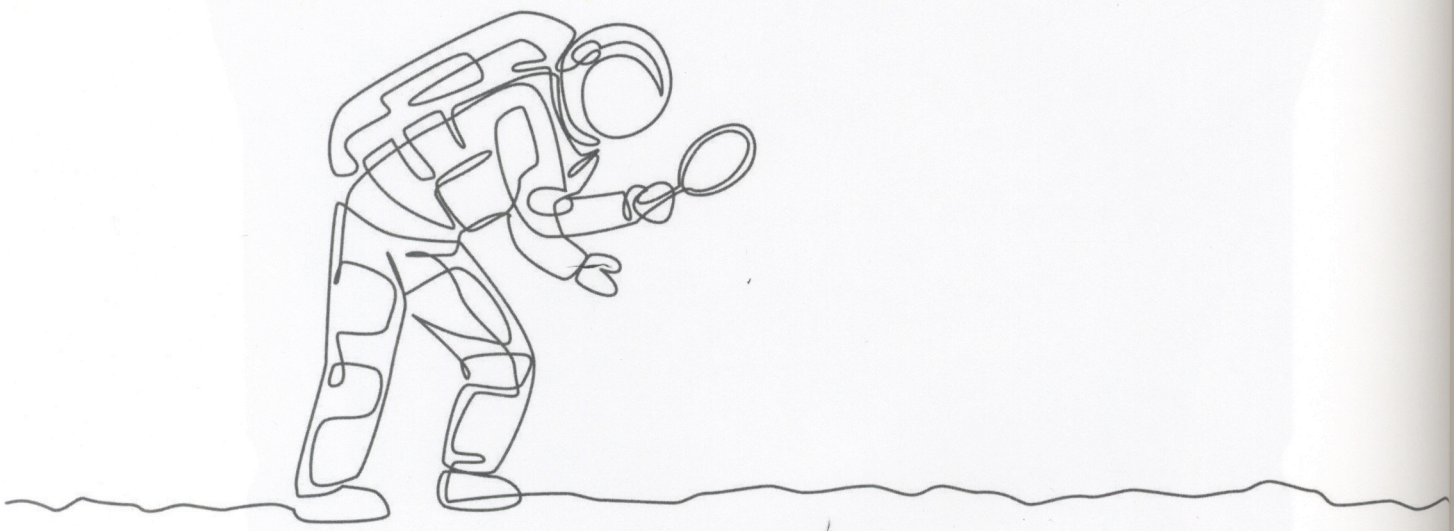


Image Source : Simple Line (Vecto

PROGRAM AND TECHNICAL ANALYSIS

CONCEPTUAL PROGRAM DIAGRAMS

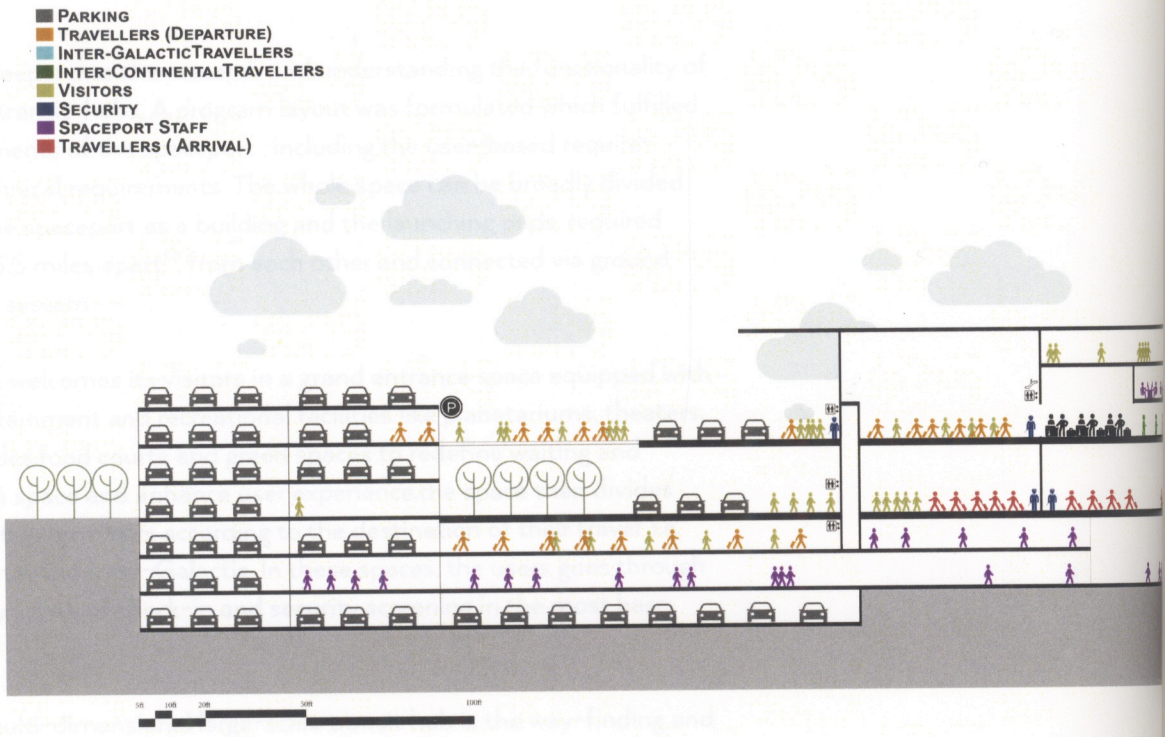


Figure. 24: Program based conceptual section

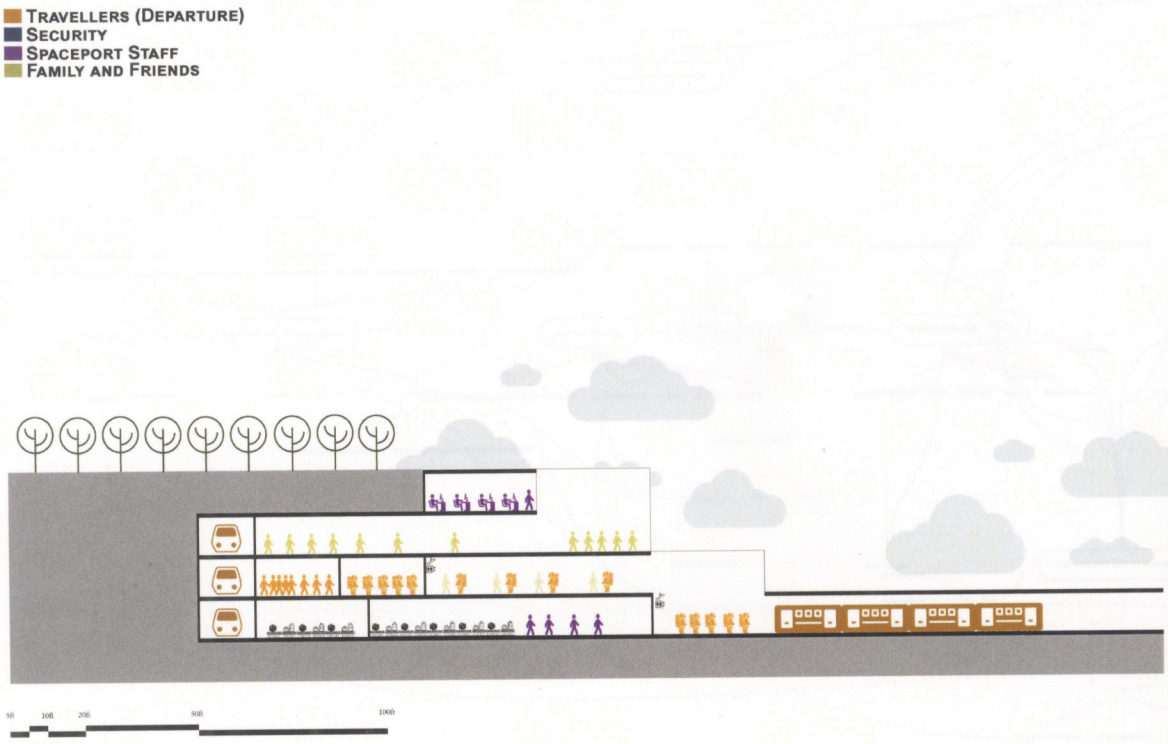
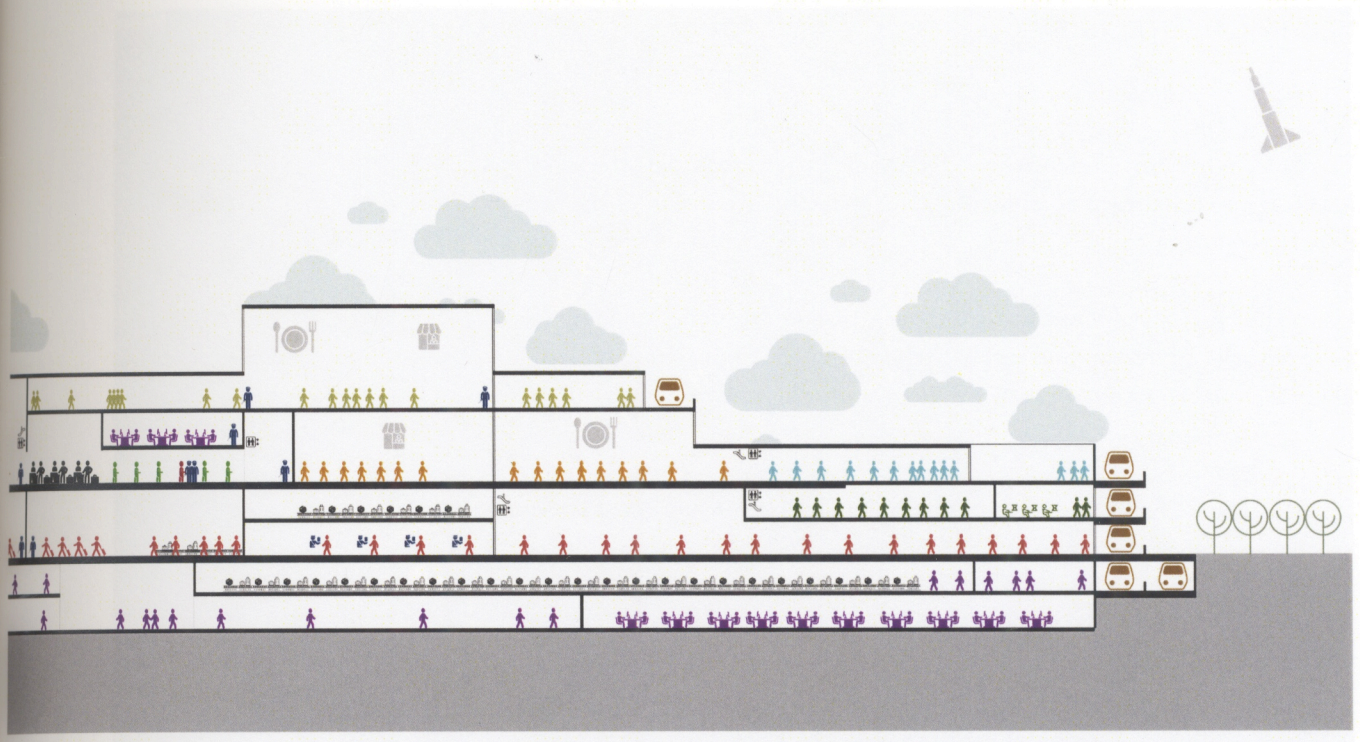


Figure. 25: Conceptual viewing deck section



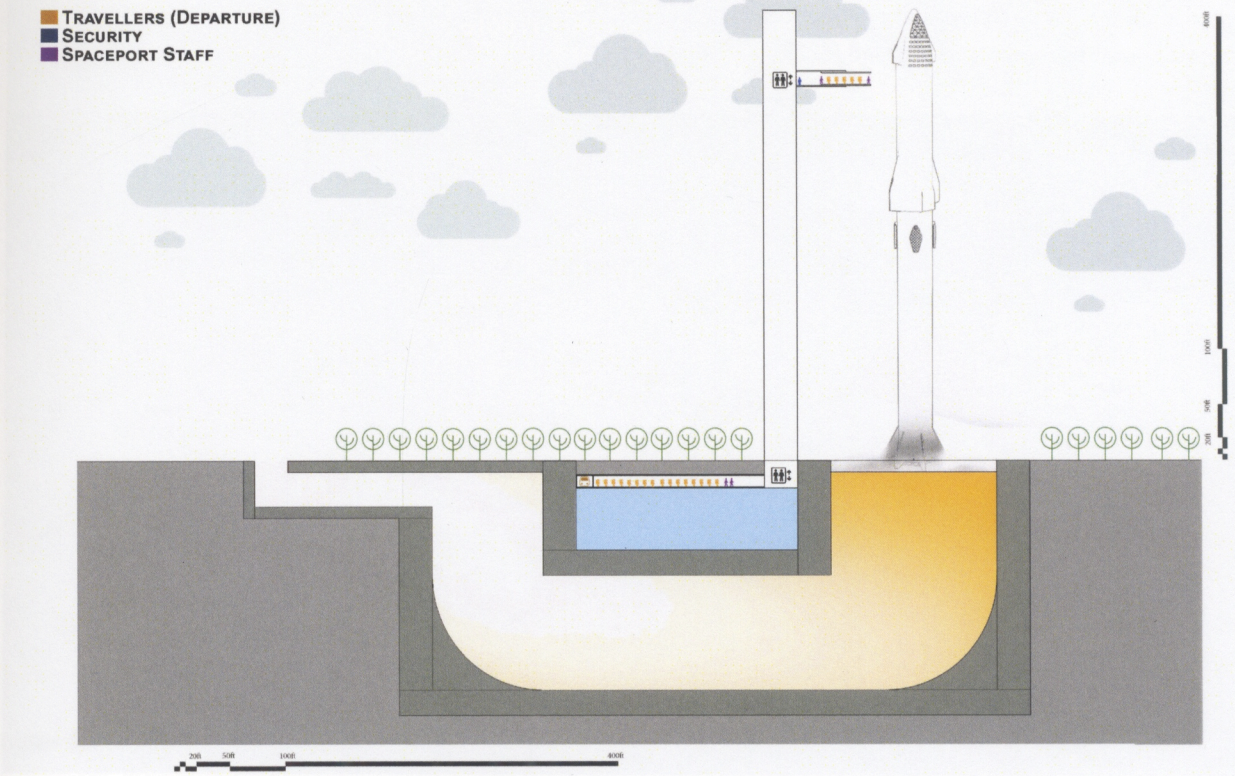


Figure. 26: Conceptual launch pad section

TECHNICAL ANALYSIS

The precedents provided a clear understanding to me regarding the variables involved into the design of launch/landing pads and expansion of the space-port facility over time.

Using the typology of airports helped me articulate my understanding for designing the spaceport and look into the expansion, considering the variables like the increase the space travelers and other private sector companies driving the industry.

- The Jewel Changi Airport in Singapore mixes two environments - acting as a connector between Indoor Garden spaces and an Intense Marketplace - to create a community centric typology.
- Beijing Daxing Airport designed by Zaha Hadid Architects in China showcases its fluidity in a built space which symbolizes movement and easy flow of people, factors essential for a Transit Hub.The different zones within the Airport seem to seamlessly connect with each other, that enhances the experience of its users.

The launching facility follows a standardized size in terms of diameter and distance from the main spaceport.and different components such as orbiter processing facility,pad terminal connection room,gaseous hydrogen facility, Hypergol maintenance and storage facility among others.

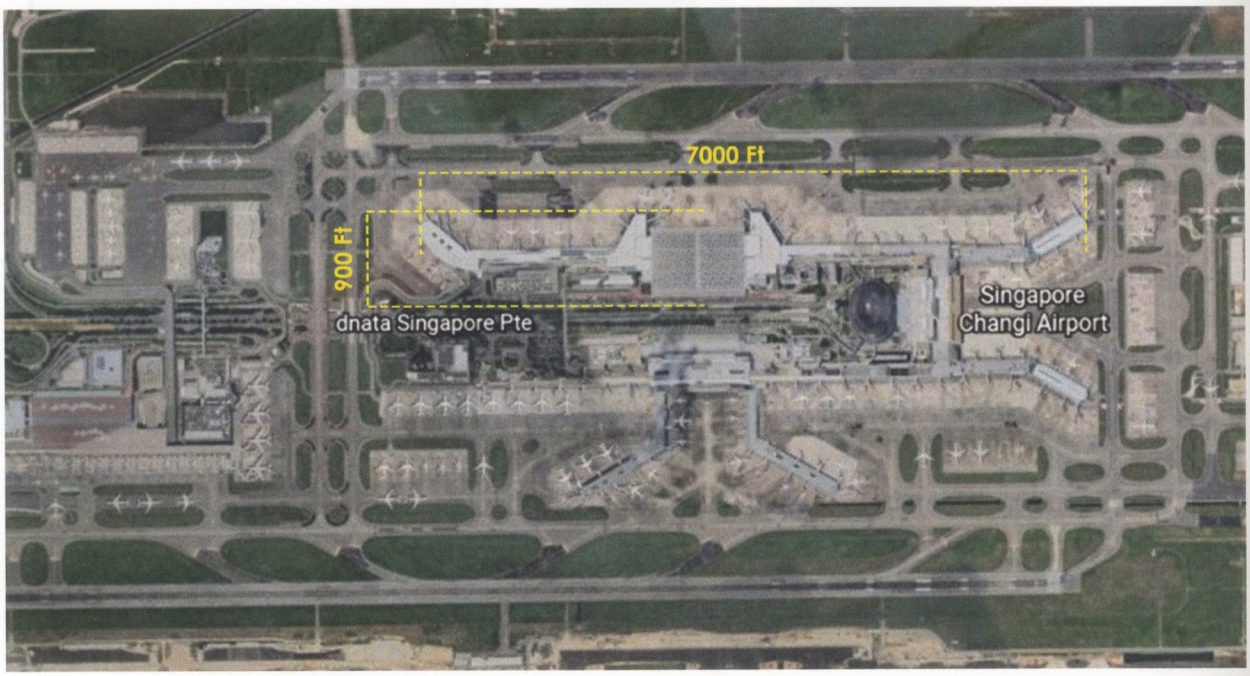


Figure. 27: Singapore Airport satellite view with overall dimensions

Base Image[59]

Figure. 28: Kennedy Space Center : Distance from facility to launch pads

Base Image[60]

Figure. 29: Kennedy Space Center : Launch pad 39 B dimensions

Base Image[61]

Image Source : Simple Line (Vecto

PROCESS WORK

INITIAL CONCEPT - HEXAGONAL GRID

The hexagonal form is prominent through various examples found in nature such as honeycomb made by bees and the formation of soap bubbles. It is a highly efficient form in terms of material used and properties of tessellation. Each unit has the scope of expansion into six different direction leading to creation of interesting forms.In order to design a highly efficient form for the spaceport, the Modularity of the Hexagonal form is explored.The modular aspect of the plan allows the design to expand uniformly as per the requirements of the space in the future with the growth in industry and influx of traffic.

Through my earlier research and precedent study, I understood how the hexagonal form is implemented in design through various parts of the building.

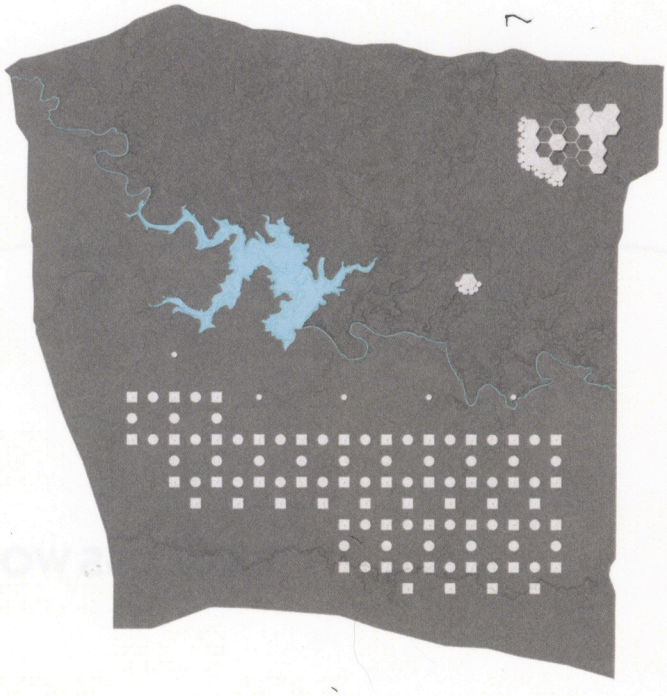


Figure. 30: Conceptual site plan ,

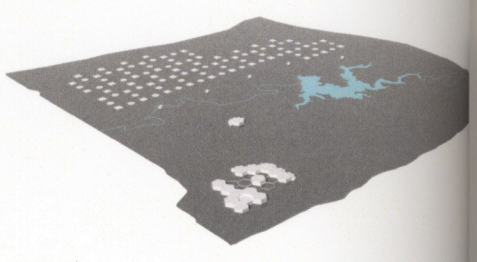


Figure. 31: Conceptual site axon

BIOMIMICRY

Figure. 32: Hexagon form Honeycomb structure[63]

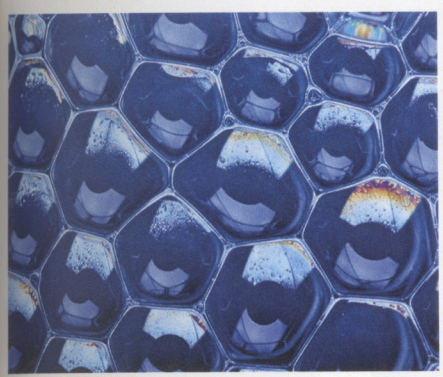


Figure. 33: Hexagon Form through soap bubble formation[64]

SPACEPORT FORM DEVELOPMENT / PROGRAMMING

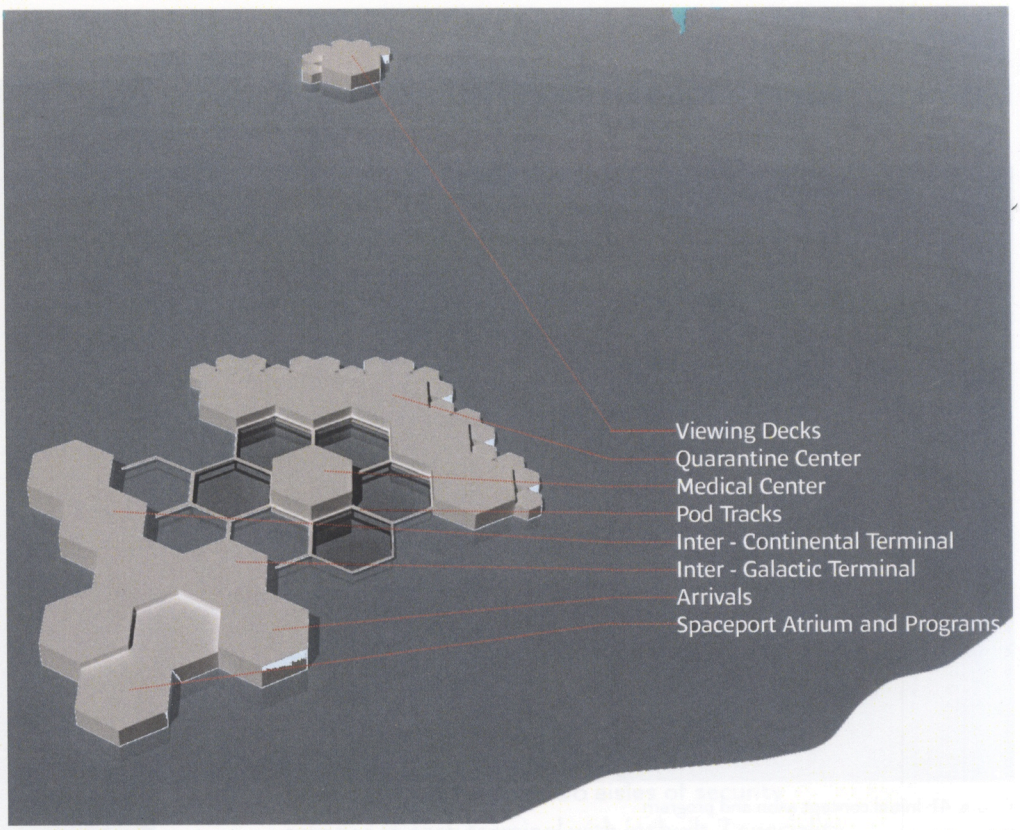


Figure. 34: Conceptual program axon

PRECEDENTS - HEXAGONAL - MODULARITY

Figure. 35: Showroom for a real estate developer in Guangzhou, China[65]

Figure. 37: New Bursa Stadium (Hexagon Park)[67]

Figure. 39: Multi-Sensorial Urban Garden Has Sprouted Up In Italy[69]

Figure. 36: Woven Wooden Canopy Covers a Botanical Garden in Colombia[66]

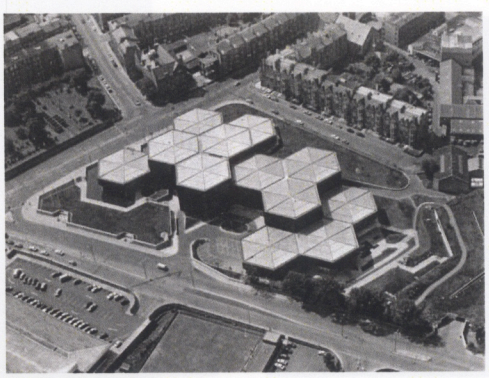


Figure. 38: Scottish Widows Office in Edinburgh[68]

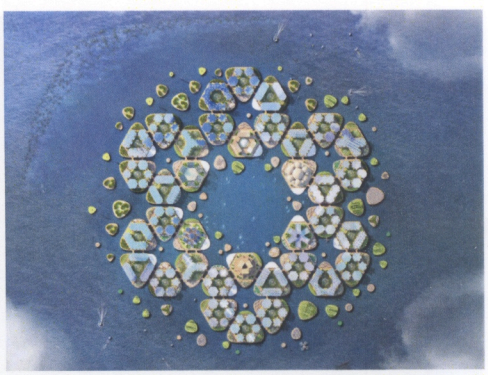


Figure. 40: Oceannix City by BIG Architects[70]

INITIAL CONCEPT - PROGRAM BASED HEXAGONAL GRID

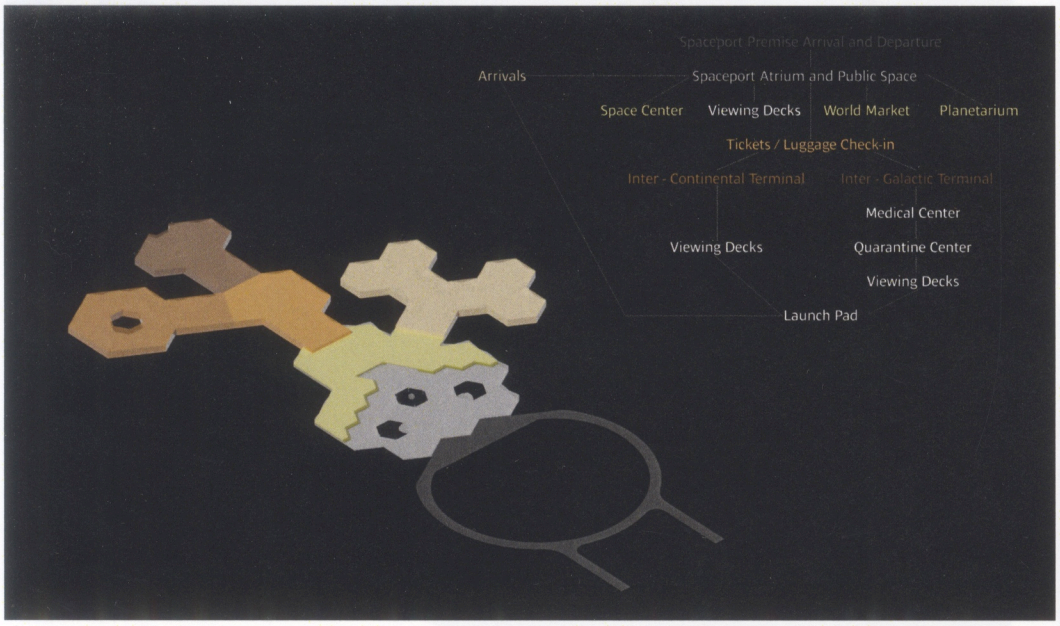


Figure. 41: Initial concept axon and program

Figure. 42: Program size compar

CONCEPTUAL SPACEPORT VIEWS

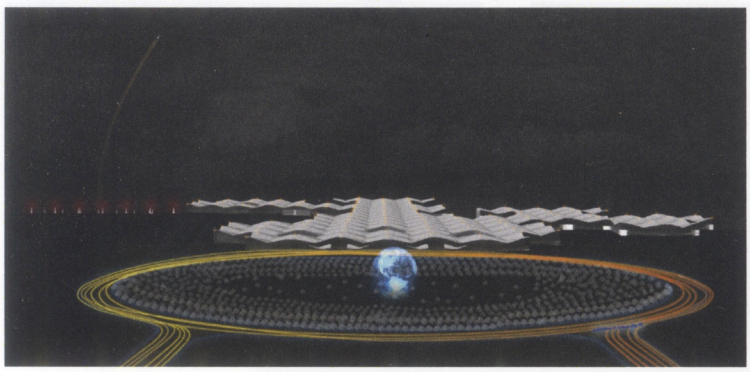


Figure. 43: Entry to site

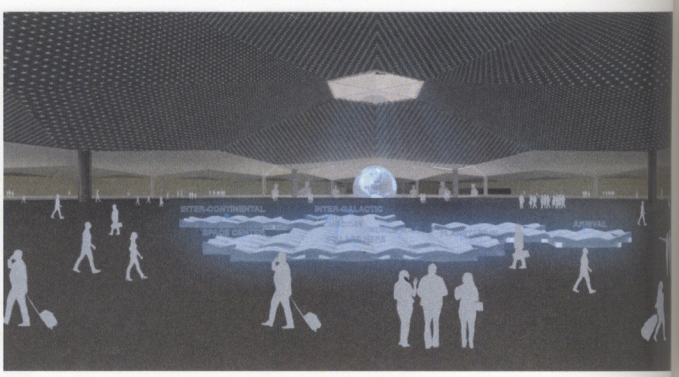


Figure. 44: Main spaceport lobby

Figure. 45: Arrival space

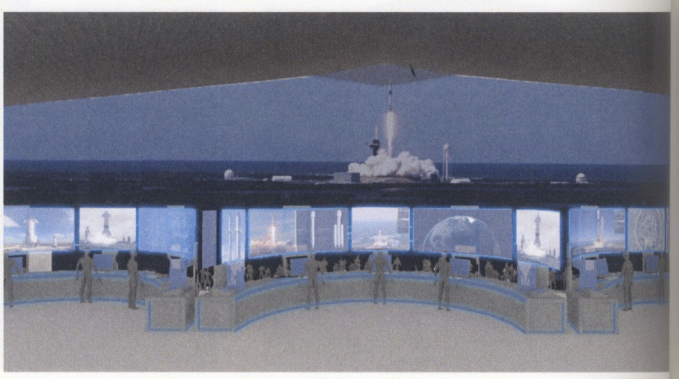
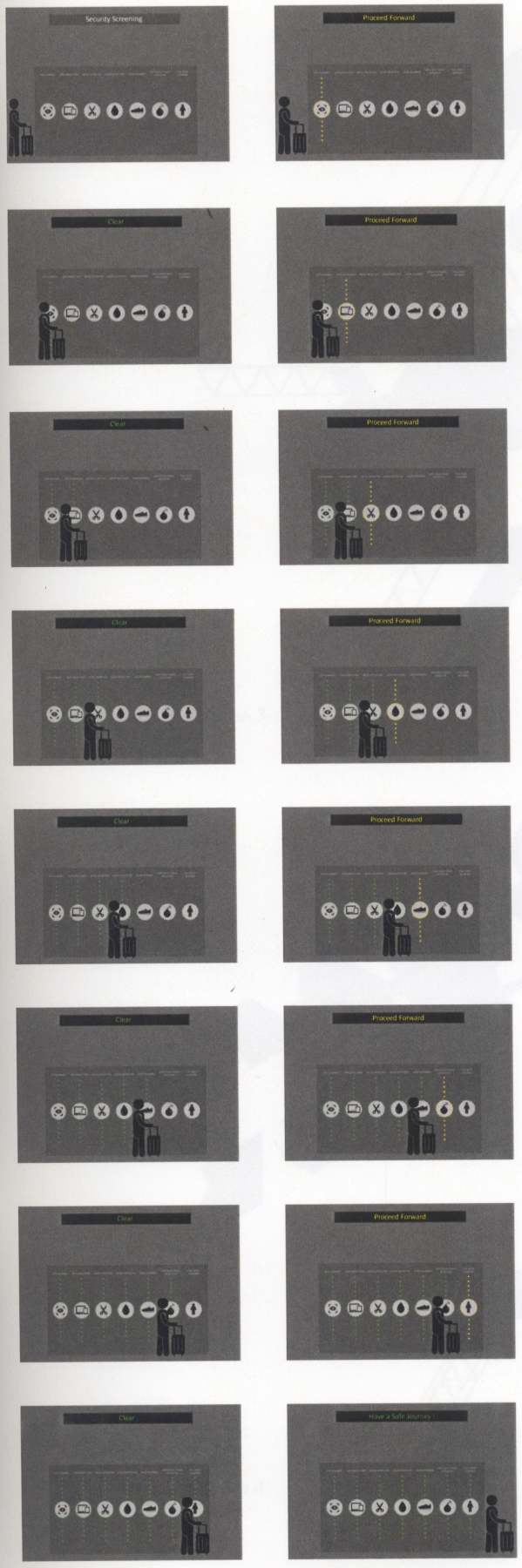


Figure. 46: Control room and viewing deck



SECURITY SCREENING

Airport security areas has the potential to become a hassle-free zone in the future as opposed to current state where they usually consume a large portion of time for a traveler, thus making the experience of a traveler invasive and laborious at times.The International Air Transport Association Aviation Security conference 2011 held in Amsterdam presented a mockup for the " Checkpoint of the future" outlining the concept for hi-tech color coded scanning corridors."By making our checkpoints smarter, and using 'known traveler' programs, we can give everybody a baseline level of security ... and in the end get everybody through security much faster," said by International Air Transport Association chief Tony Tyler said at the conference.

The spaceport features 36 aisles of security corridor at each terminal with in-built 7 speciality scanners at equal intervals.The scanners comprises of retina scanners, detectors for Appliances, Metal, Liquids, shoes and a full body scanner system.The passengers are required to pass through these corridors without the need of removing their shoes or emptying their bags.It reduces the need of physical monitoring and Security personals are only alerted at the time of system raising an alarm for physical scanning thus not disrupting the overall user experience.

Figure. 47: Security screening sequence (Left to right,Top-Down)

CONCEPTUAL SPACEPORT MASSING

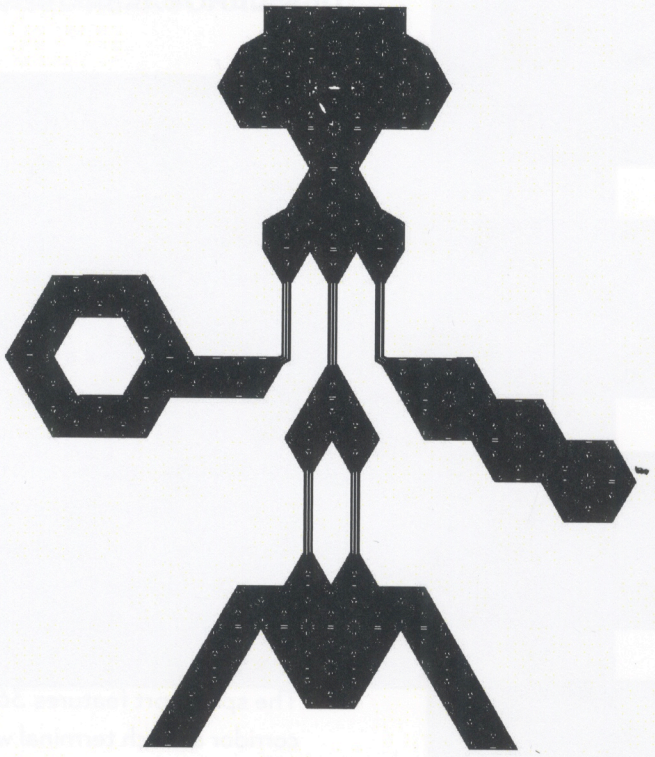


Figure. 48: Massing option 1

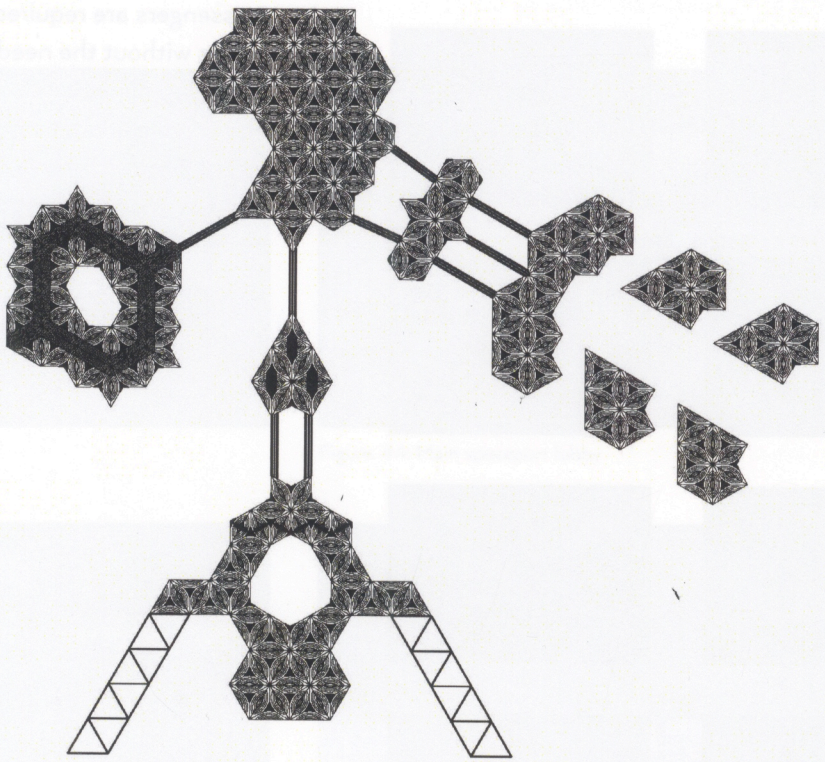


Figure. 49: Massing option 2

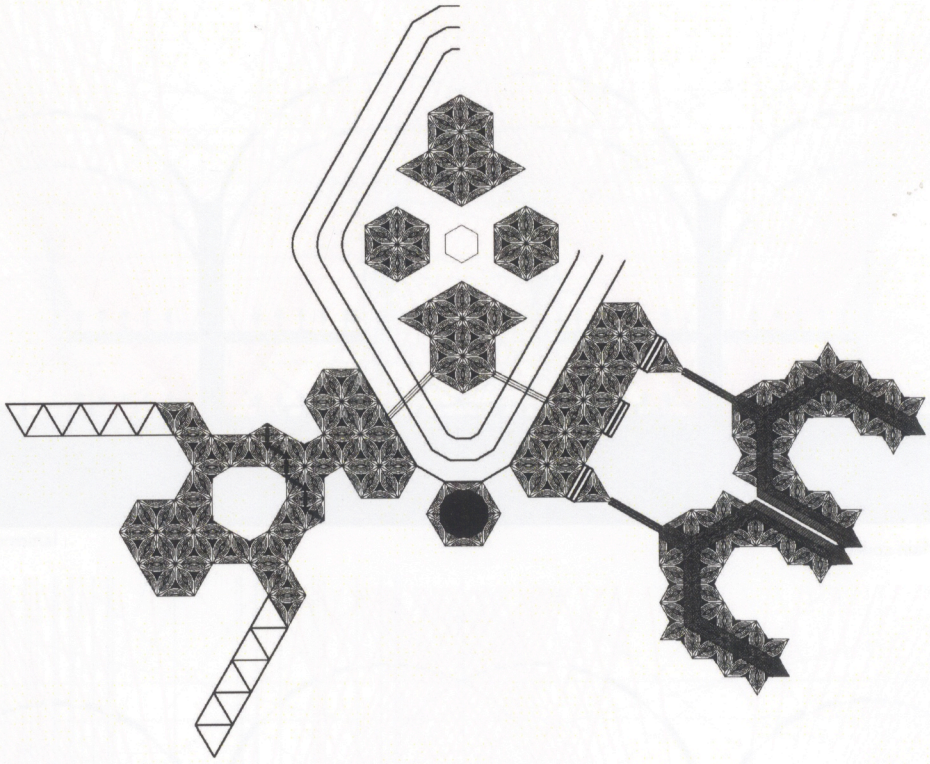


Figure. 50: Massing option 3

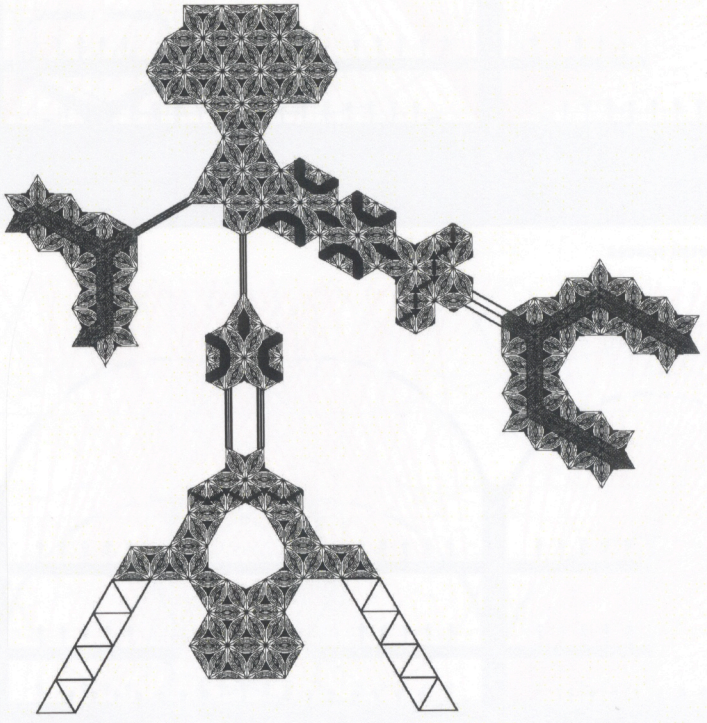


Figure. 51: Massing option 4

CONCEPTUAL SPACEPORT SECTIONS

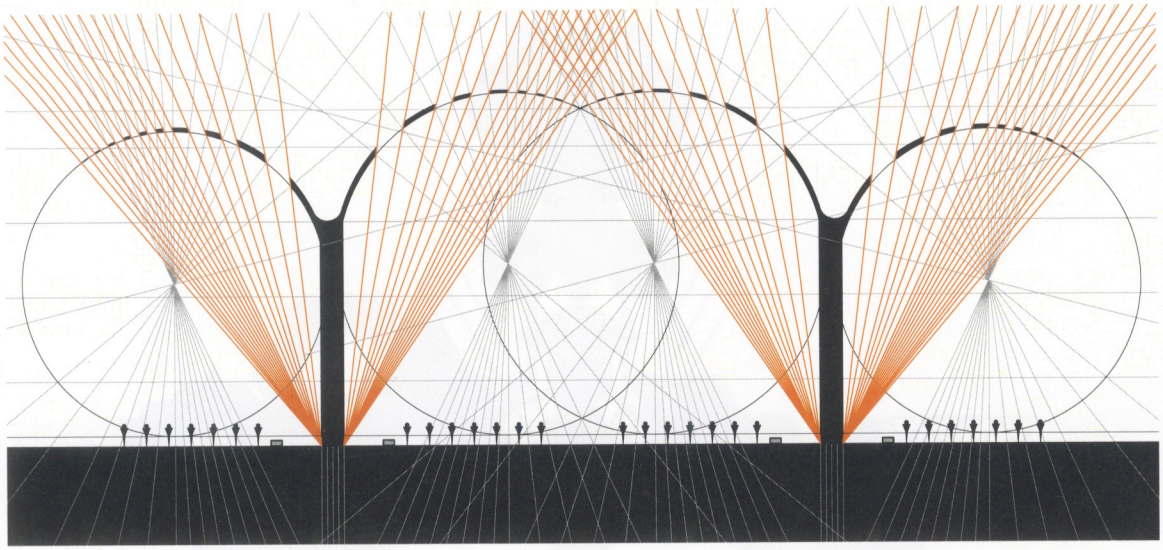


Figure. 52: Main concourse

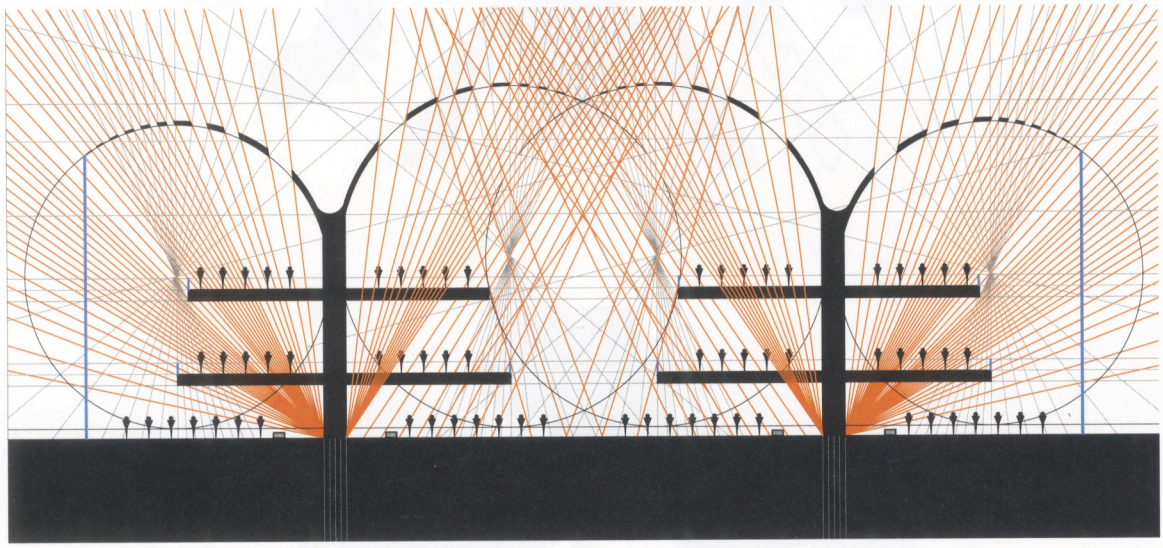


Figure. 53: Retail spaces

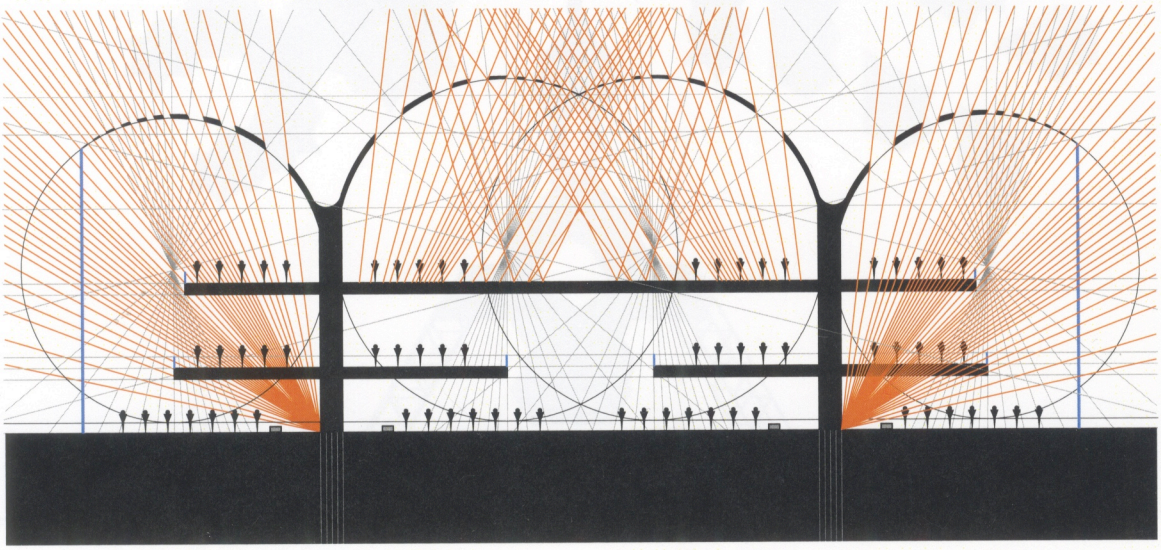


Figure. 54: Retail and Terminal

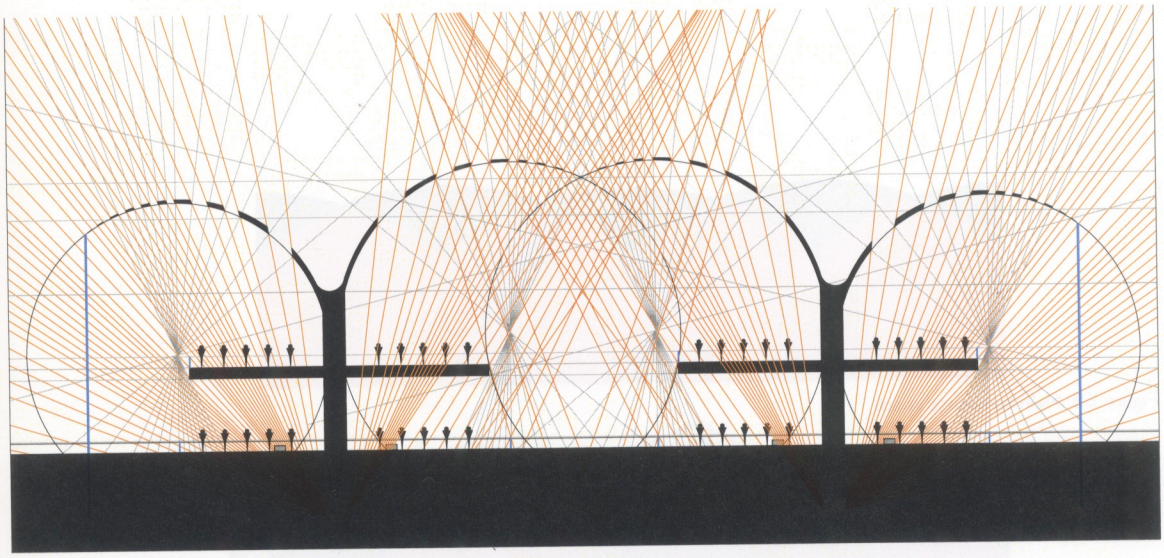


Figure. 55: Terminal

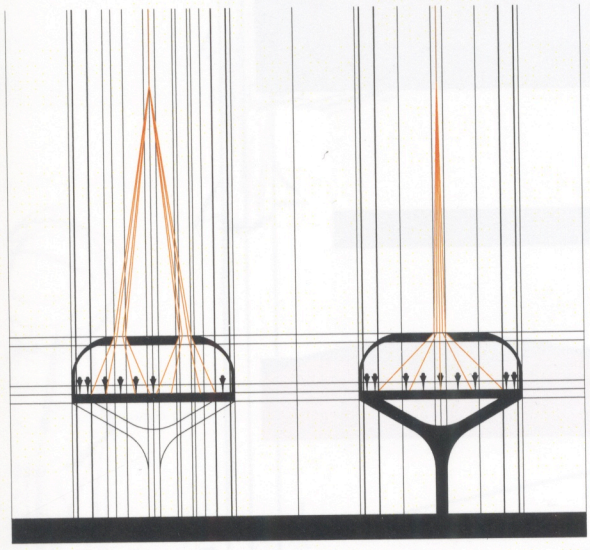


Figure. 56: Tunnel connecting spaceport to Terminals

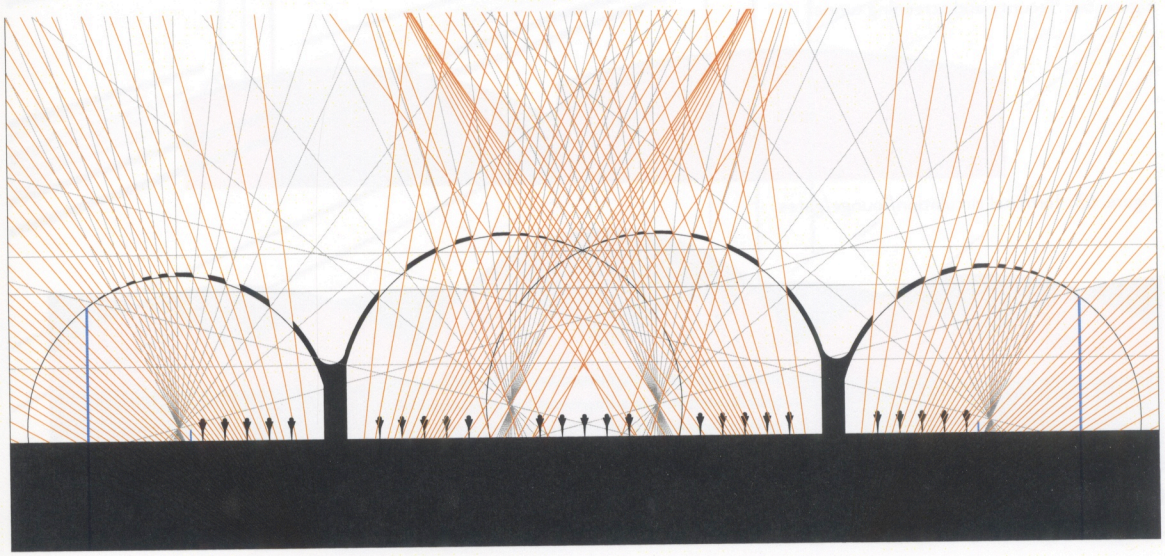


Figure. 57: Terminal circulation and gates

SPACEPORT HEIGHT DIAGRAMS

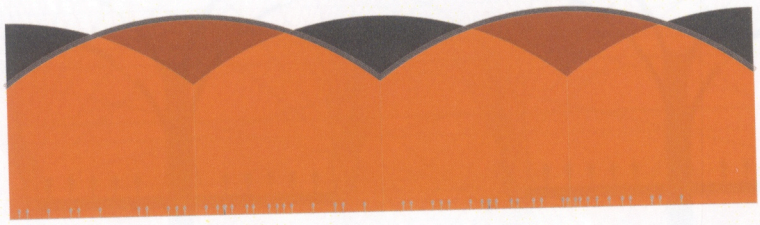


Figure. 58: Main concourse space

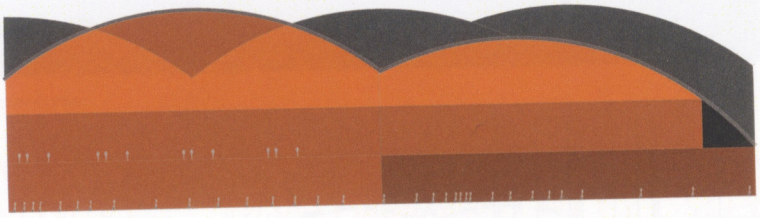


Figure. 59: Public space and facilities

Figure. 60: Connecting tunnels

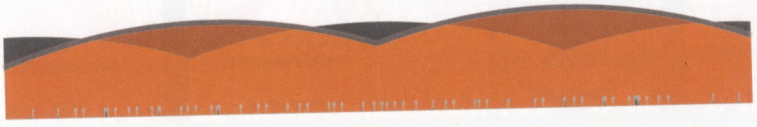


Figure. 61: Ticketing and lugguage check-in

Figure. 62: Security and screening tunnel

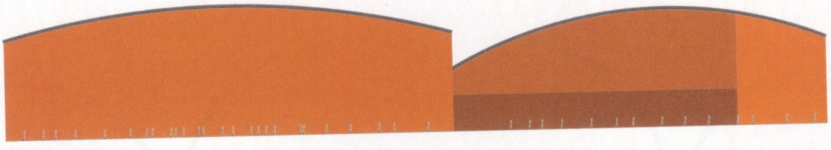


Figure. 63: Terminal circulation/lounge/gates

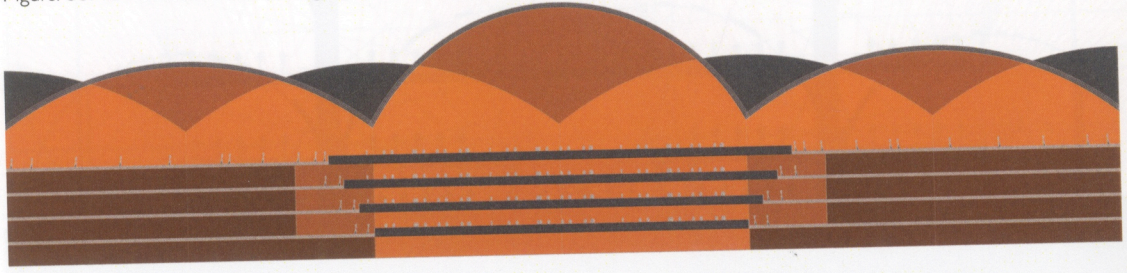


Figure. 64: Quarantine centers

CONCEPTUAL LAUNCH PAD AXON

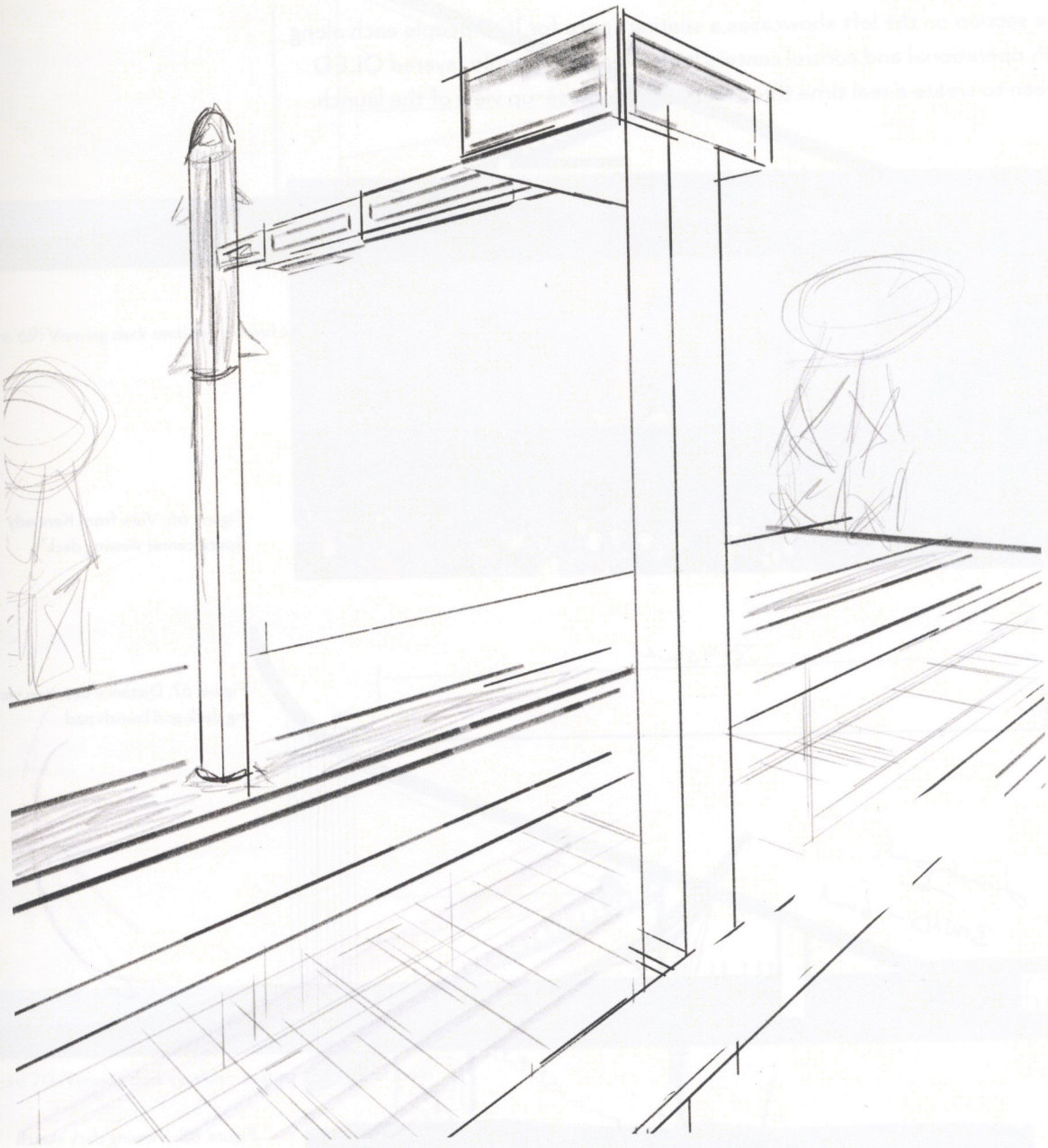


Figure. 65: Conceptual sketch- launch pad axon

VIEWING DECK CONCEPTUAL

Witnessing a rocket launch is a bucket-list experience for many. The space-port houses a separate dedicated facility for people to waive greetings to the space travelers before their journey and enjoy a part of it by themselves. The viewing deck is placed by the Colorado river flowing through the site and positioned between the range of 3-4.5 miles[71] from the launch pads,providing the viewers to experience the liftoff of spacecraft under its full power, but from a safe distance.

The section on the left showcases a seating space for 100 people each along with operational and control centers.It also features a multi layered OLED screen to create a real time three-dimensional close-up view of the launch.

Figure. 66: View from Kennedy Space center viewing deck[72]

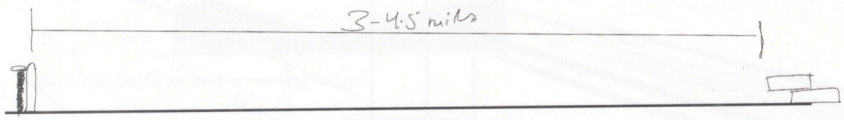


Figure. 67: Distance between viewing deck and launch pad

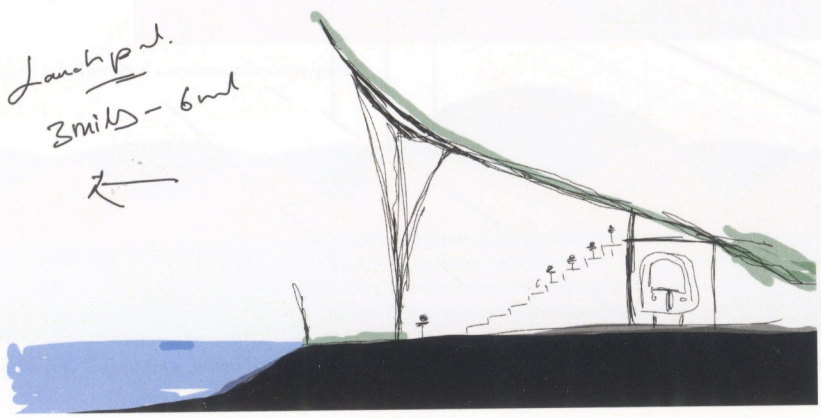


Figure. 68: Viewing deck sketch

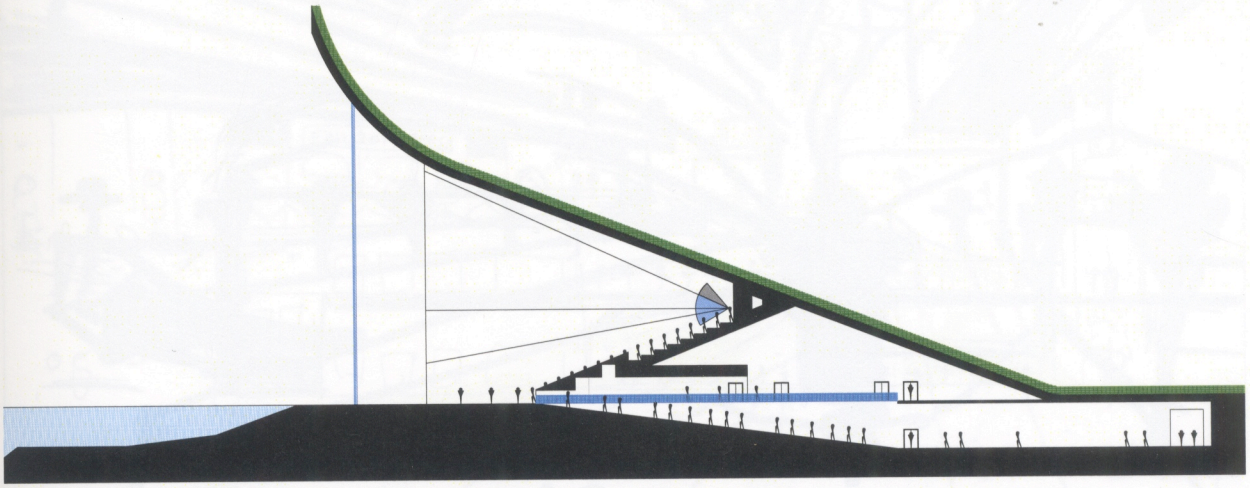


Figure. 69: Viewing deck section - Arrival sequence

Figure. 70: Viewing deck section - seating and control room

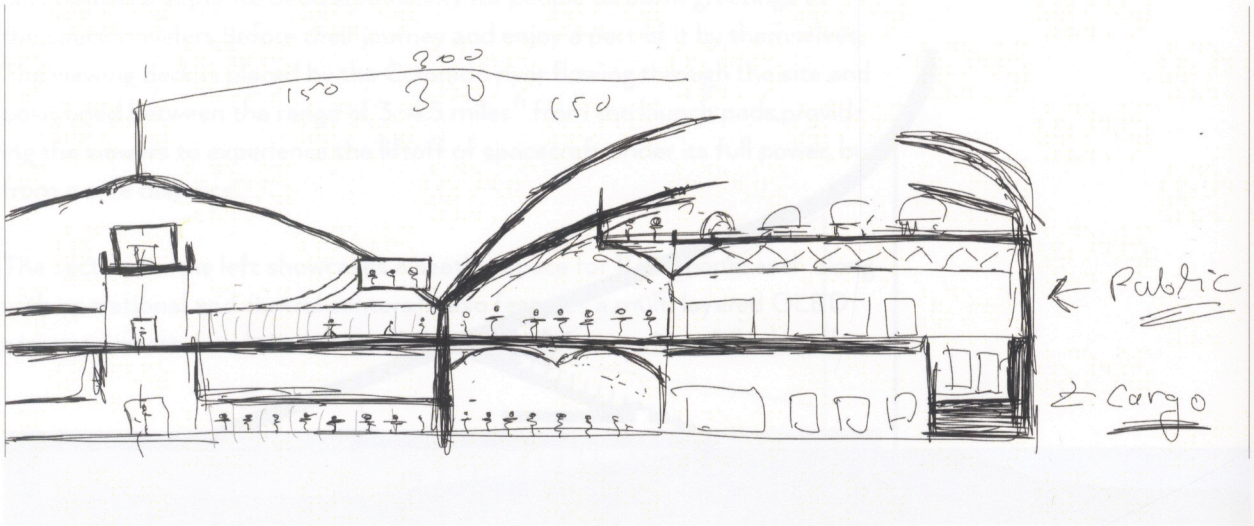


Figure. 71: Hyperloop station/Arrival sequence

Figure. 72: Retail and entryway to terminals

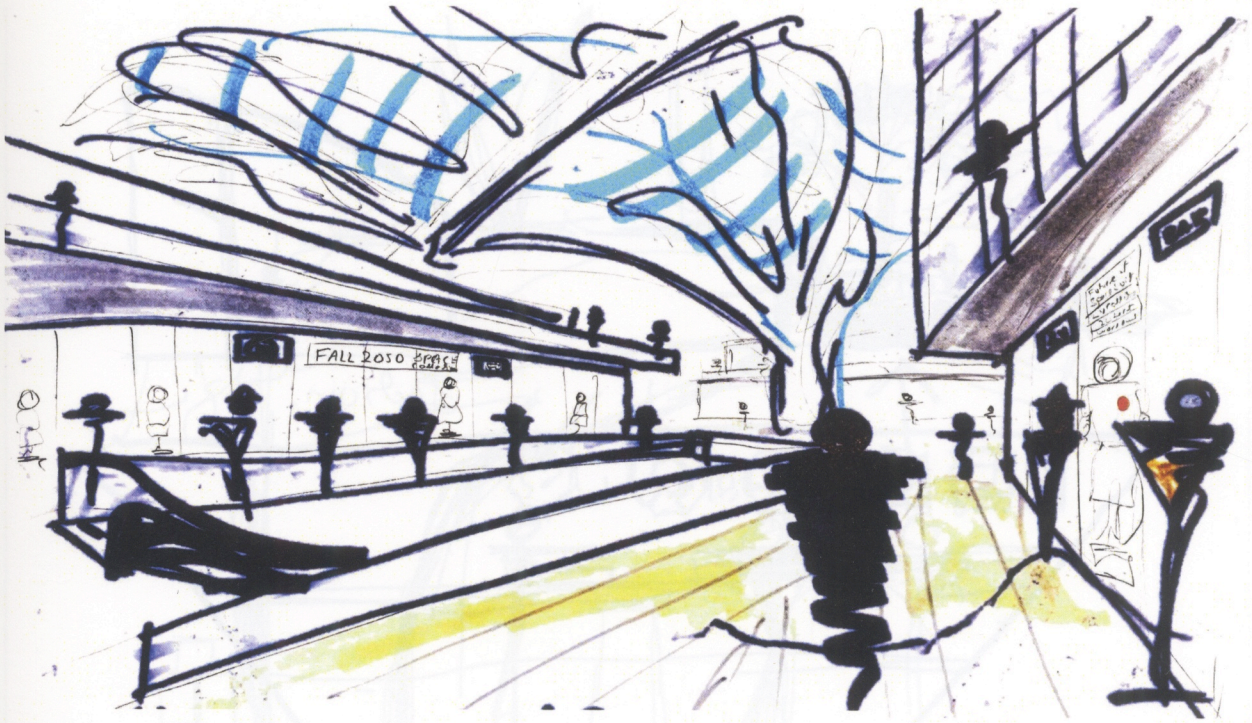


Figure. 73: Retail space

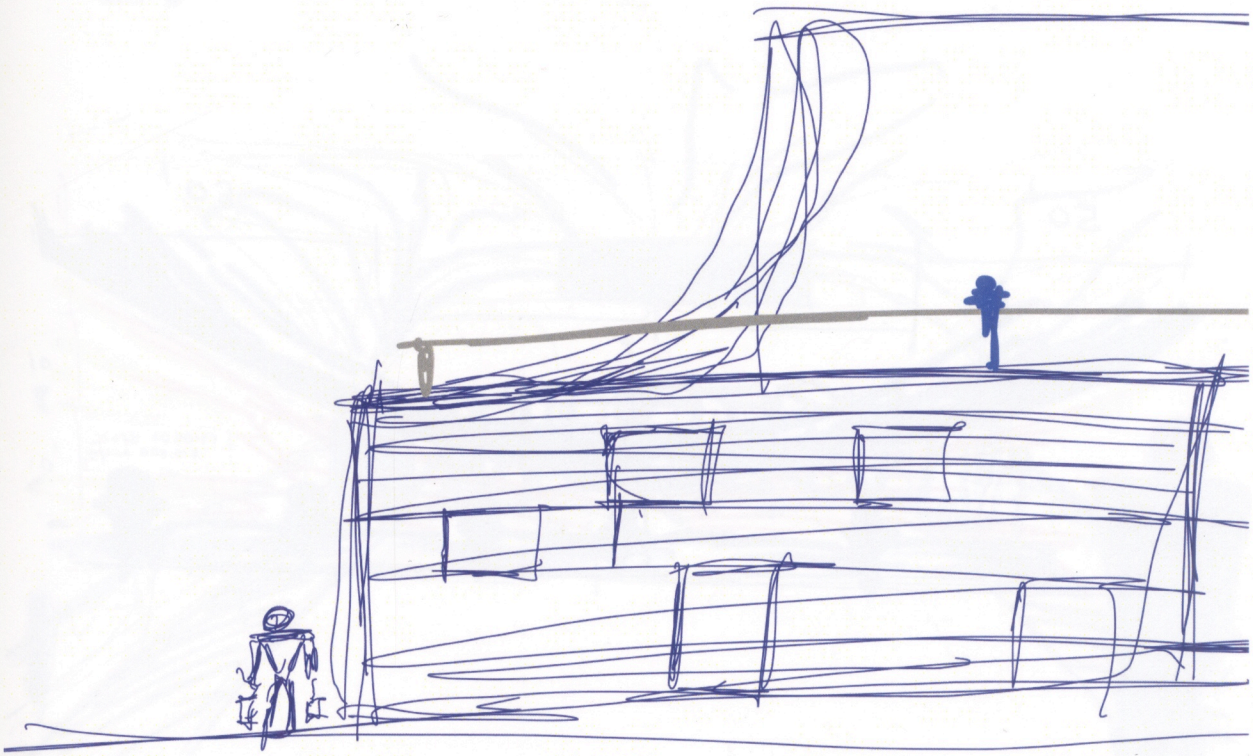


Figure. 74: Retail space elevation

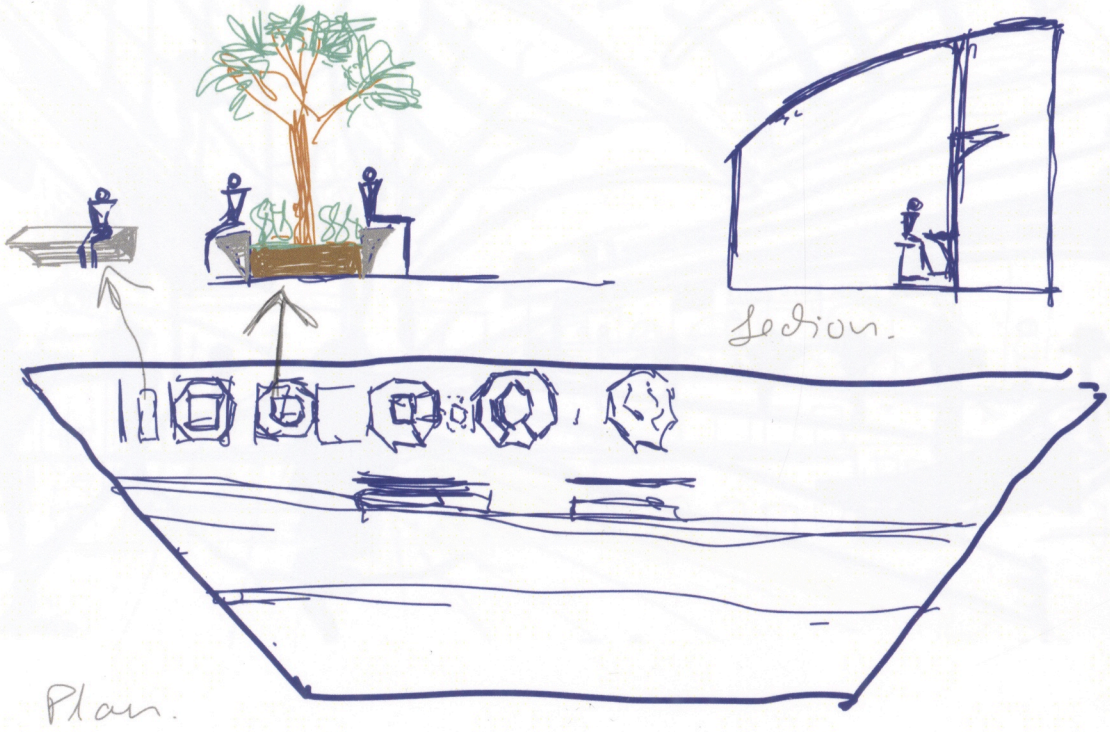


Figure. 75: Public seating area: section and plan

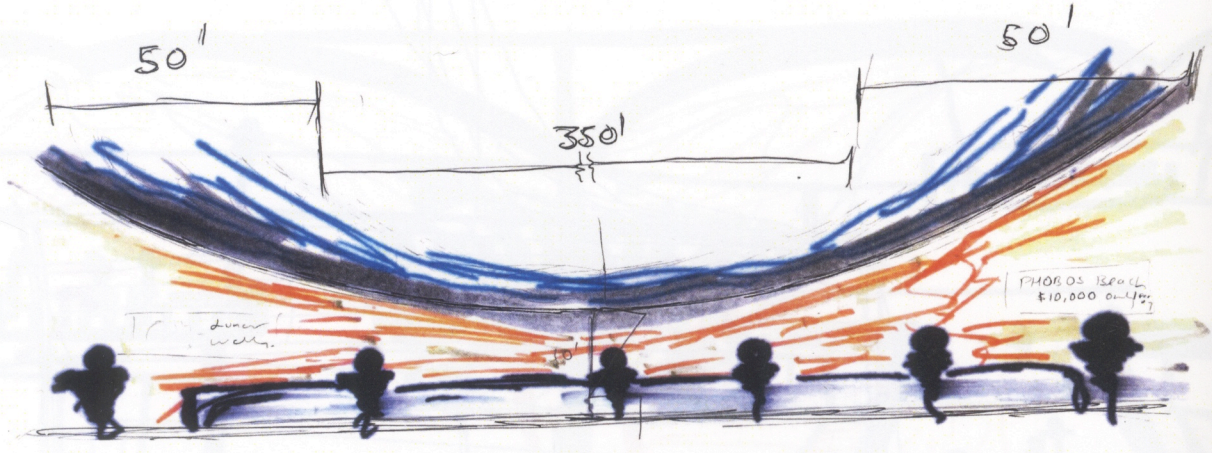


Figure. 76: Connecting tunnnels

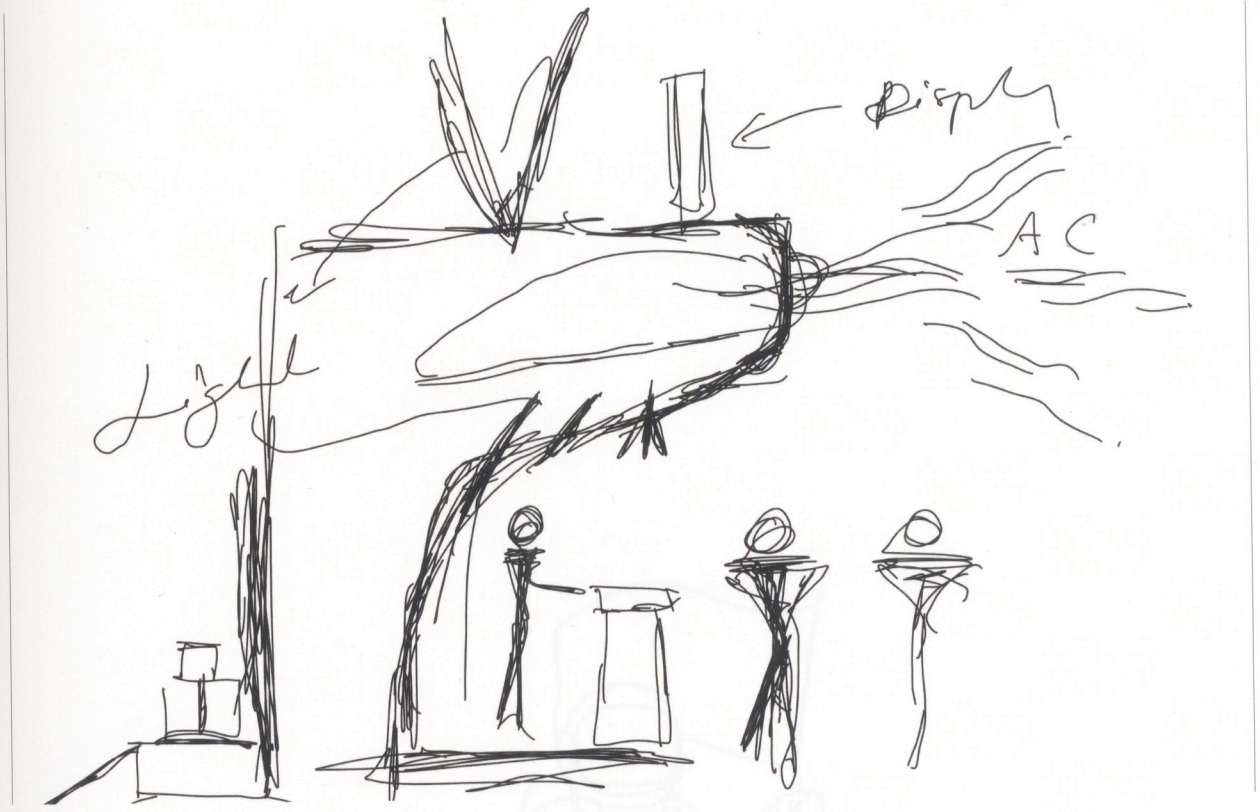


Figure. 77: Check-in space section

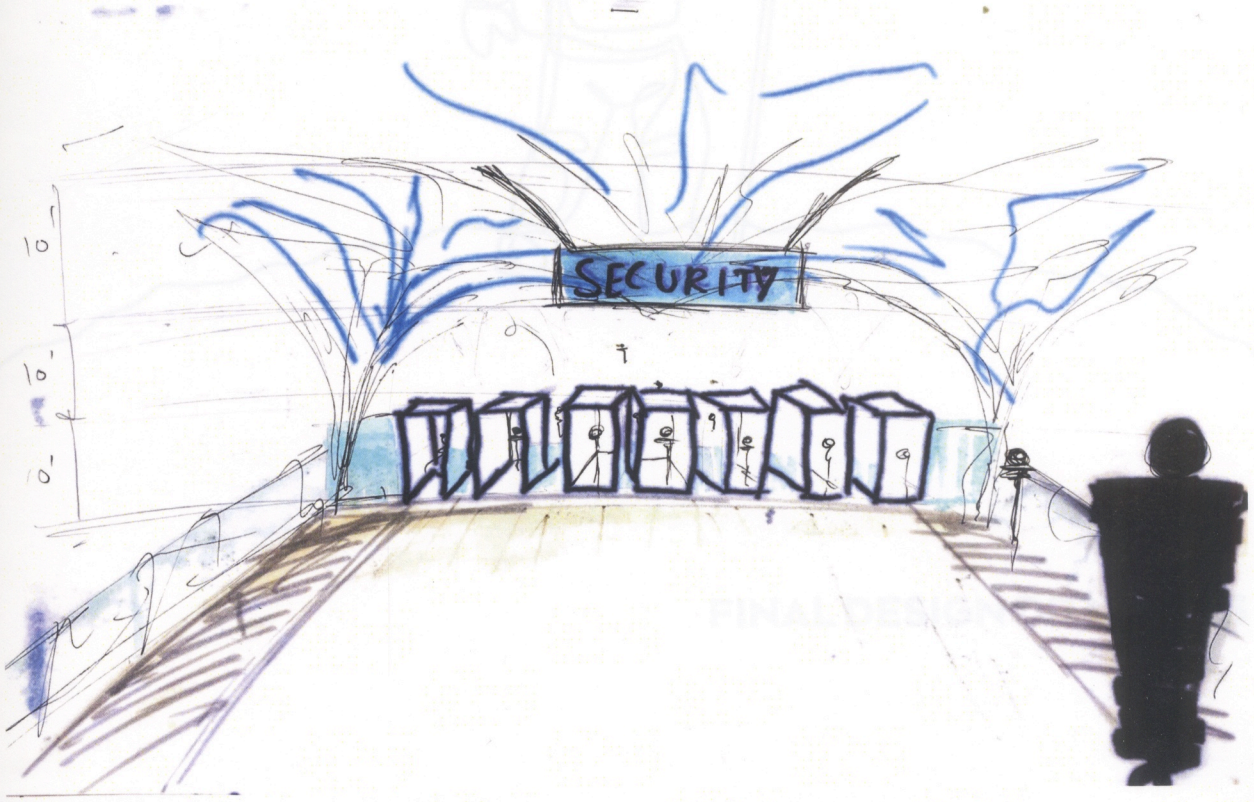


Figure. 78: Security screening

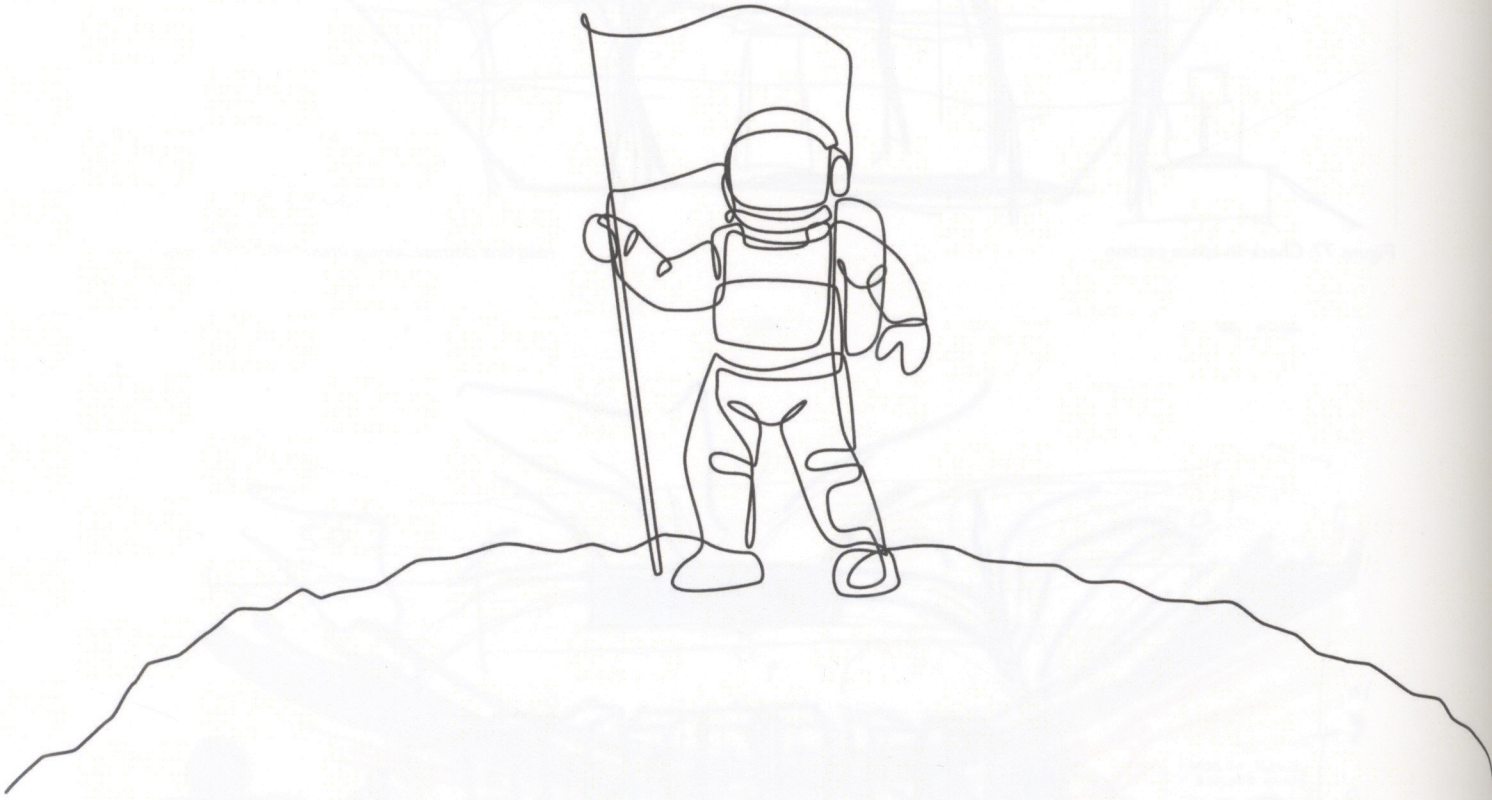
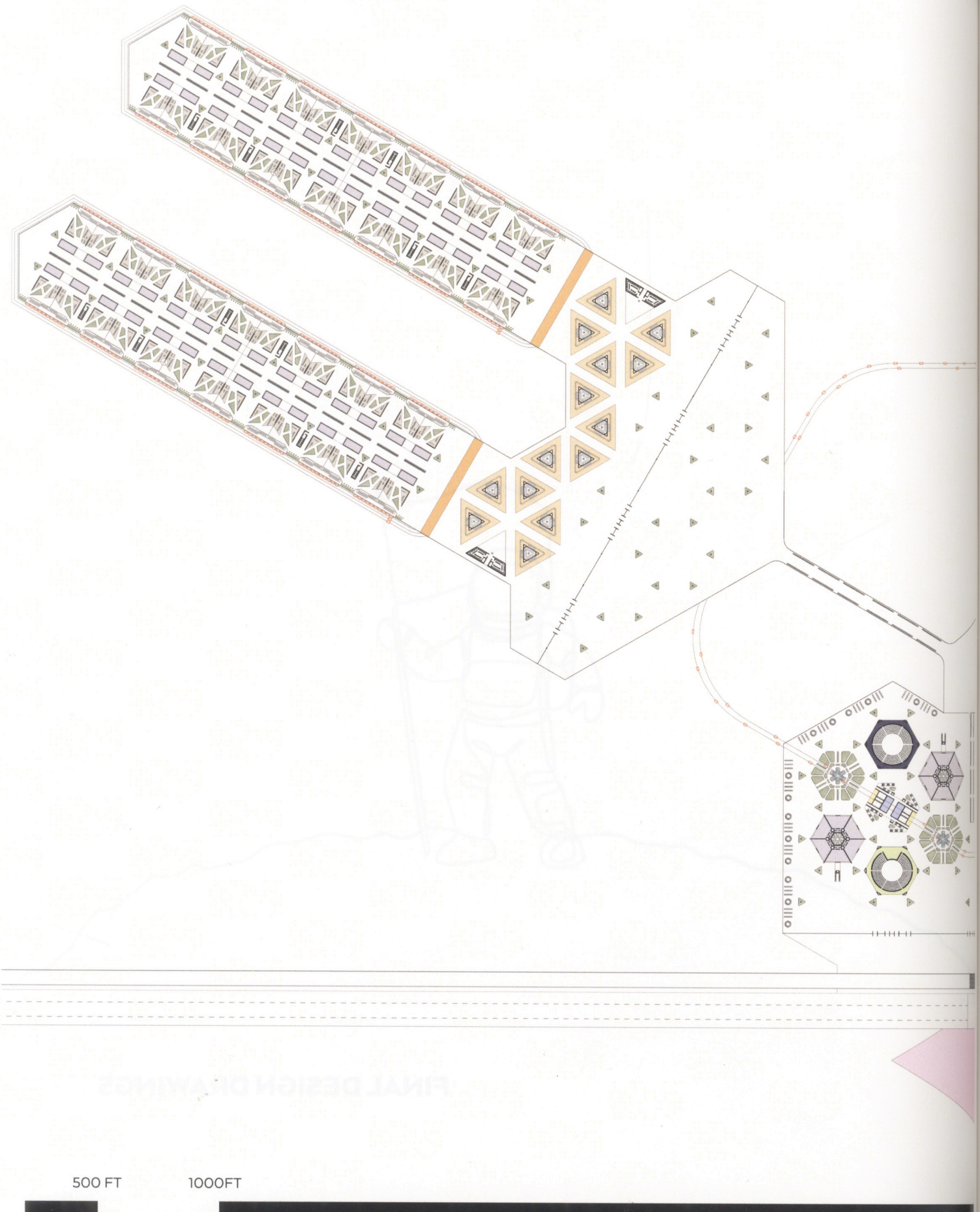


Image Source : Simple Line (Vecteezy.com)

FINAL DESIGN DRAWINGS



SITE PLAN

HYPERLOOP STATION
SHOPS
PLANETARIUM
ANTI-GRAVITY THEATRE
INFORMATION DESK
PRE-APPROVED LUGGAGE CHECK-IN
SKY RAIL PODS
URBAN FOREST
CHECK-IN COUNTERS
WALK THROUGH SECURITY GATES

1 MILE

FACADE

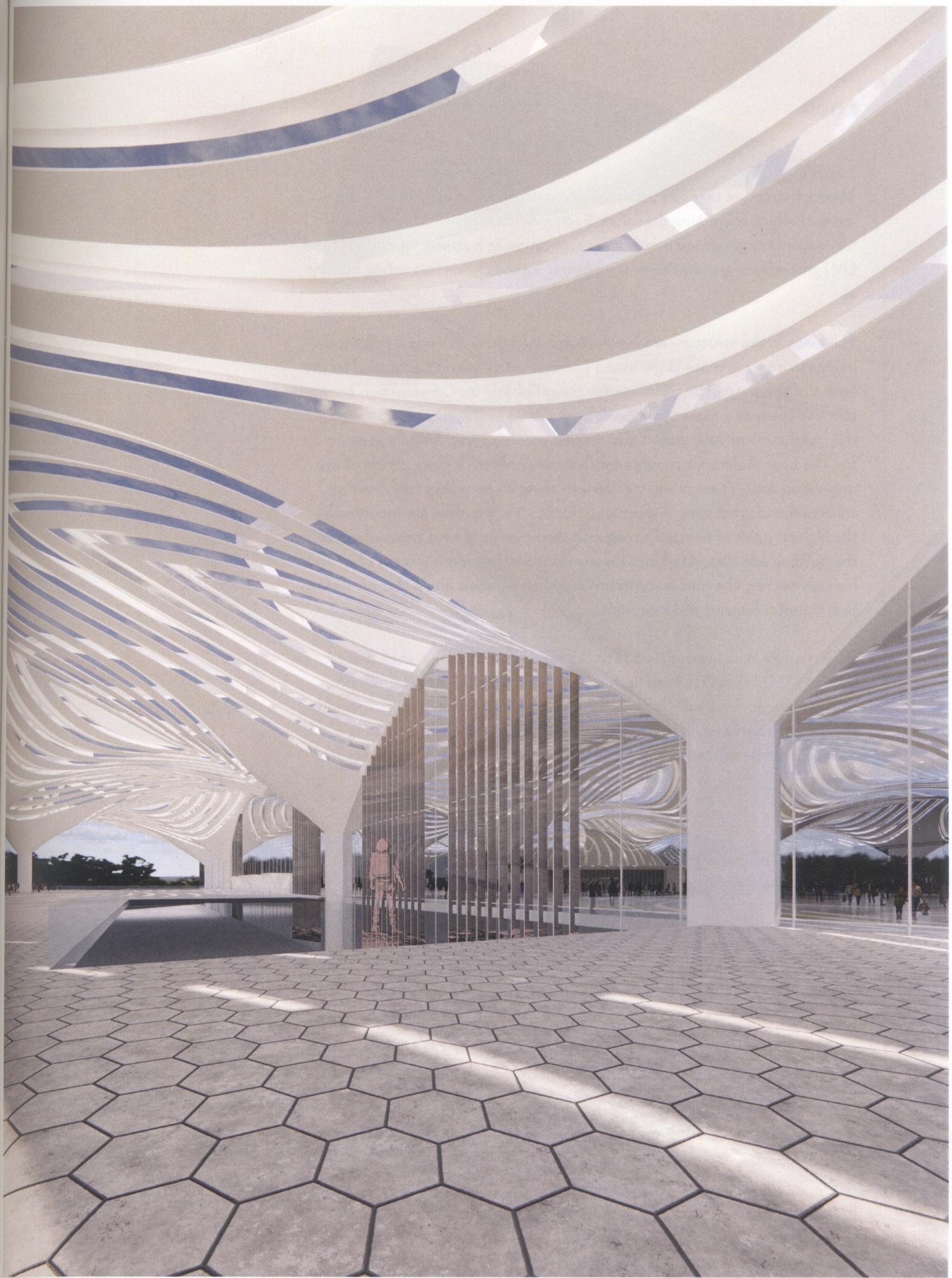
The Facade of the Spaceport features extended vertical members running through the height of the building, which also acts as a structural member. These vertical members differ in angle following the skeleton of the roof. This creates an illusion of movement, the same as the user moving internally throughout the space.

These vertical louvers on the facade feature Lenticular art throughout transition zones depicting artwork as per the destination of people. For instance, visuals of Mars and other planets while a person is moving towards Departures and visuals of earthly elements on their arrival.

This Lenticular form of art signifying space journey elevates the space in aesthetics and results in an immersive user experience.

Figure. 79: Lenticular facade

Facde graphic Source[74]



ROOF

The roof structure takes its inspiration from the form of flight and movement of a bird, mimicking the wings. Each module comprises two layers of recyclable Polycarbonate panel for its reputation as a strong, lightweight, and UV light-reflecting material, thus making it a good choice for roofing material.

The loads in the structure are evenly distributed through three 2.5 ft truss beams in a way to make larger spans possible with ease, as demanded by the layout of the space. The building uses Solar Panel in its Compression zone to move towards a more sustainable approach, which is achieved through the installation of solar panels customized according to the roof's geometry. The base skeleton is mounted with three pane-thick glass panels above its tension zone. There is a gutter system along its periphery for rainwater collection and processing in a separate facility. Vent outlets are mounted at the highest point of the roof to regulate the amount of heat trapped inside the building and dissipated into the atmosphere, considering Texas's hot and humid weather. The roof features embedded led panels and a clip-on system to fix interior finishes and materials.

Each module is supported by 6 ft thick columns encased in a shell, placed between 150 ft-300 ft from each other. This makes the larger spans possible, as demanded by the layout of the space. This complete structure, with the distance between its every skeletal panel, acts as skylights, creating a seamless lightweight structure forming a sense of perceptual openness for the users.

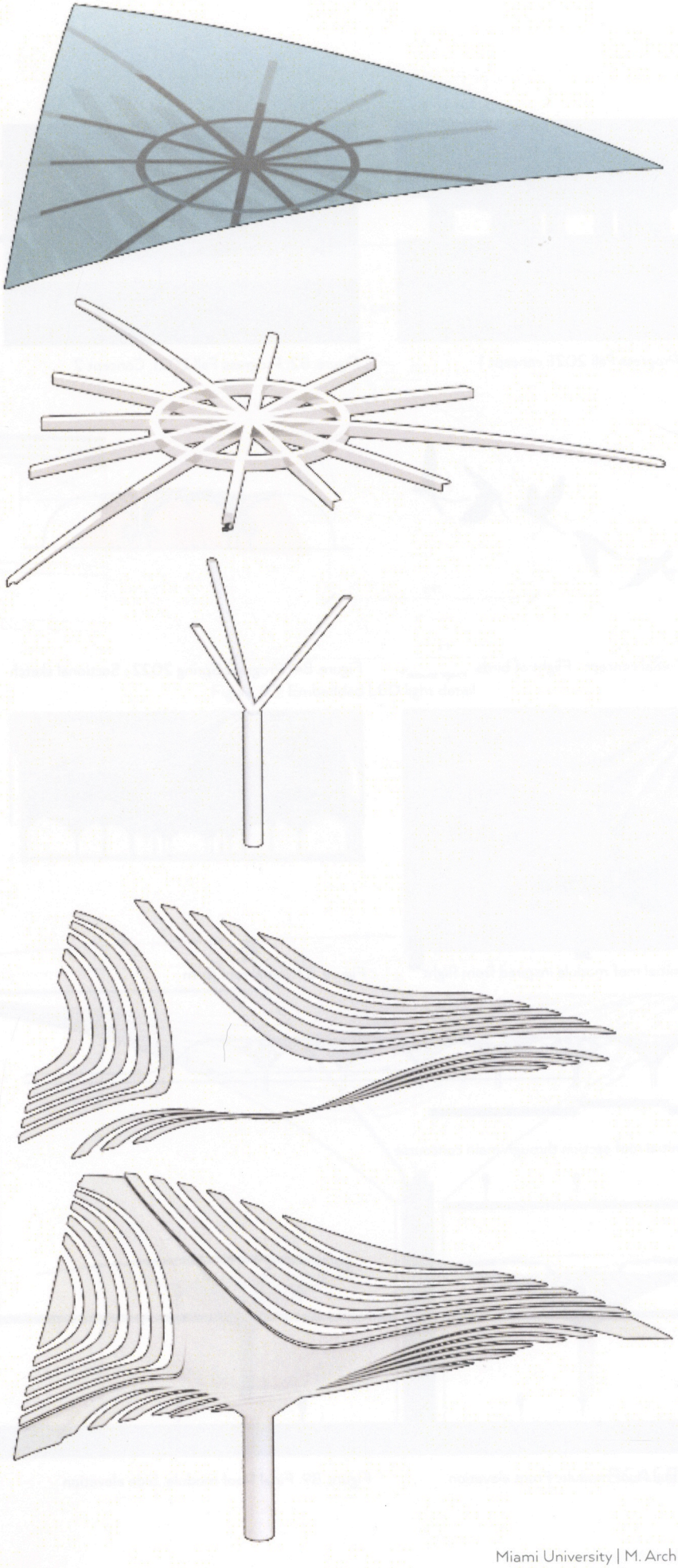


Figure. 80: Exploded roof axon

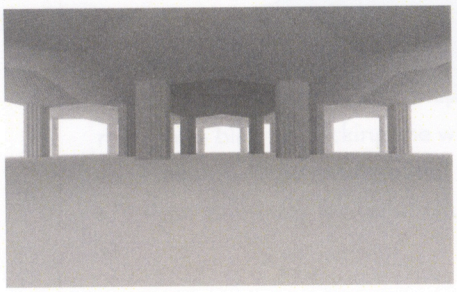


Figure. 81: Progress Fall 2021: concept 1

Figure. 82: Progress Fall 2021: Concept 2

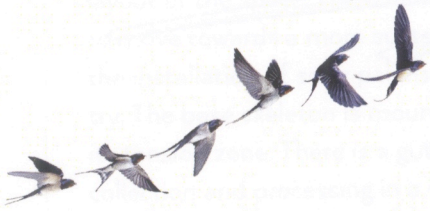


Figure. 83: Initial concept : Flight of birds Image source[75]

Figure. 84: Progress Spring 2022 : Sectional sketch

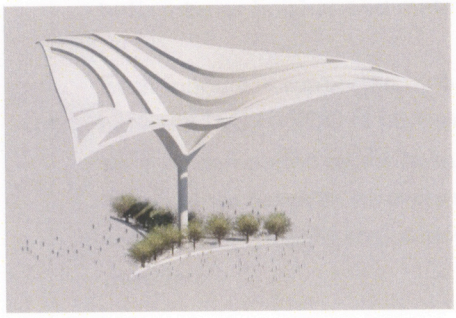


Figure. 85: Initial roof module inspired from flight of birds

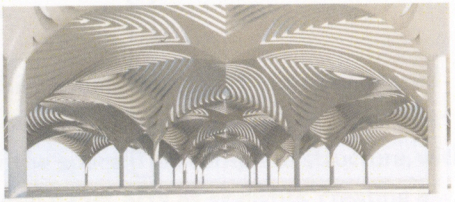


Figure. 87: Initial roof form

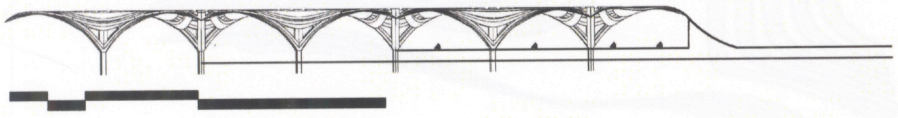


Figure. 86: Initial roof section through main concourse

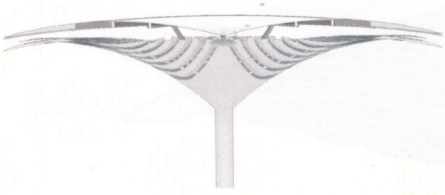


Figure. 88: Final Roof module: Front elevation

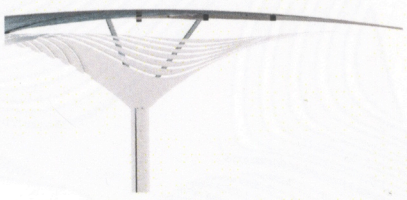


Figure. 89: Final Roof module: Side elevation

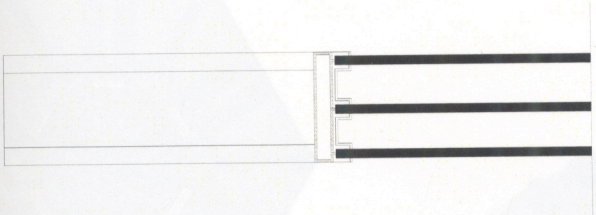


Figure. 90: 3-pane glass detail

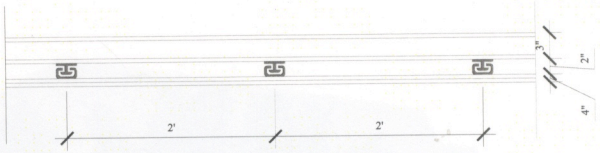


Figure. 91: Roof clip-on panel

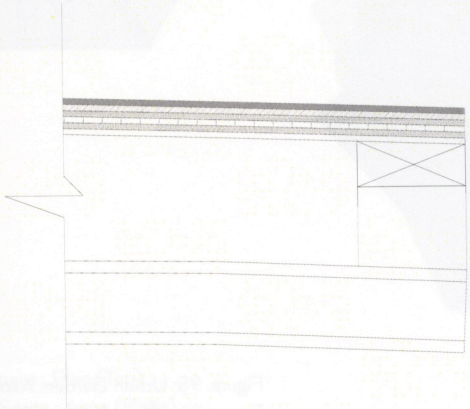


Figure. 92: Solar roof detail

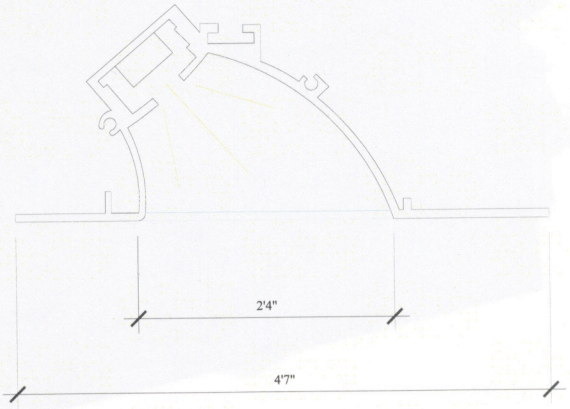


Figure. 93: Embedded LED light detail

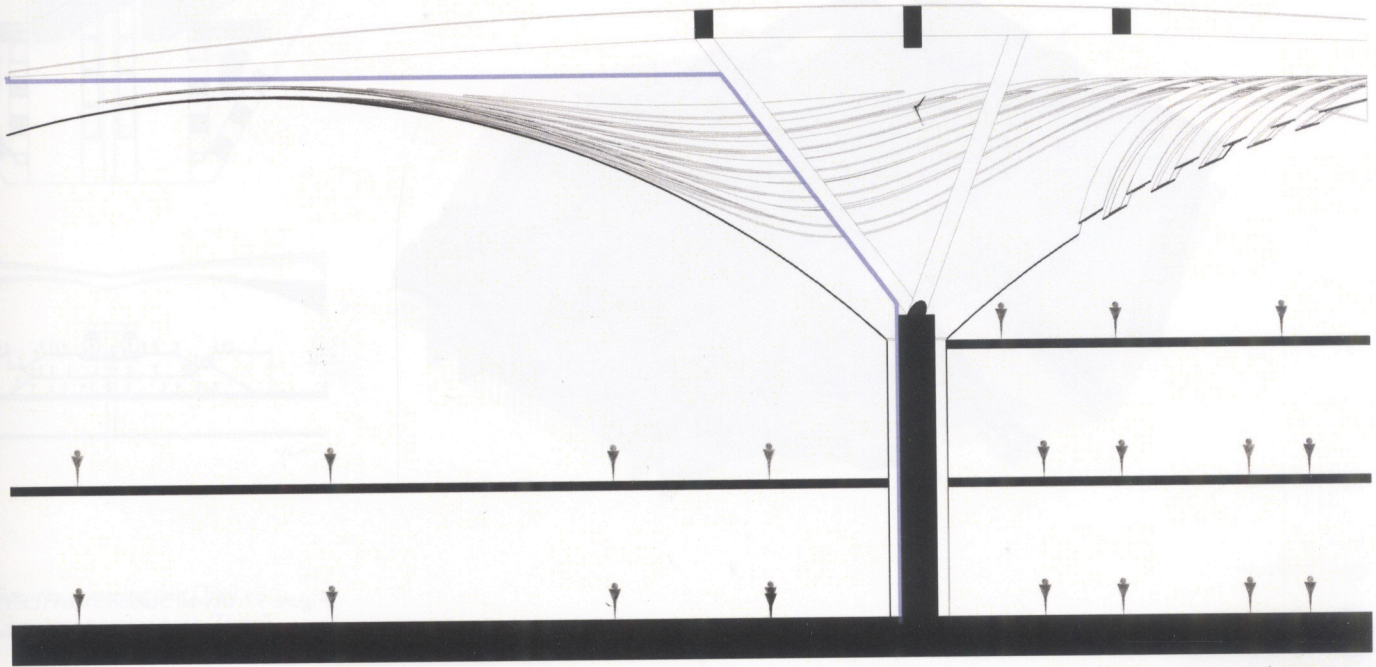
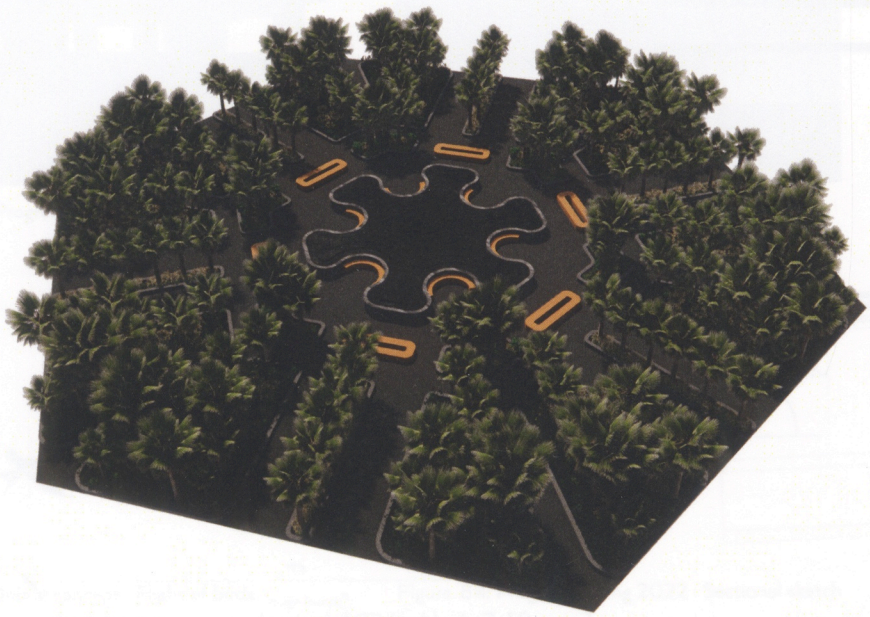


Figure. 94: Roof/column section

SCALE 1/32"=1'0"

URBAN GARDEN MODULE



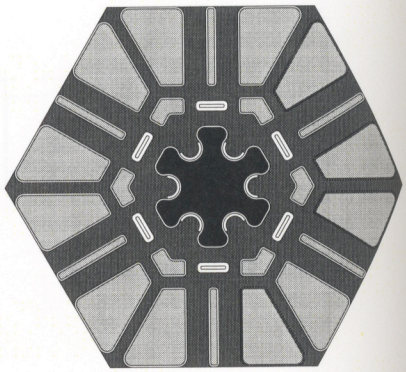
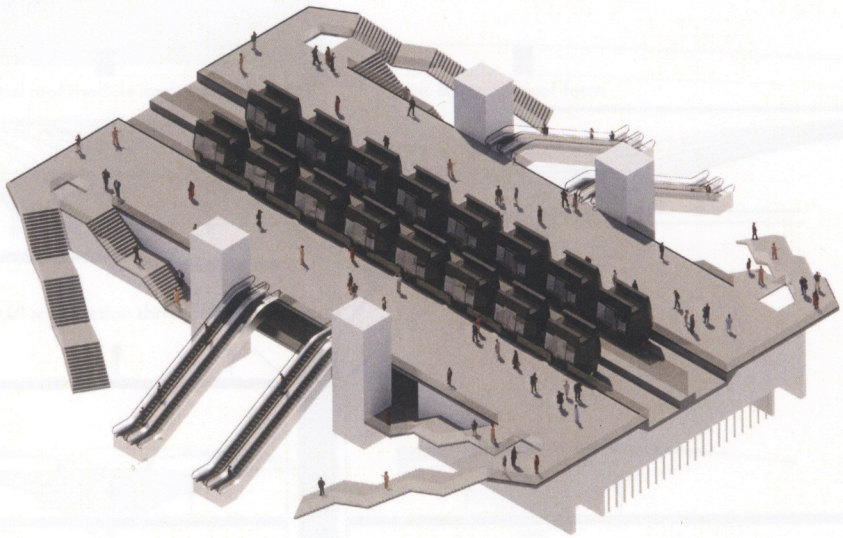
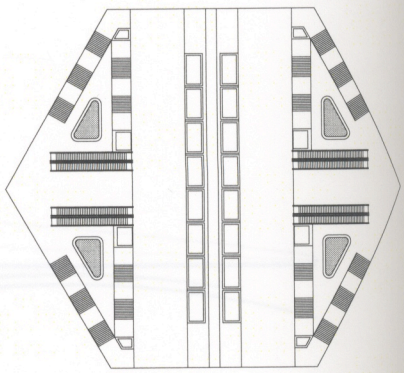


Figure. 95: Urban Garden: Axon (Left)
Figure. 96: Urban Garden: Plan (Top)

SKYRAIL STATION MODULE





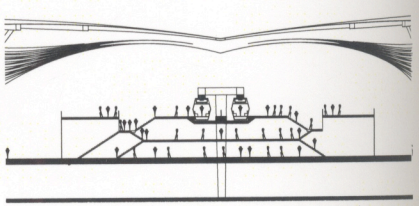
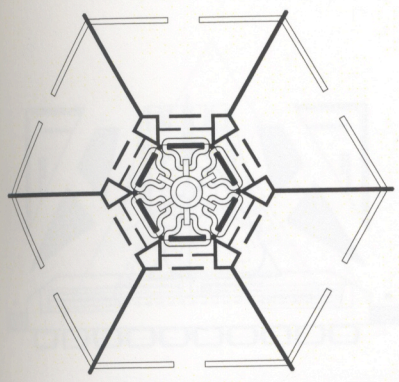


Figure. 97: Skyrail Station :Axon (Left)
Figure. 98: Skyrail Station :Plan and section (Top)

RETAIL SPACE MODULE



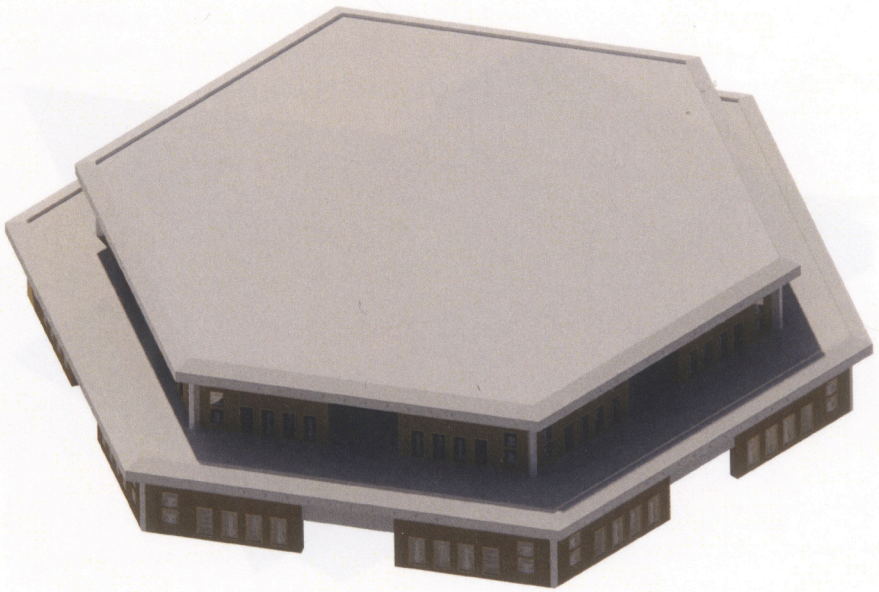
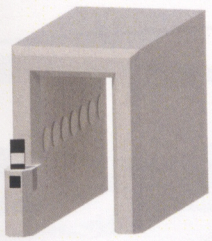


Figure. 99: Retail Space : Plan (Top)
Figure. 100: Retail Space : Axon (Right)

SECURITY SCREENING MODULE



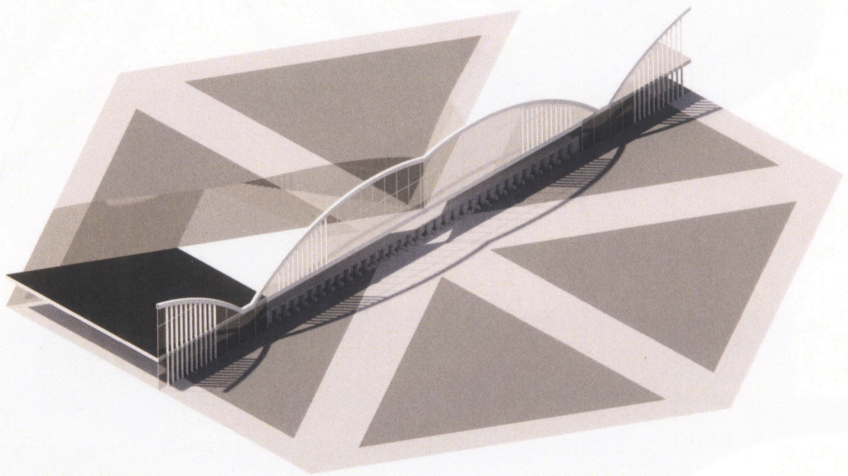
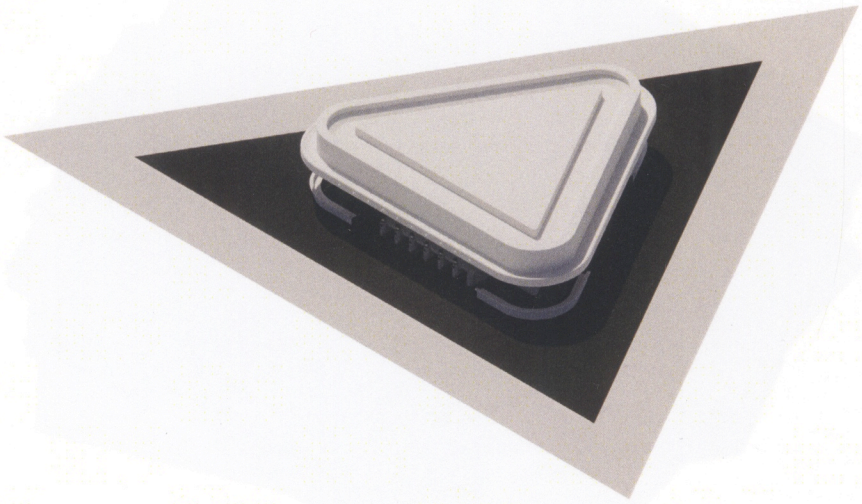


Figure. 101: Security screening unit (Top)
Figure. 102: Security screening Axon (Right)

CHECK-IN SPACE MODULE



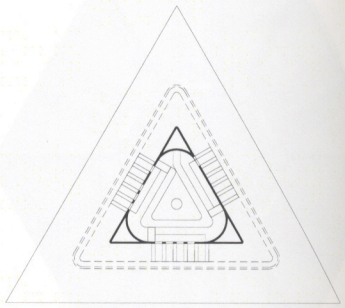
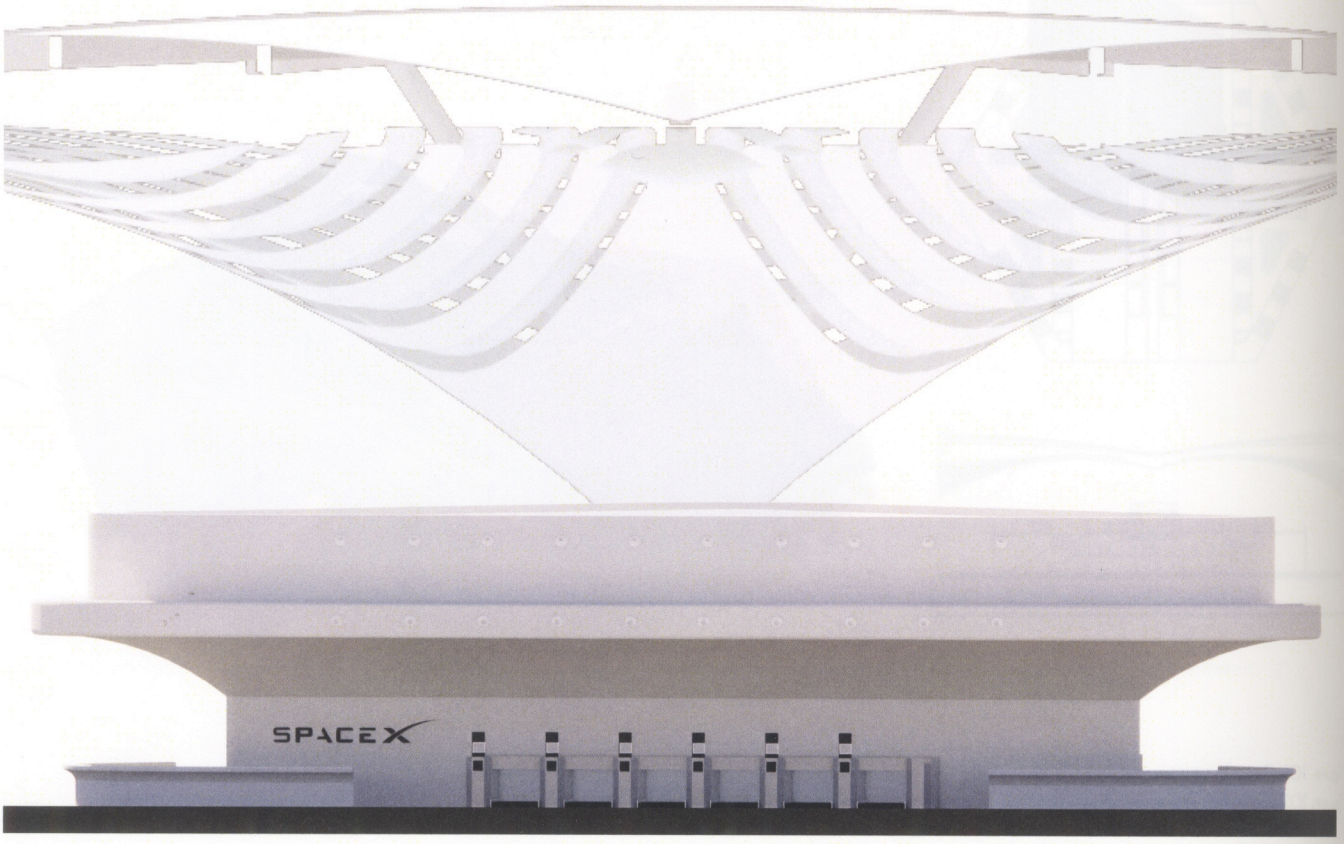
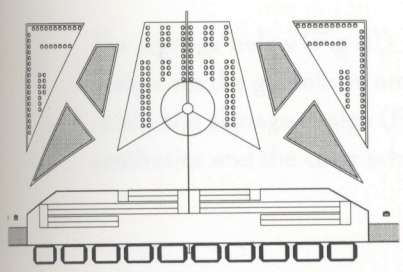


Figure. 103: Check-in space : Axon (Left)
Figure. 104: Check-in space : Plan (Top)
Figure. 105: Check-in space : Elevation (Below)



DEPARTURE GATE MODULE



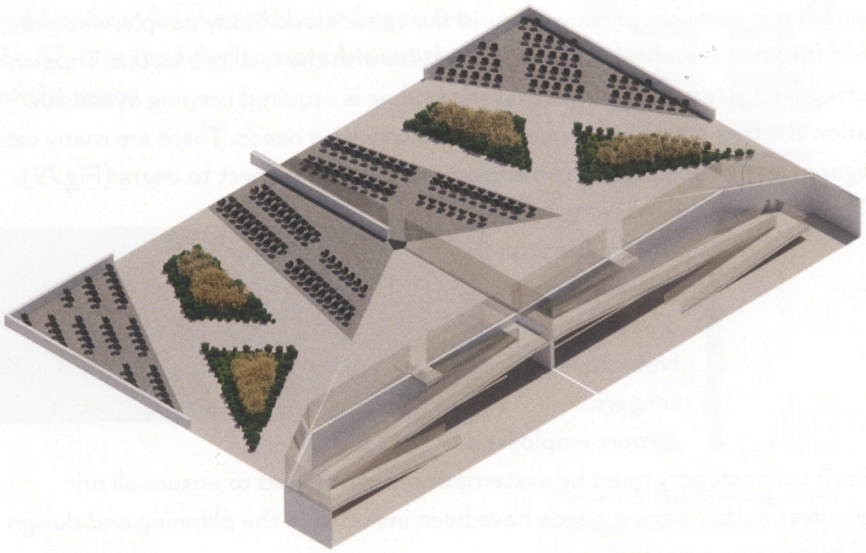


Figure. 106: Departure Gate : Plan (Top)
Figure. 107: Departure Gate : Axon (Right)

TERMINAL SHOP/RESTAURANT MODULE

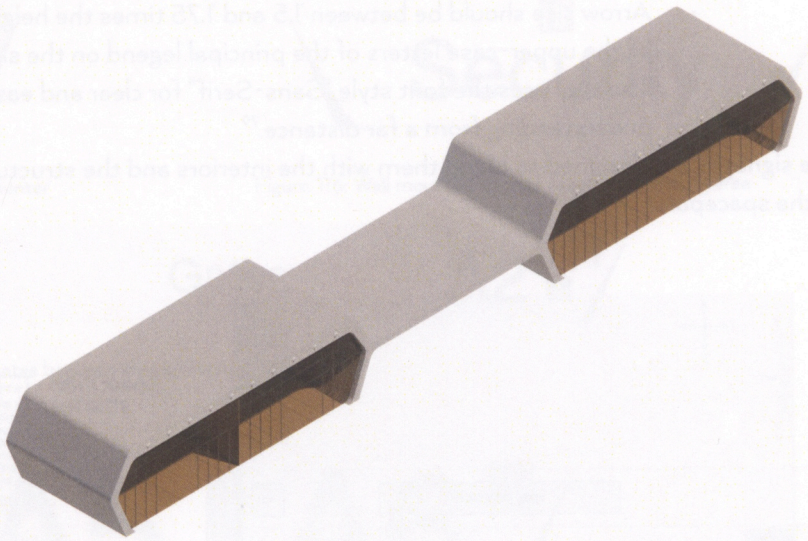


Figure. 108: Terminal Shop/Restaurant : Elevation (Top)
Figure. 109: Terminal Shop/Restaurant : Axon (Right)

SIGNAGES

Any transitional facility often requires travelers to move different arterials within the premises or move around the same block. Many people, who are not frequent travelers, may not be familiar with the facility's layout. Thus an effective system of signages and wayfinding is required keeping in consideration the user's physical, perceptual and cognitive needs. There are many categories to be considered in an airport setting with respect to users (Fig.79). These include the following[76]:

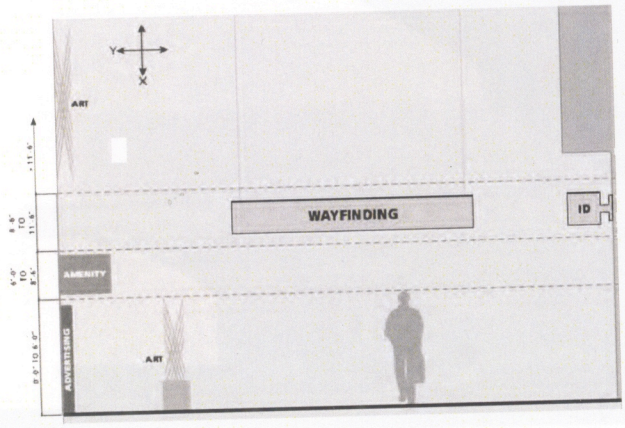
- Unfamiliar passengers
- Familiar passengers
- Passengers with disabilities of various kinds,
- Non-traveling visitors who are there to greet/send off passengers,
- Airport employees.

Each user category must be systematically considered to ensure all origin-destination signing needs have been included in the planning and design of the signing system.[77]

The spaceport follows the guidelines laid out by the Federal Aviation Administration(FAA) in terms of the use of Terminology used, Color coding, Text sizes, and symbiotic representations. Some of the guidelines applied in this project include[78] (Fig . 80):

- Using a 3-inch tall letter that would be legible from 120 feet,
- Arrow size should be between 1.5 and 1.75 times the height of the upper-case letters of the principal legend on the sign
- The text uses the font style "Sans-Serif" for clear and easy understanding from a far distance.[79]

The signages are designed to blend them with the interiors and the structure of the spaceport.



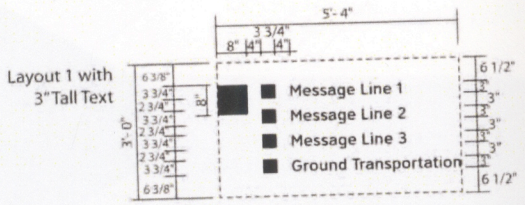


Figure. 110: Typical example from Mineta San Jose International Airport wayfinding (Left)[80]
Figure. 111: The Graphic is an example of a typical sign grid study with a 3" Text. (Top)[81]

TYPICAL SPACEPORT SIGNAGE AND WAY FINDING SYSTEM

The signage below (Fig 81) is a representation of the most standardized design. As the guidelines are not rigid and can be changed according to the space, the signage design (Fig. 82 - 87) was modified to complement the aesthetics and the color scheme of the space.

Figure. 112: Initial signage design

Figure. 113: Free-standing winged signage : main concourse

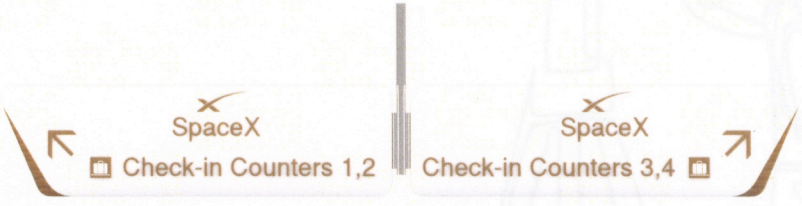


Figure. 114: Ceiling suspended signage: check-in space

Figure. 115: Soffit mounted signage check-in counter

Figure. 116: Wall mounted signage : security screening area

Figure. 117: Wall mounted singage : departure gates between shops/restaurants

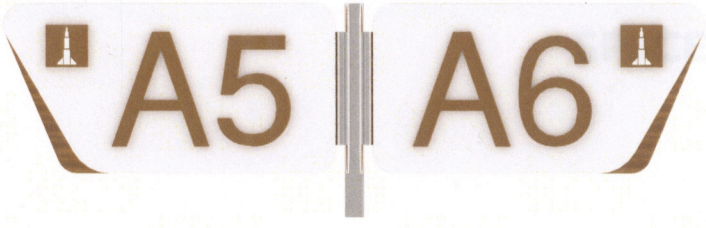


Figure. 118: Post mounted signage : departure gates

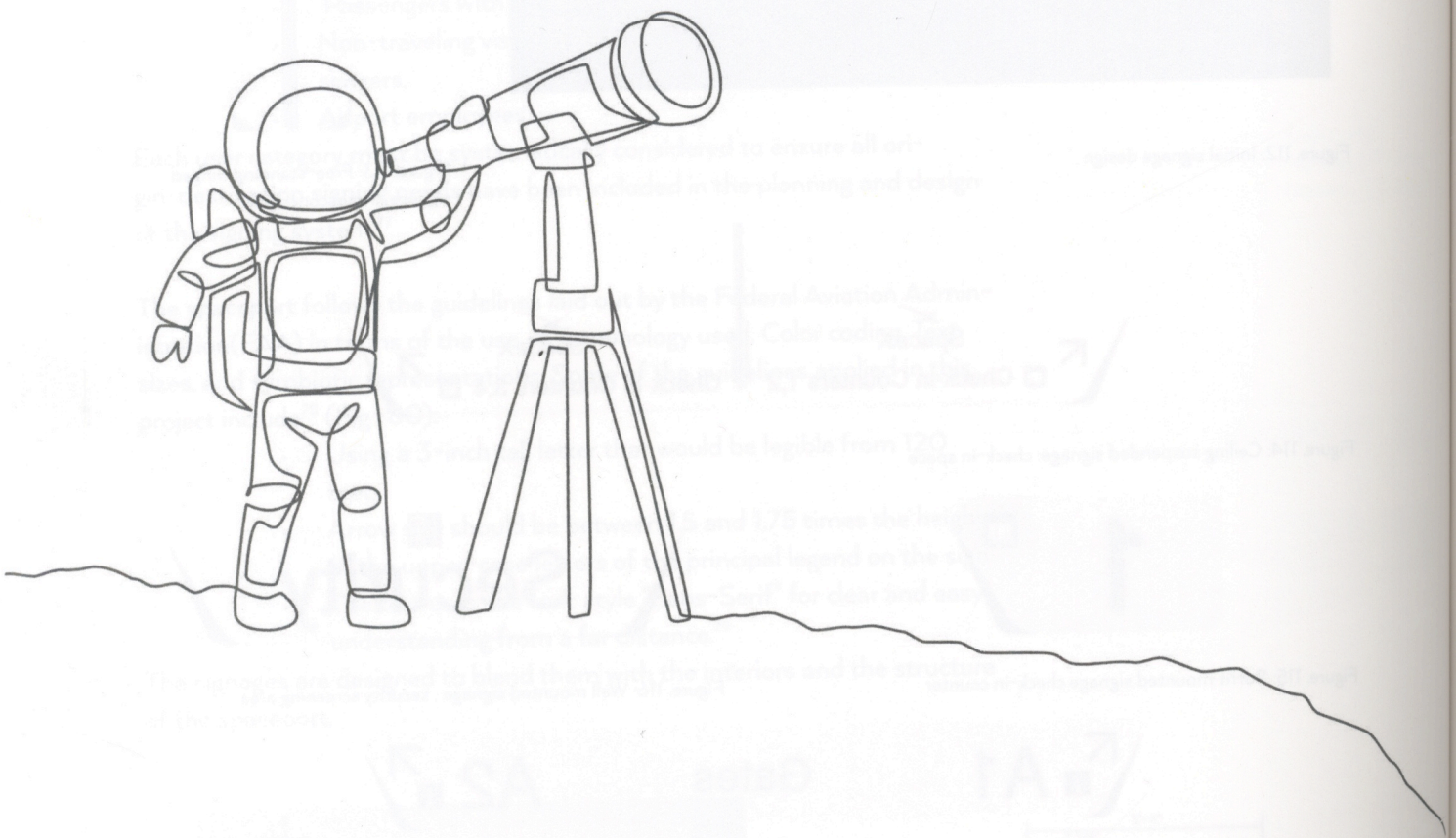


Image Source : Simple Line (Vecteezy.com)

SPACEPORT VIEWS

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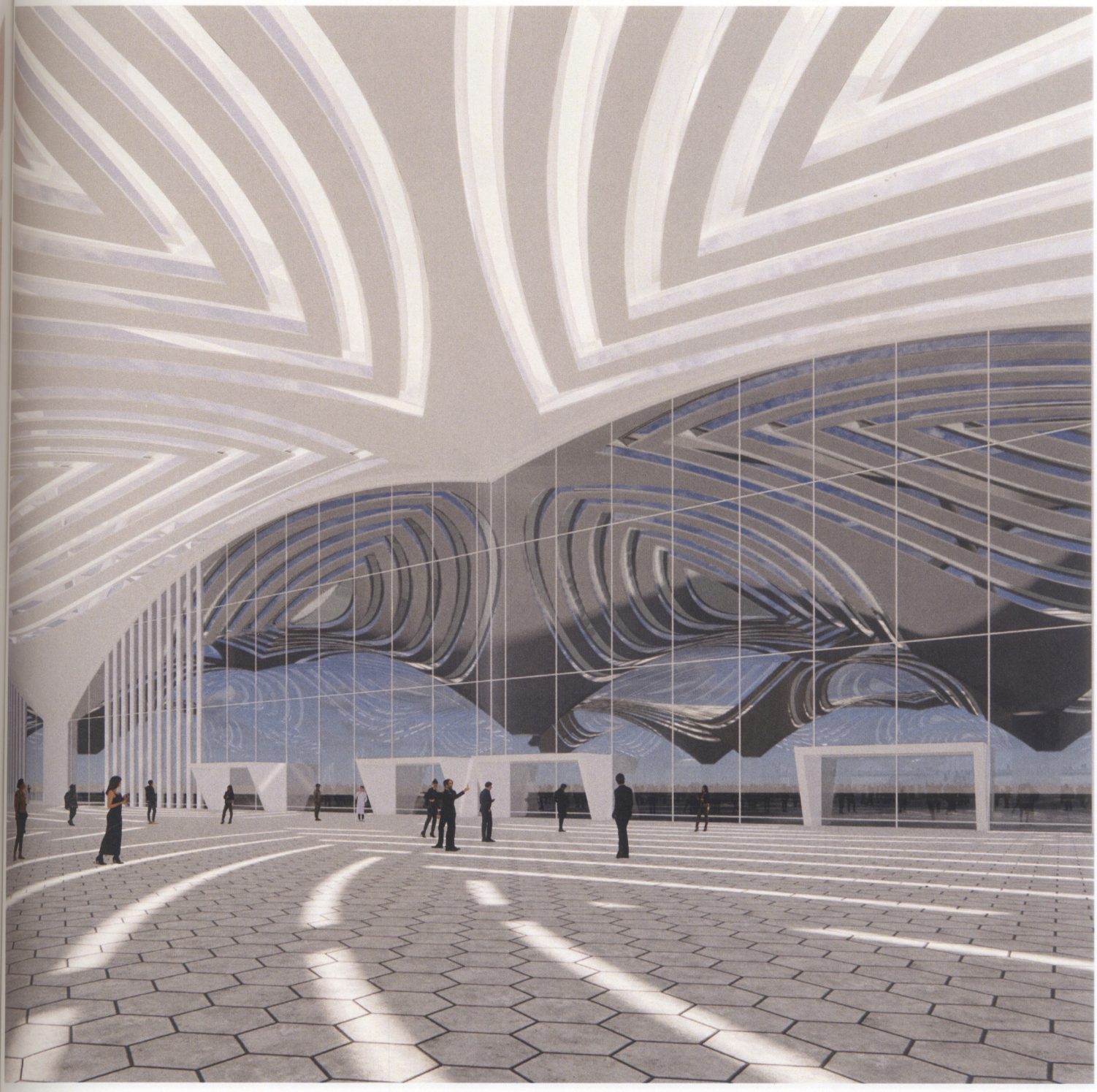

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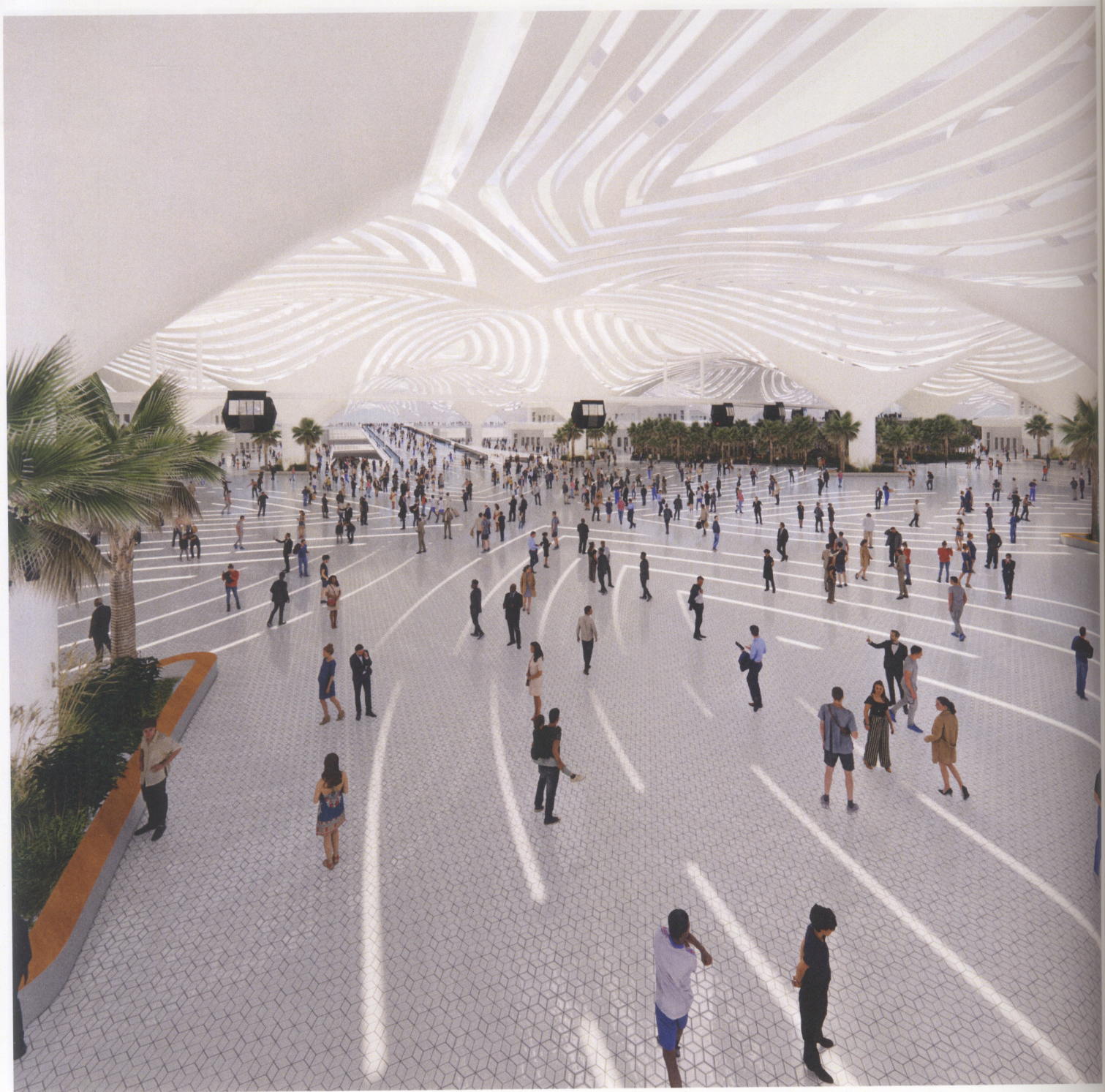

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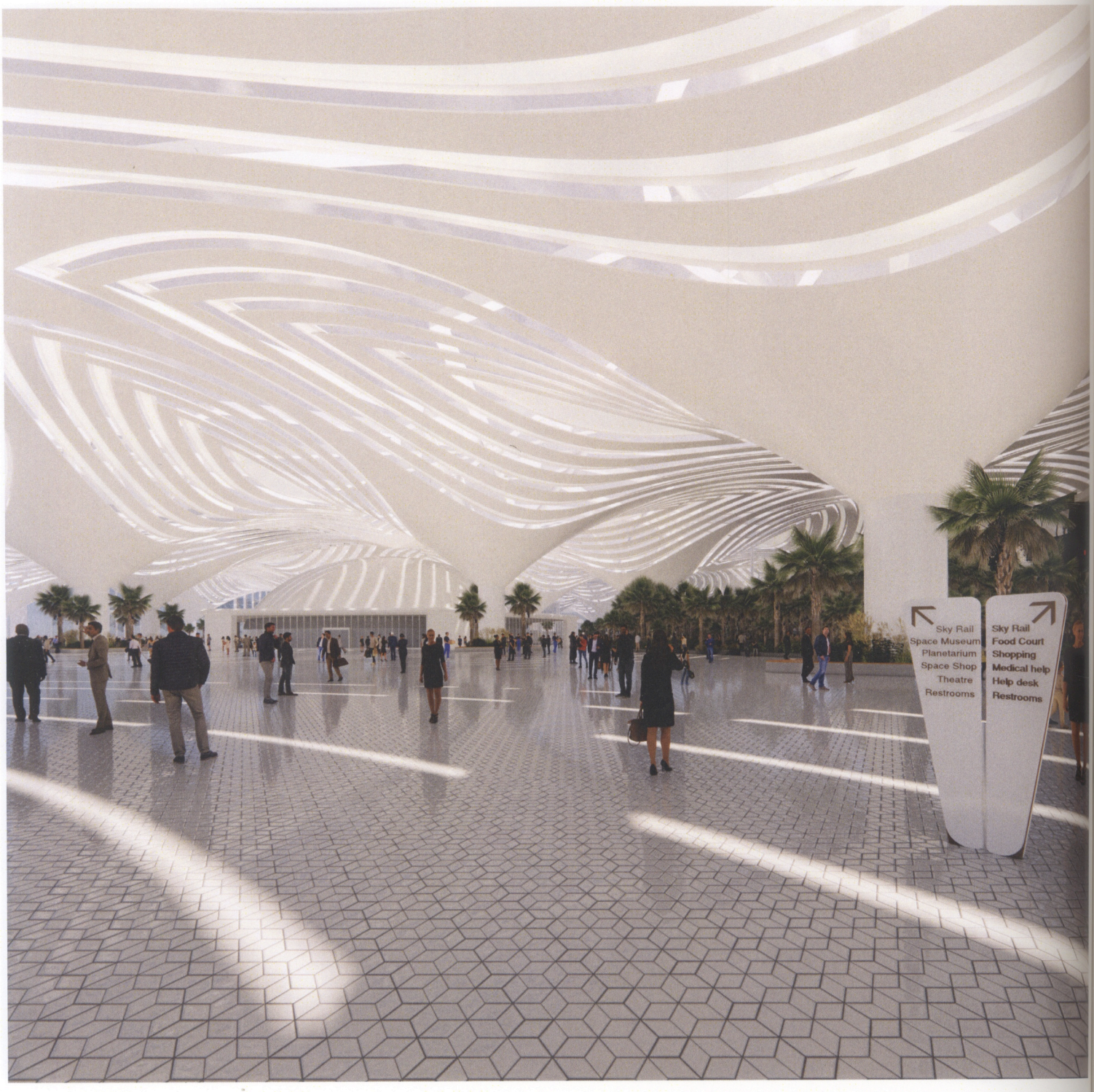

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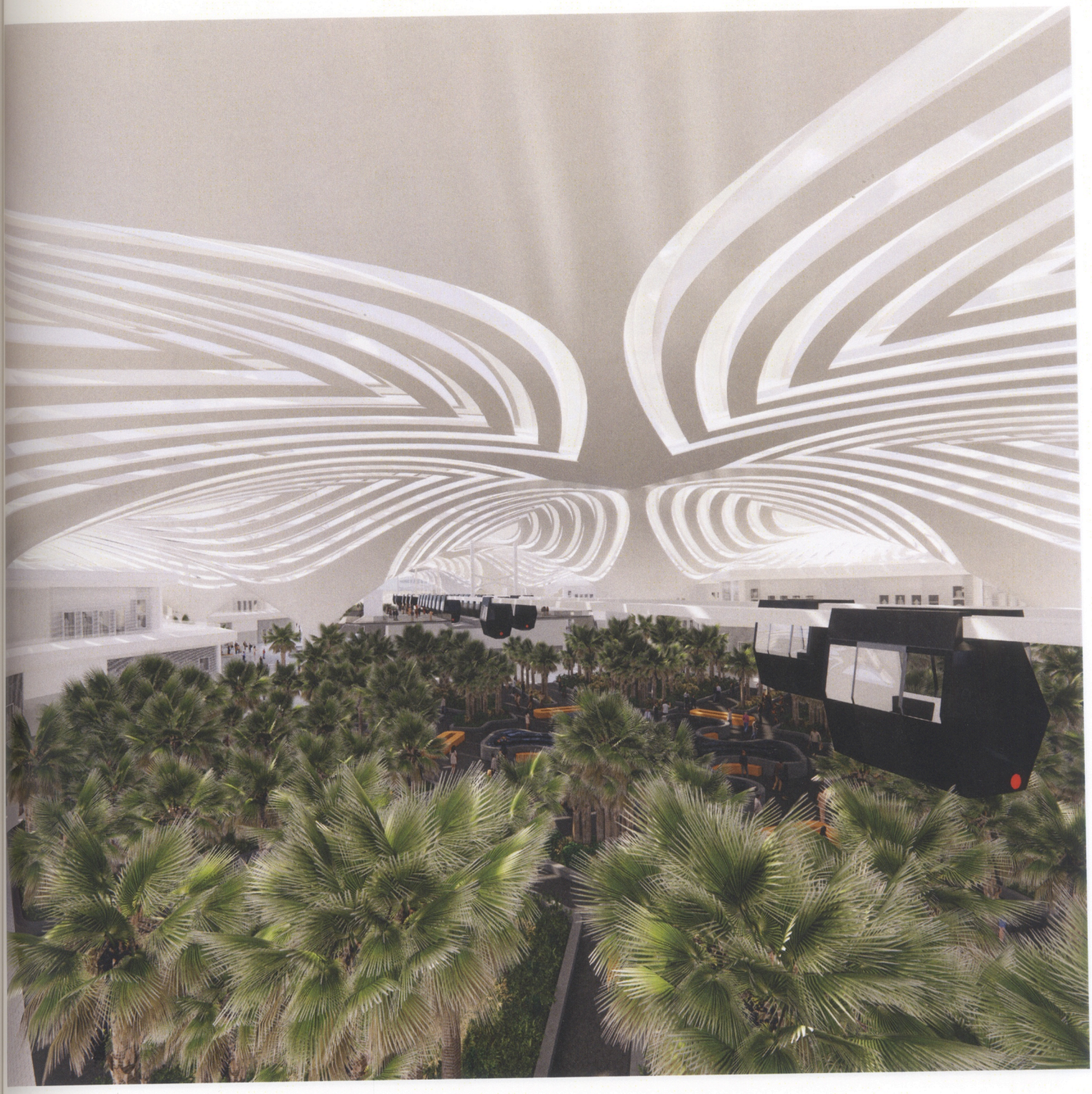

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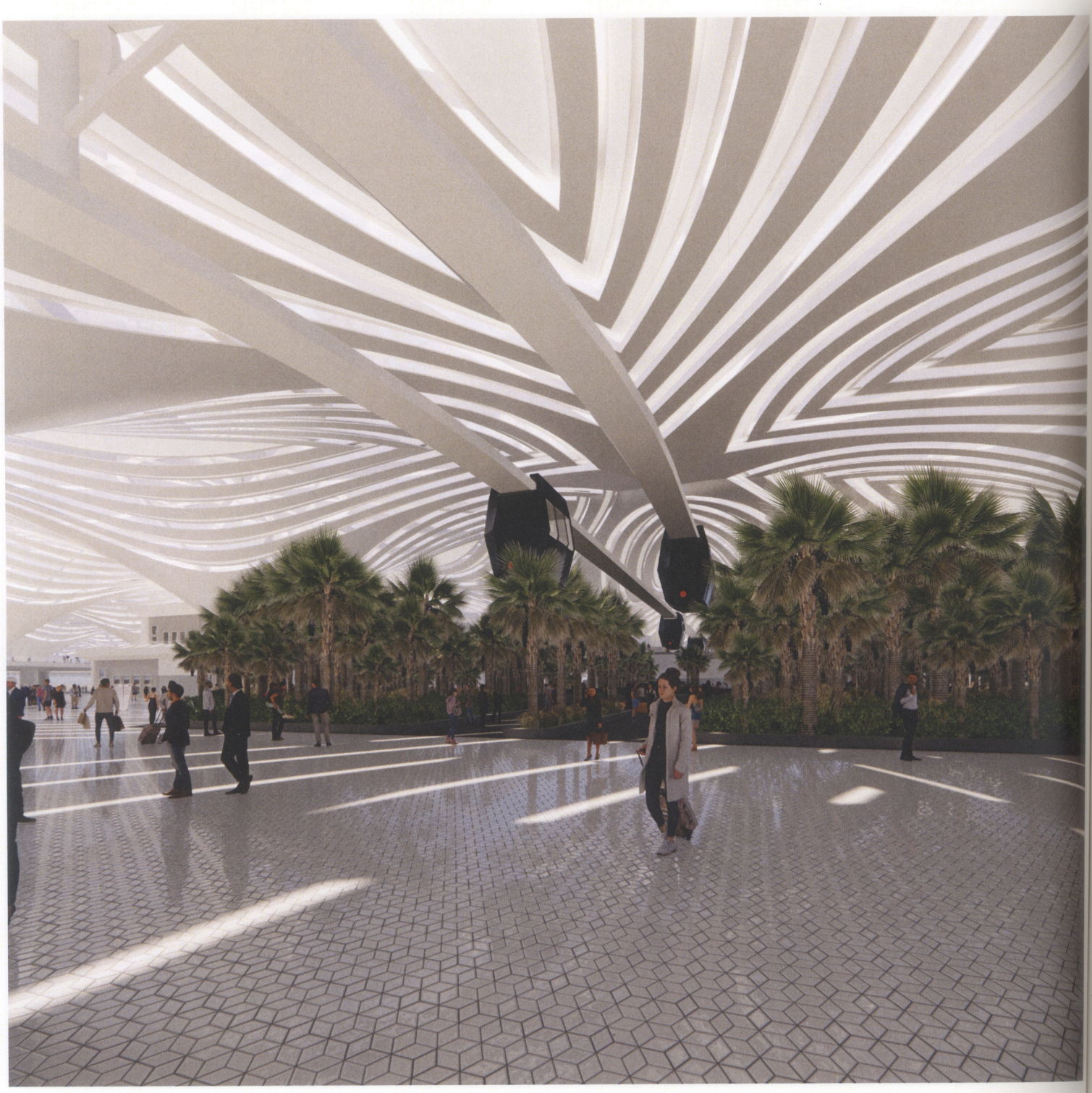

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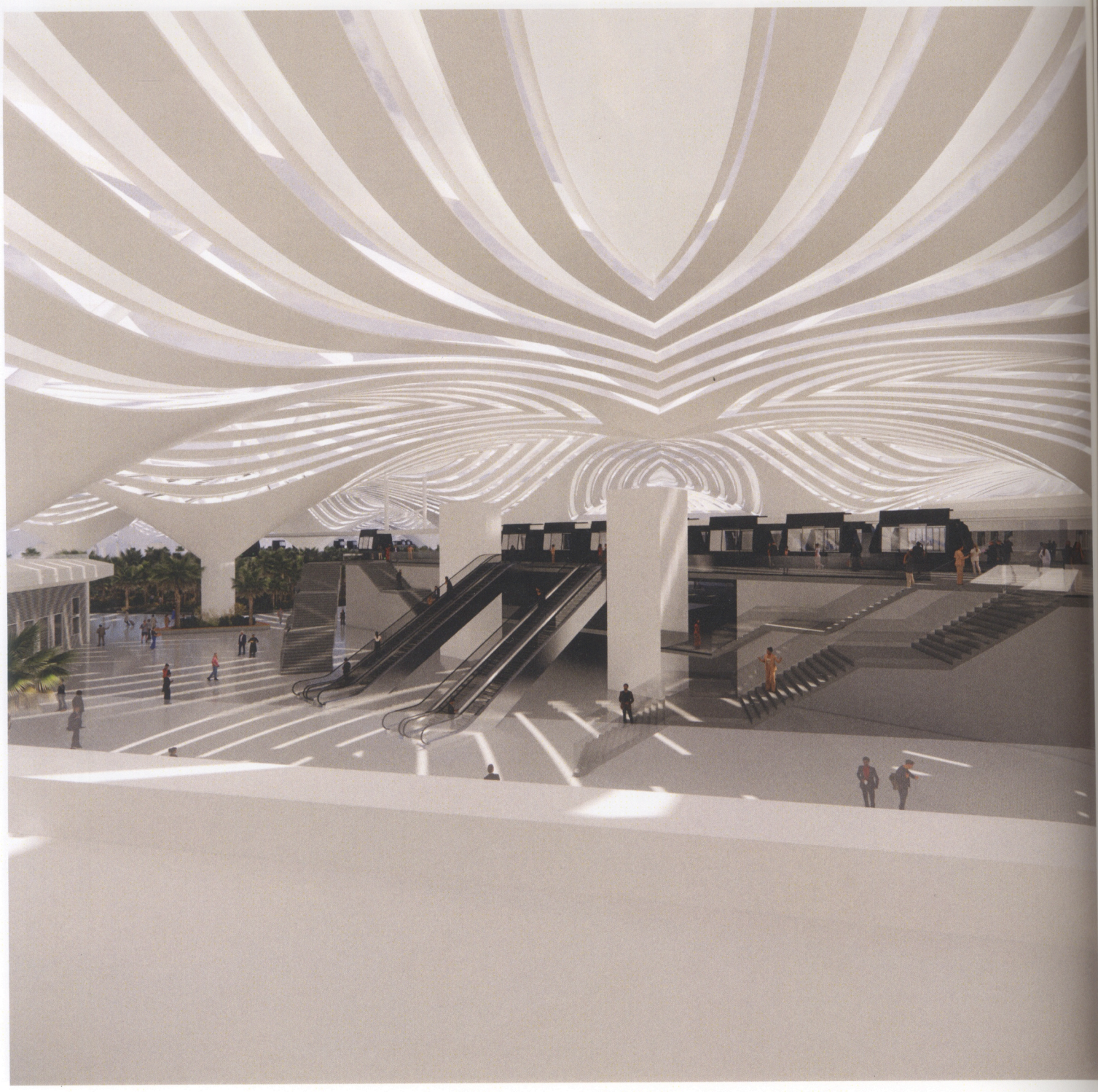

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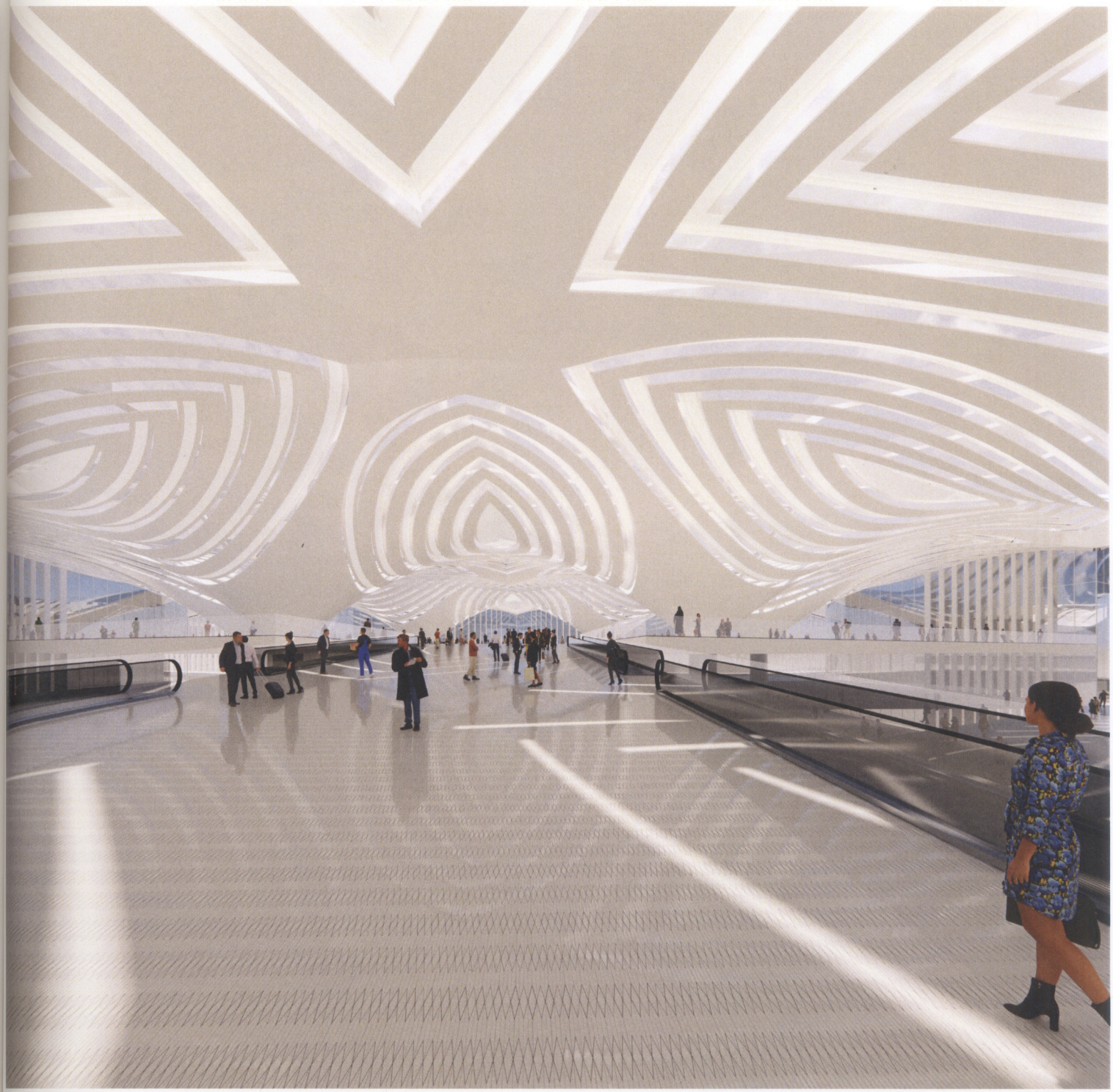

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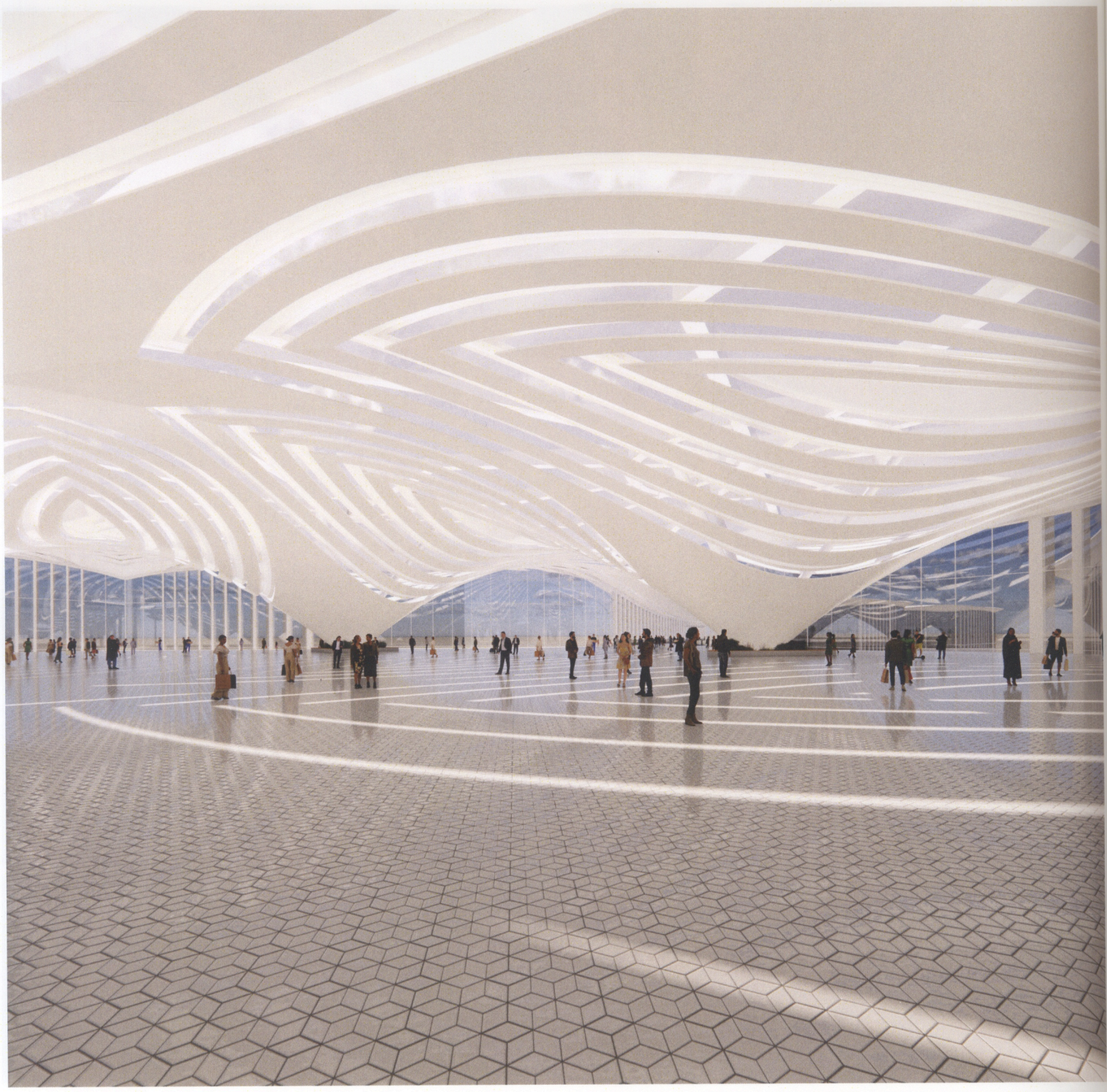
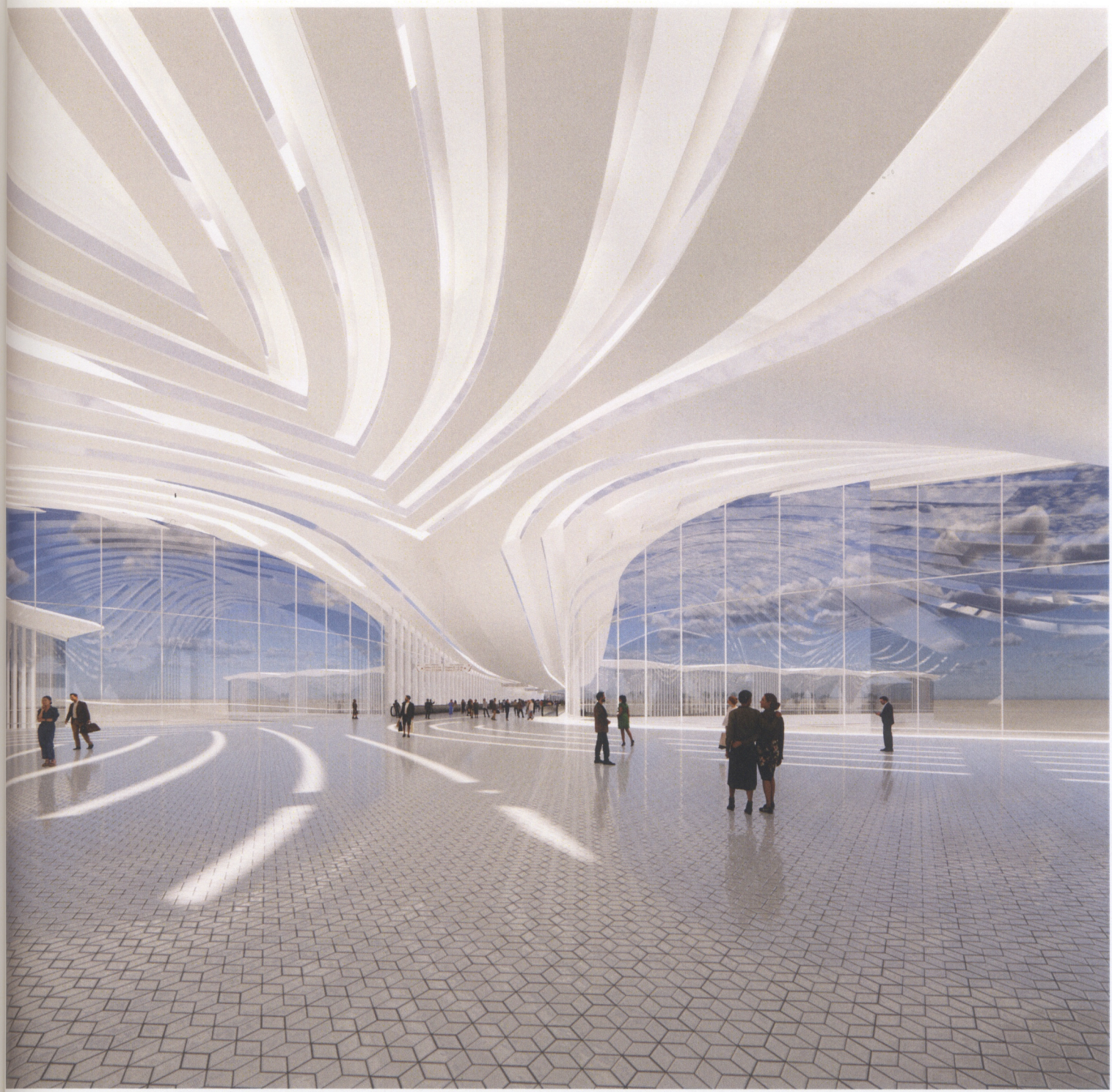


Figure. 131: View from upper deck towards the Inter-Galactic terminal



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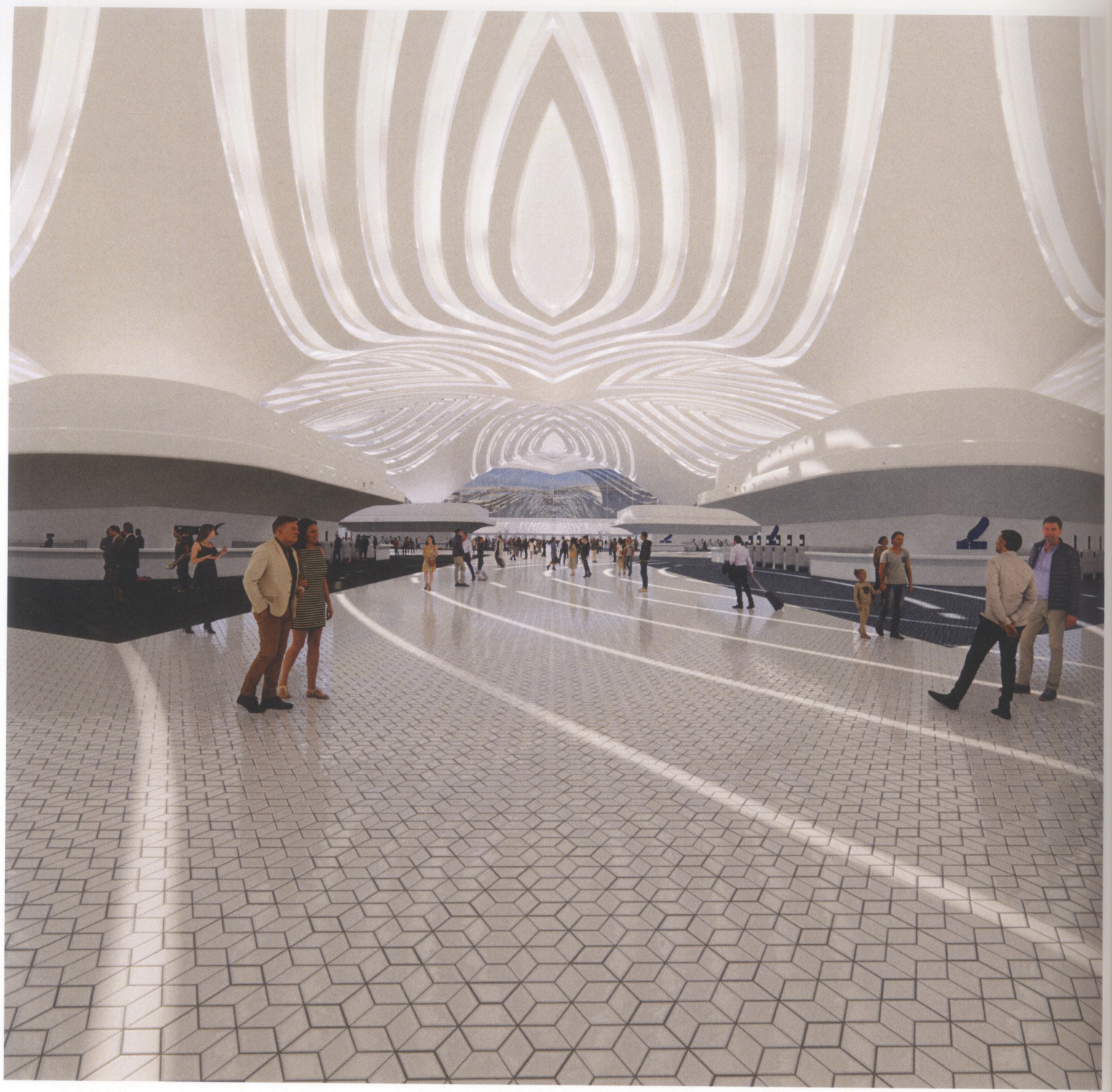

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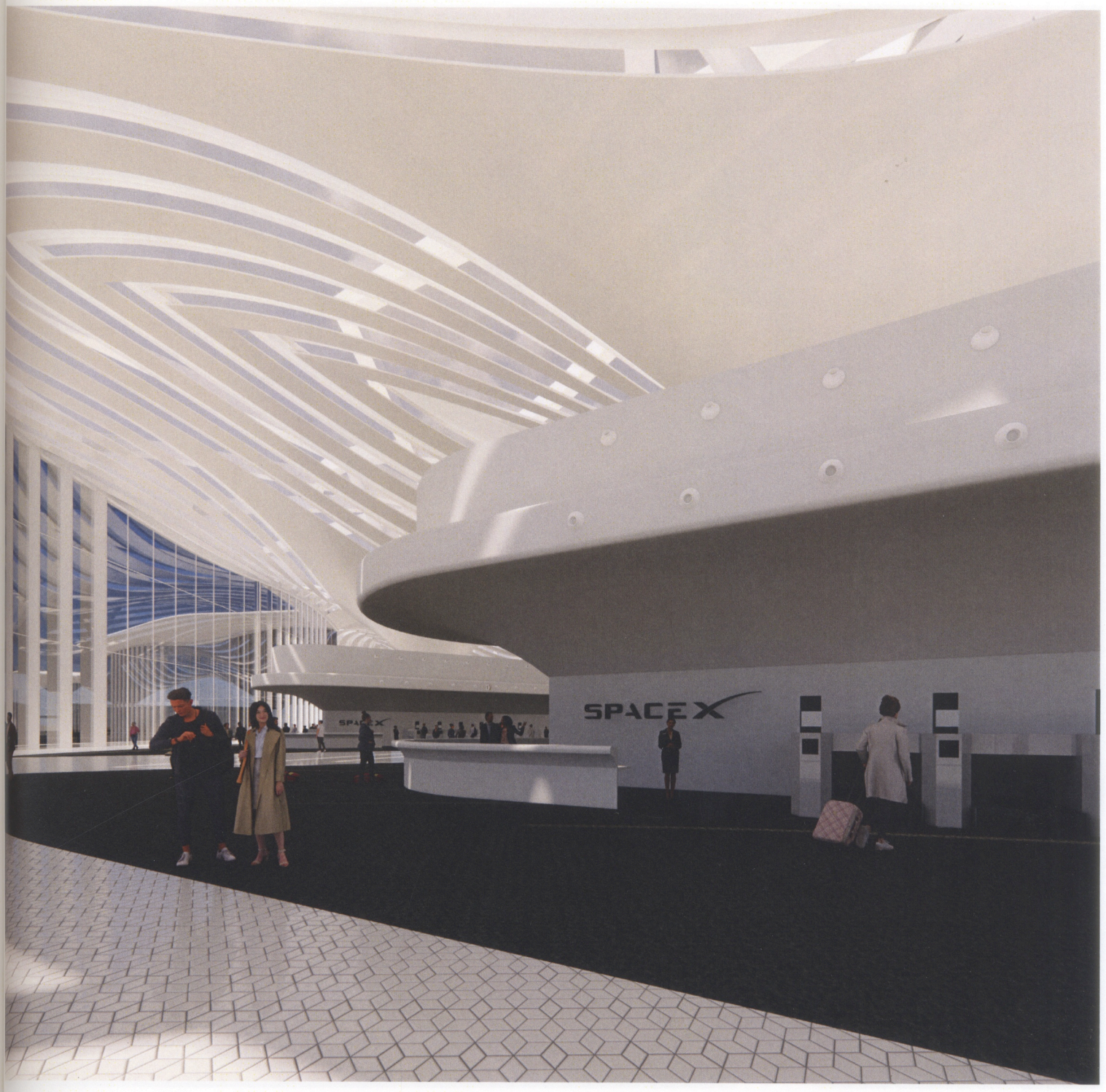

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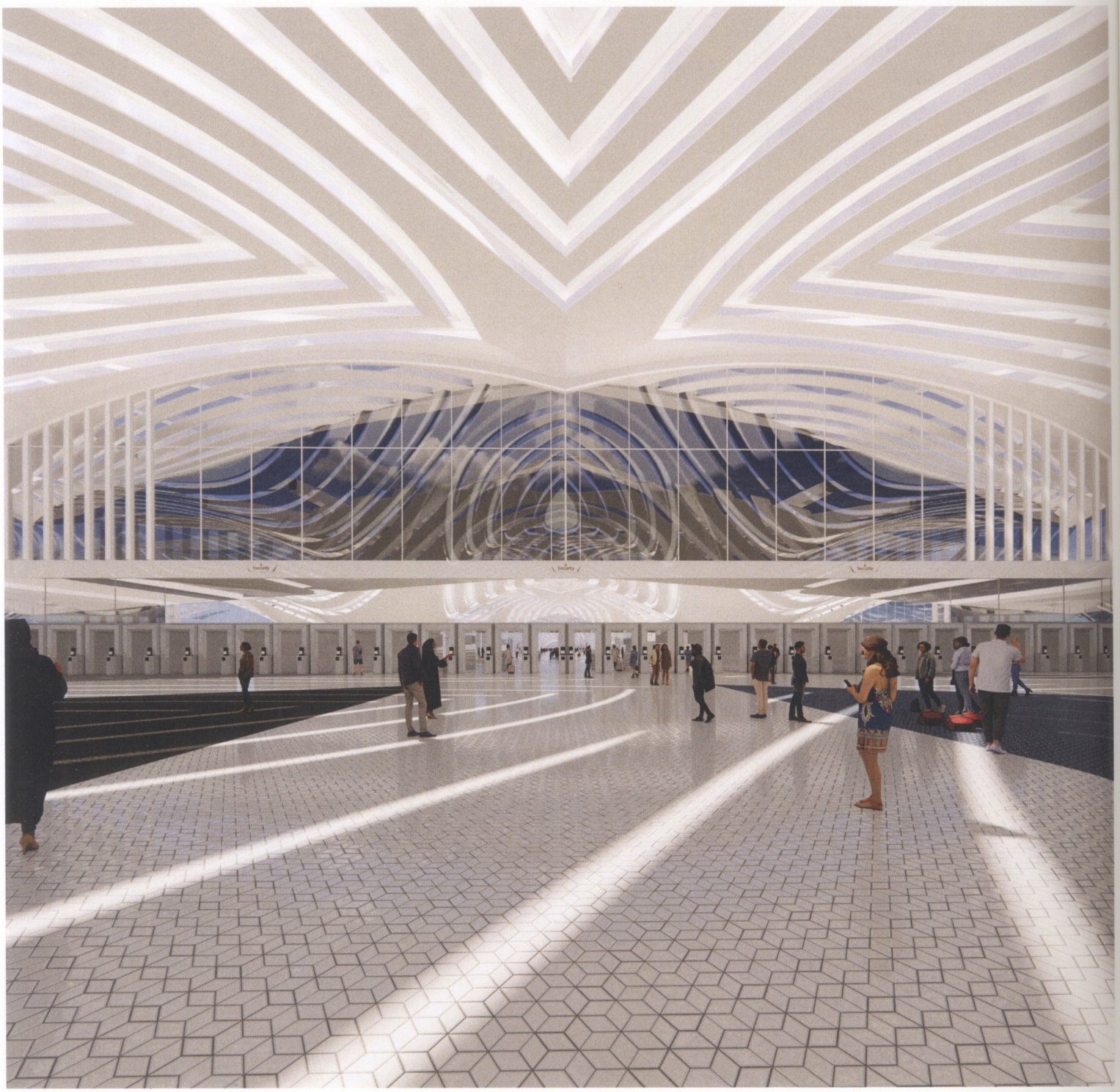

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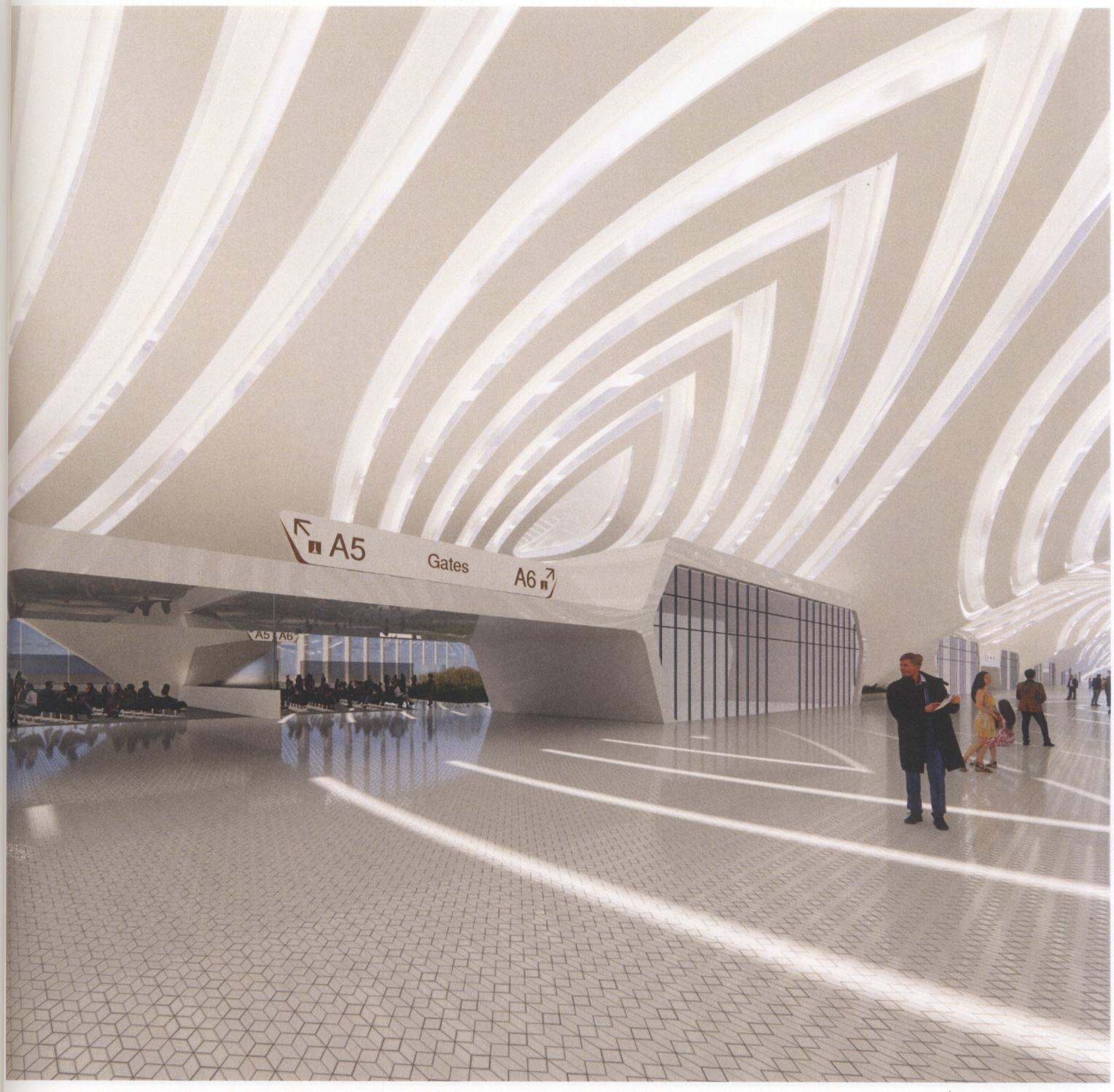

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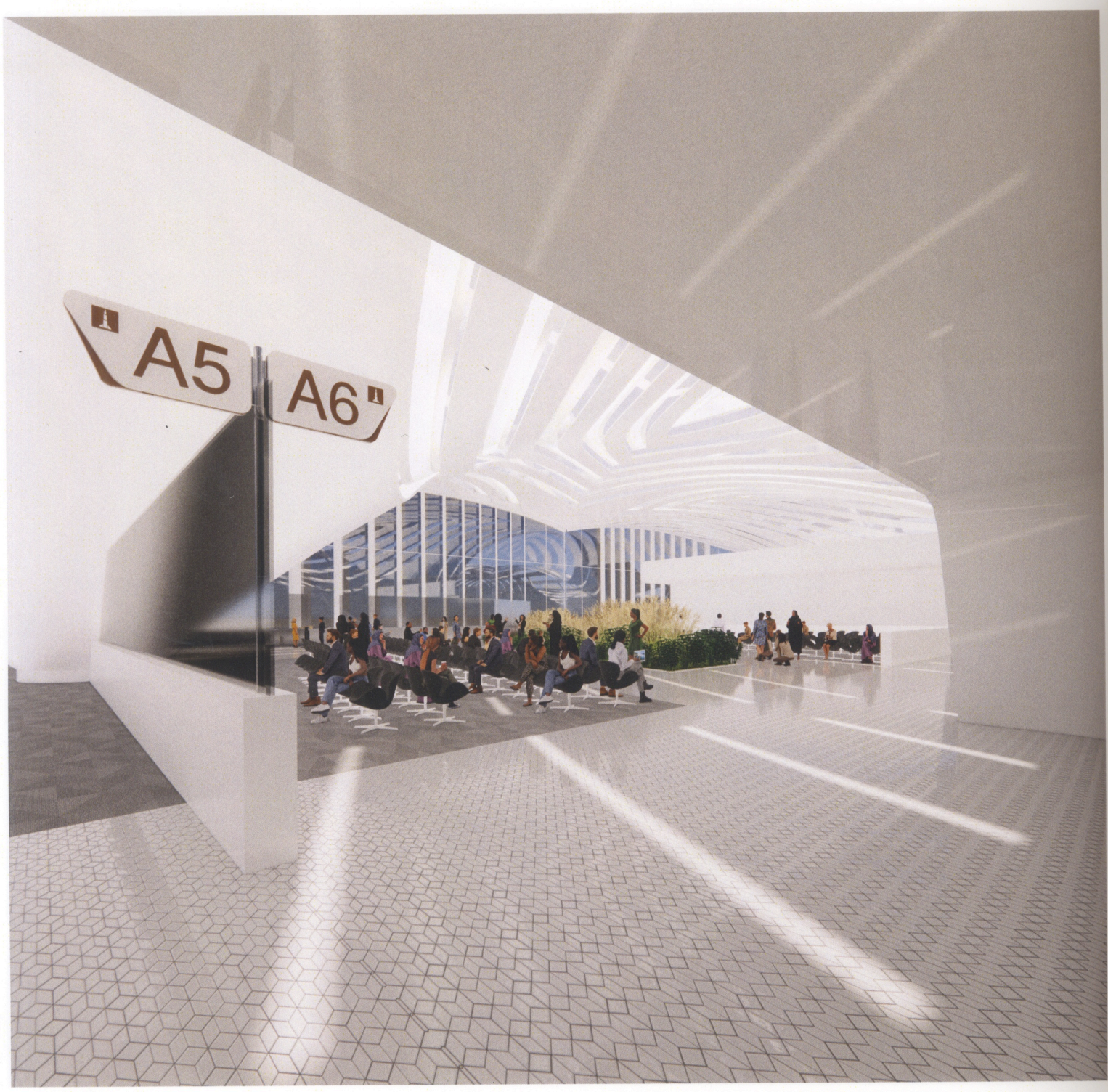

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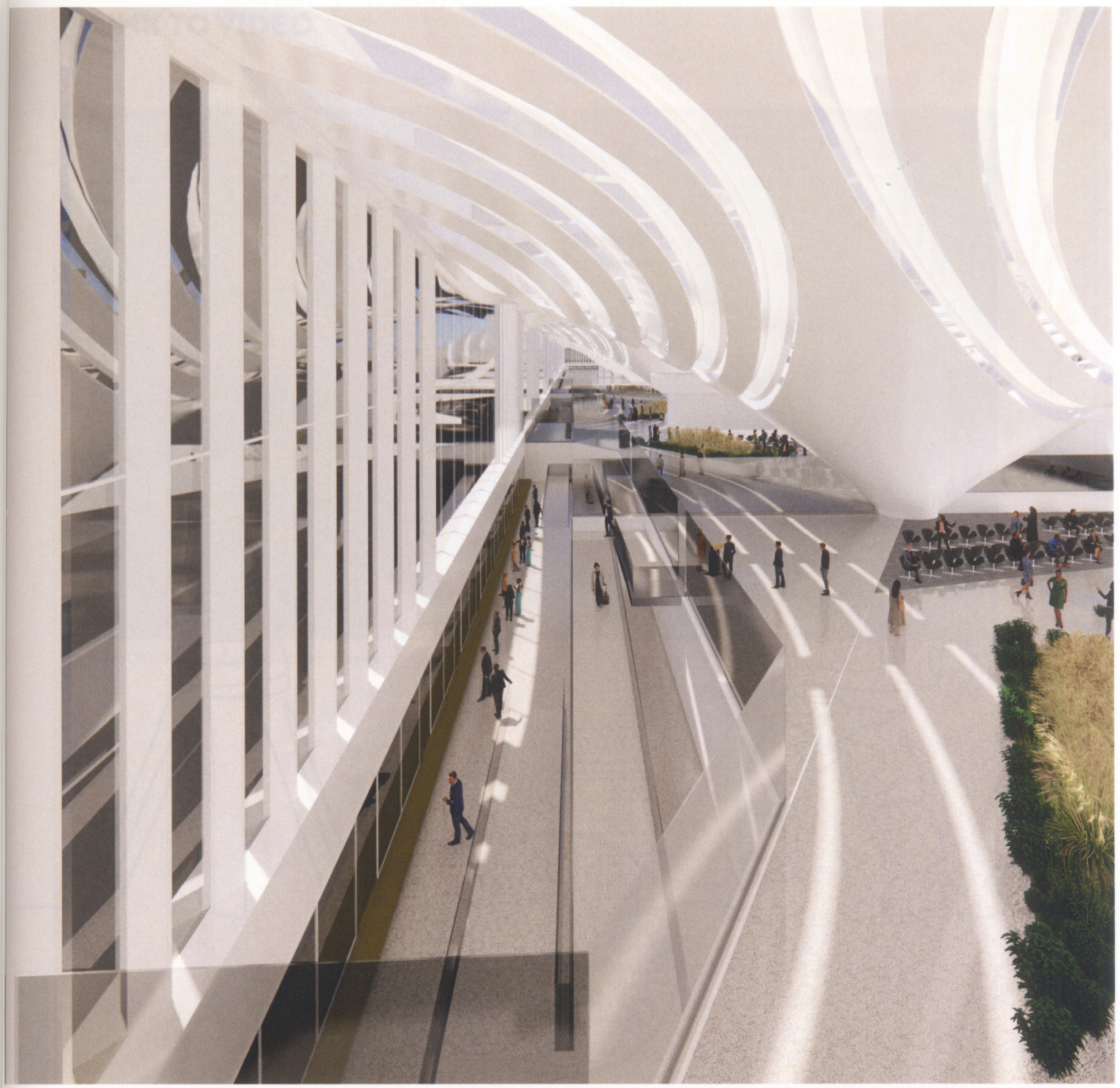

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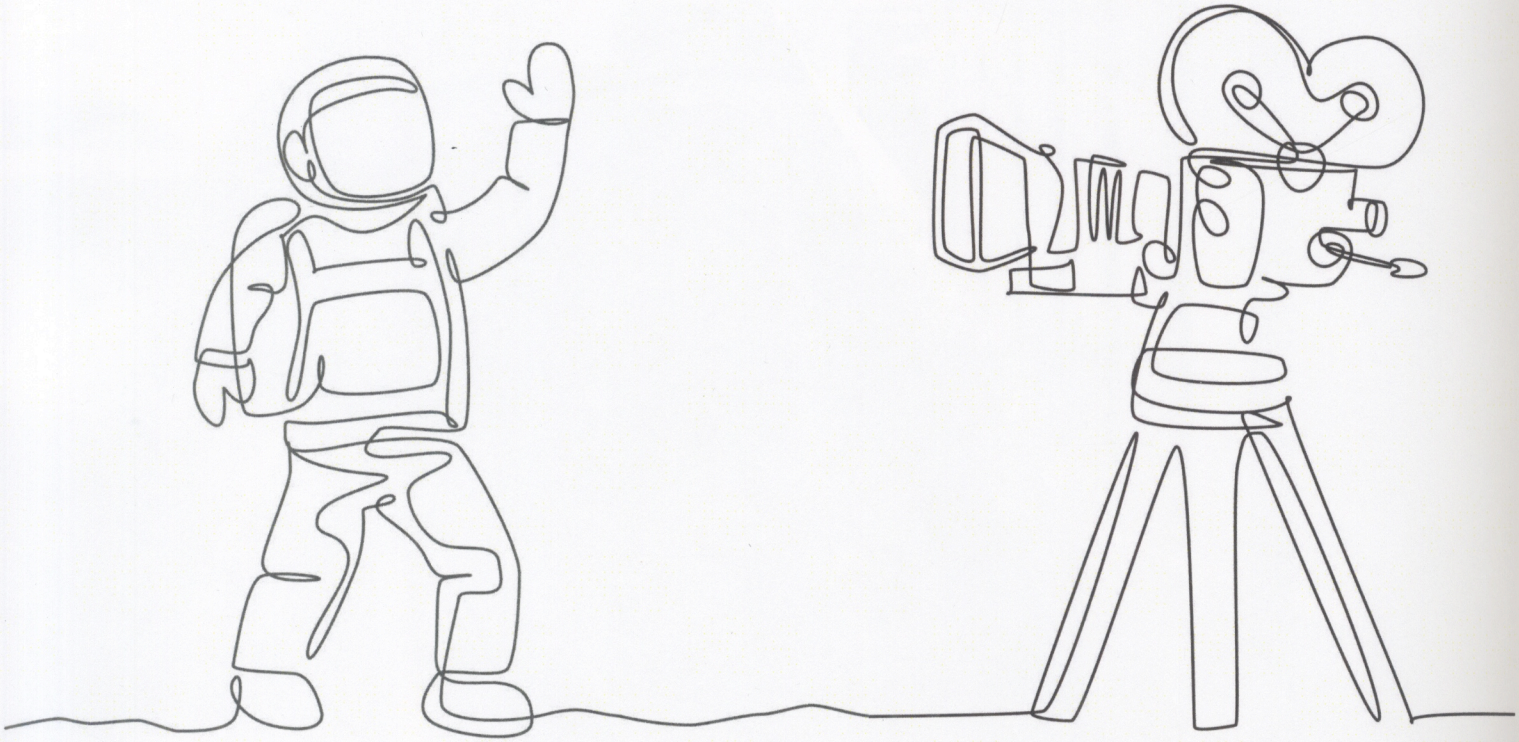
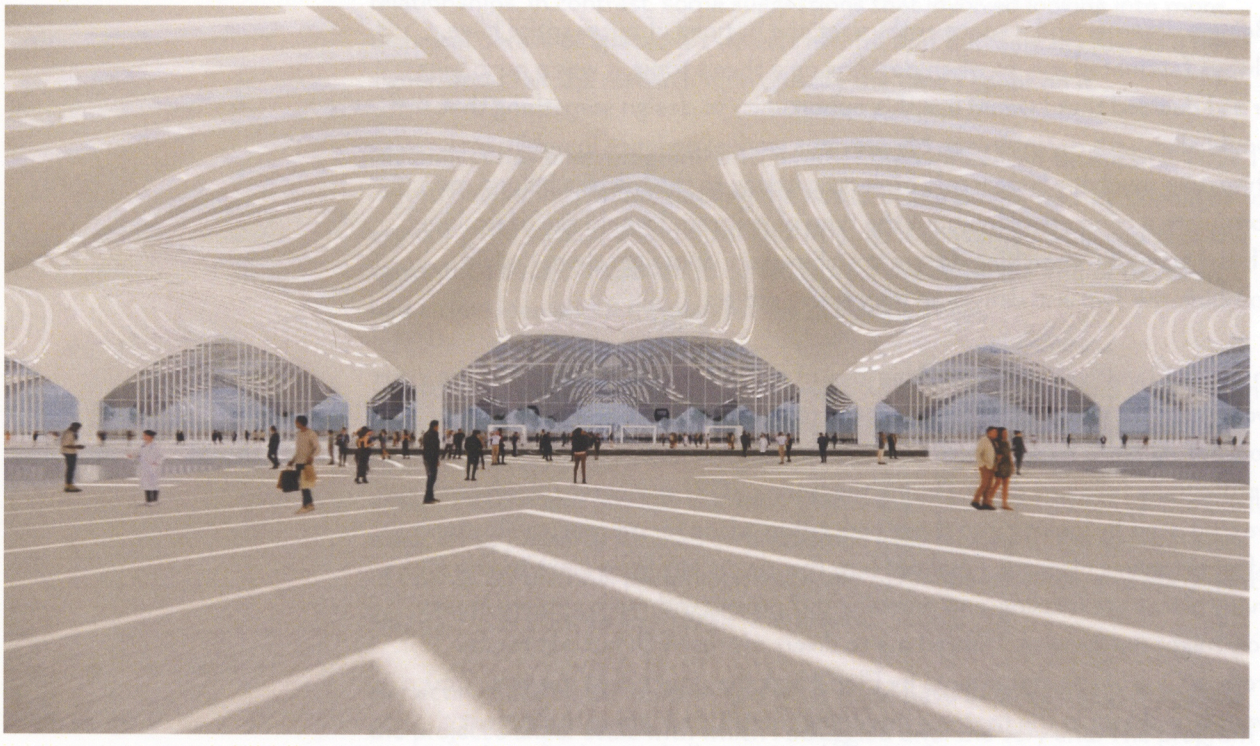


Image Source : Simple Line (Vecteezy.com)[83]

LINK TO VIDEO



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SCAN ME

End Credits
Countdown[84]
Rocket Launch[85]
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REFLECTION

Being a dreamer and a space enthusiast, the notions of outer space have always fascinated me, so when deciding on a thesis topic, it was a no-brainer as I decided that I would use this opportunity to design something that would align with my interests. My previous work experience in public architecture involving large-scale projects catering to the masses helped me formulate a concrete plan about the type of program I would like to explore. Thus, I started researching different architecture domains where I could combine the Two and deliver an impressive project.

In 2016, Elon Musk announced his idea of space travel and presented the world with his vision of landing a crew on the red planet. Since then, many conceptual plans by designers around the globe started making rounds, and I profoundly followed them. During the Spring 2021 semester, my research was initiated by looking into these conceptual plans for martian civilization. After extensive research, I realized how the idea is still like a giant puzzle and many pieces are missing, and pursuing this project without complete know-how might not be wise. This led me to divert my research but not too far from it. One of the statements by Elon Musk that stuck with me was, *"You want to wake up in the morning and think the future is going to be great - and that's what being a spacefaring civilization is all about. It's about believing in the future and thinking that the future will be better than the past. And I can't think of anything more exciting than going out there and being among the stars."*[87] His idea led me to look into means of travel to space and how it would require an infrastructure for its operational purposes. As the space program was taking shape into expanding itself for the general public for space exploration and Inter-continental travel through the means of rockets, Spaceports as a new typology of infrastructure has emerged. Recently, other companies like Blue Origin and Virgin Galactic simultaneously aligned themselves with SpaceX's vision and invested vast sums of money into researching and developing infrastructural facilities. With Everything the space mission aims to accomplish in the future, my project is designed to serve the future travelers, probably within the next 3-4 decades.

Due to the unavailability of any building of the same scale that could serve as a precedent for my project, I looked into diverse options to formulate my understanding. Airports, to understand the circulation patterns and movement through a big transit space and Active Rocket Launching facilities to know the technical Know-how.

After the Symposium in September 2021, many questions were raised by the reviewers, and I was made aware of a lot of dimensions associated with

the project. Some of them eventually helped me achieve what I have to this day, like focusing on human experience and experience of waiting, expansion of space over time, circulation of people within the space, and site vs. Building relationships. In contrast, some suggestions that involved looking into more technical details of spacecraft weren't helpful as it outcasts my role as a designer, and I felt the research didn't justify the time I spent on it.

My project has been program-driven rather than influenced by the site. Thus, I delved deeper into understanding the basics of the program's functionality and exploring the structure's modularity. Although it consumed a big chunk of the semester, I believe it proved to be fruitful for me as, by the end of the term, I had a clear idea about my plan for the designing stage.

The Spring 2022 semester was intense, focused on designing and finalizing the layout and production. I generated multiple iterations of my design, and with each bi-weekly review and desk crits, the design kept evolving, and a refined design was the end product the week before the thesis. From then till the finals week, it has primarily focused on production work leading to the development of boards for the final presentation day, my 3D rendered video, and documenting the whole process as a thesis document.

Reflecting back on the process and what could have been better in my case is the project's sheer scale with which I struggled until the very end. The program in itself had a lot of requirements, and designing Everything in detail for this project in the given time frame could not be possible. If given a chance to revise or go back a year ago, I would choose a smaller site than the present one as it imposed many challenges in size and topographical features. Many things in this project were left at a conceptual stage that I would like to develop for my understanding, starting with the back-of-the-house services, which go into the smooth functioning of such an extensive facility.

In the future, I would like to explore the back-of-the-house architecture of the spaces and explore how the experience of a futuristic and Technology-driven space will be different for its support crew than the travelers.

Finally, I would sum up by saying that it has been a rollercoaster ride for me with both happy days filled with zest and zeal and some gloomy days, but never letting go of my optimism for excellence has made me put my 100% soul into this project. Overall it has been a great learning experience for me, letting me try my hands-on different 3d visualization software and learn new technology and innovations associated with the AEC industry.

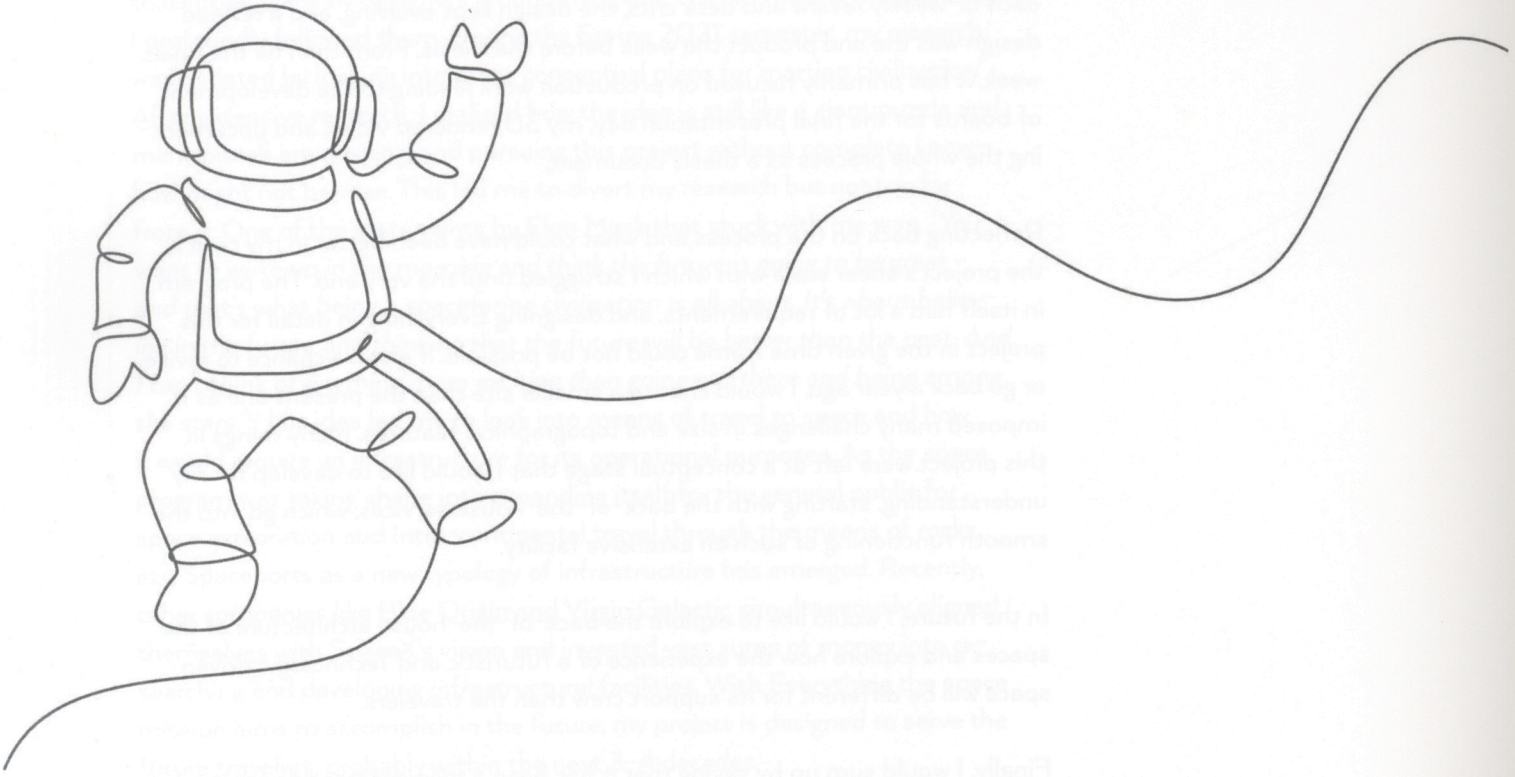

Image Source : Simple Line (Vecteezy.com)[98]

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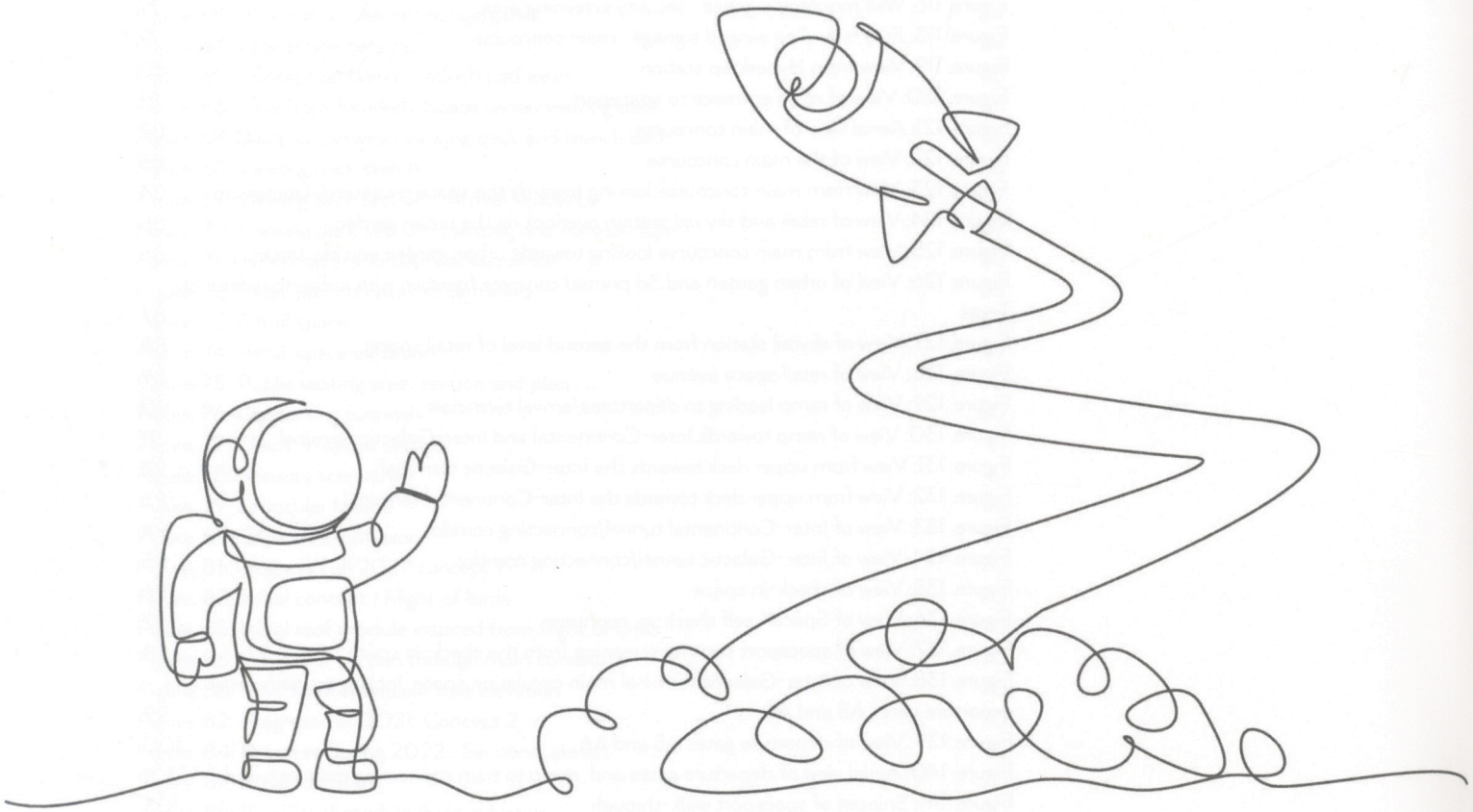

Image Source : Simple Line (Vecteezy.com)[89]

ENDNOTES

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