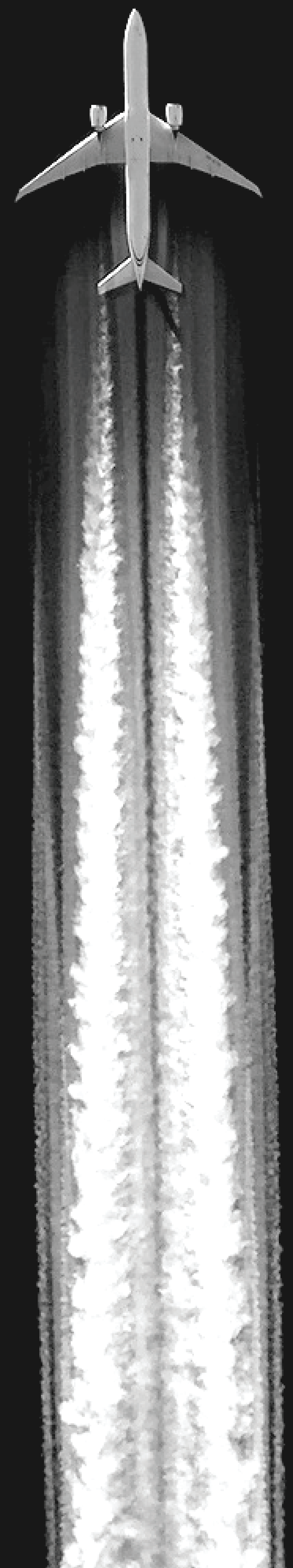
FLIGHT



THESIS QUESTION:

HOW CAN SUSTAINABLE ARCHITECTURE HELP REDUCE THE ENVIRONMENTAL IMPACT OF AIR-TRAVEL WHILE INCORPORATING NATURE WITHIN ARCHITECTURE?

PROJECT GOALS:

1. Create a strong connection to nature.
2. Reduce the environmental impact of the facility.
3. Utilize sustainable design practices.

The First Successful Flight

On the morning of December 17, 1903 the Wright Brothers successfully completed the first powered flight. The flight lasted only around 12 seconds and covered a short distance of approximately 120 feet, but this was the first successful powered airplane flight in the world. The photo below shows the Wright Flyer shortly after leaving the ground. “*This photo is arguably one of the most famous photographs ever taken” ~ Russell Freedman.*

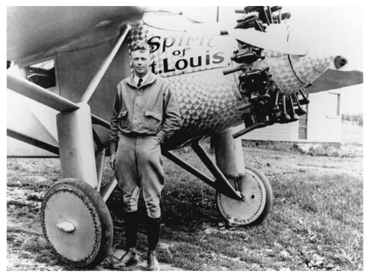
This started the age of modern aviation.

HISTORY OF FLIGHT

In a little over 100 years from the first flight to present day the advancements in technology of flight have increased at an extremely high rate. Fast forward to present day time and these advancements are still on the rise but have seemed to have focused on fuel efficiency techniques such as lighter composite materials or new efficient fan blades on jet engines.

1843
Otto Lilienthal designs & flies biplane gliders.

1903
Wright Brothers first recorded heavier then air powered flight.



1927
First Trans-Atlantic Flight by Charles Lindberg

1930
First jet engine invented by Frank Whittle

1932
Amelia Earhart makes the first Trans-Atlantic flight piloted by a woman

WWII 1938-1945

1938
During WWII Germany successfully flew the first jet powered aircraft the Heinkel 178

1947
First supersonic flight recorded by Charles Yeager

1969
First supersonic passenger aircraft flies

1970
Boeing 747 makes the first commercial flight

1976
The french Concorde starts passenger service

1986
First non-stop flight around the world

2005
The Airbus A380 makes its first flight

2009
Boeing 787 makes first flight

2013
The Airbus A350 makes its first flight

CURRENT MSP AIRPORT

The current MSP Airport by the numbers:

- Airport Site: 3,400 Acres
- 17th Busiest Airport In the United States
- 12th Busiest for aircraft operations
- Supports over 86,000 jobs
- Passenger Traffic in 2018: 38,037,381
- Take-offs | Landings in 2018: 407,476
- Originating Passengers: 60%
- Connecting Passengers: 40%
- Markets Served: 136 Domestic | 27 International
- Total Gates: 104

MSP Airport Issues:

- Nearing passenger capacity
- Current site is “Land-Locked”
- No room for growth on site

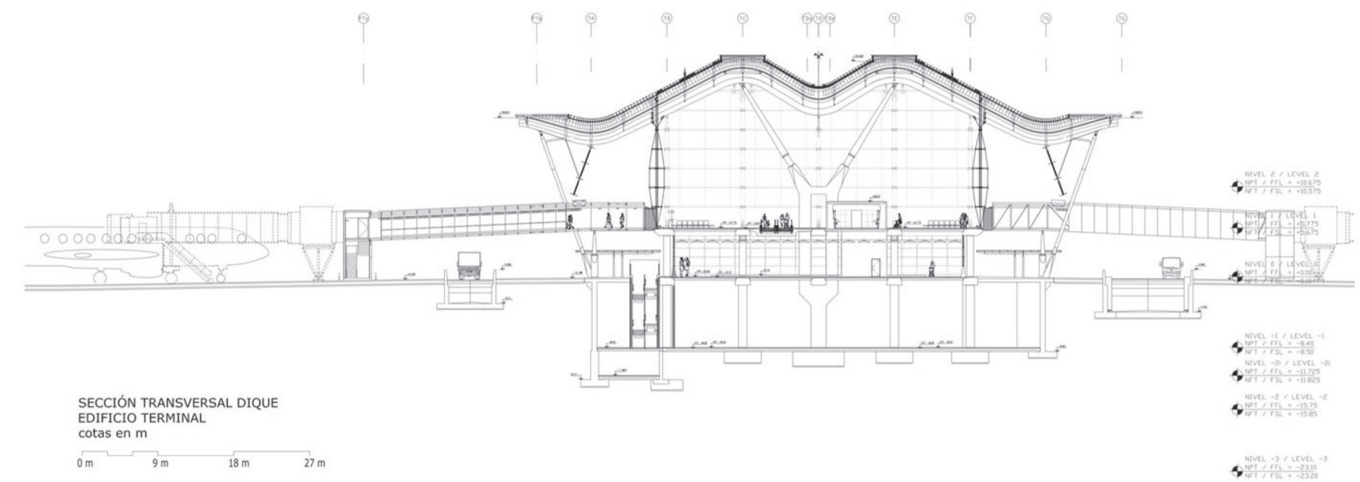
CASE STUDIES

Madrid Barajas Terminal 4

Location	Madrid | Spain
Architect	Richard Rogers | Carlos Lamela
Year Complete	2005
Floor Area	1,158,00 sq. m.
Construction Cost	€1,238,000,000
Type	Airport Terminal

Terminal 4 Overview

Madrid's airport is the largest airport by surface terminals in Europe. For this case study I will focus on Terminal 4 of Madrid Airport. Currently the Madrid airport serves as many as 35 million passengers a year and is expected increase to over 50 million by 2020. I was also very lucky to have briefly visited this amazing structure when I was on the NDSU study abroad trip during spring of 2018.

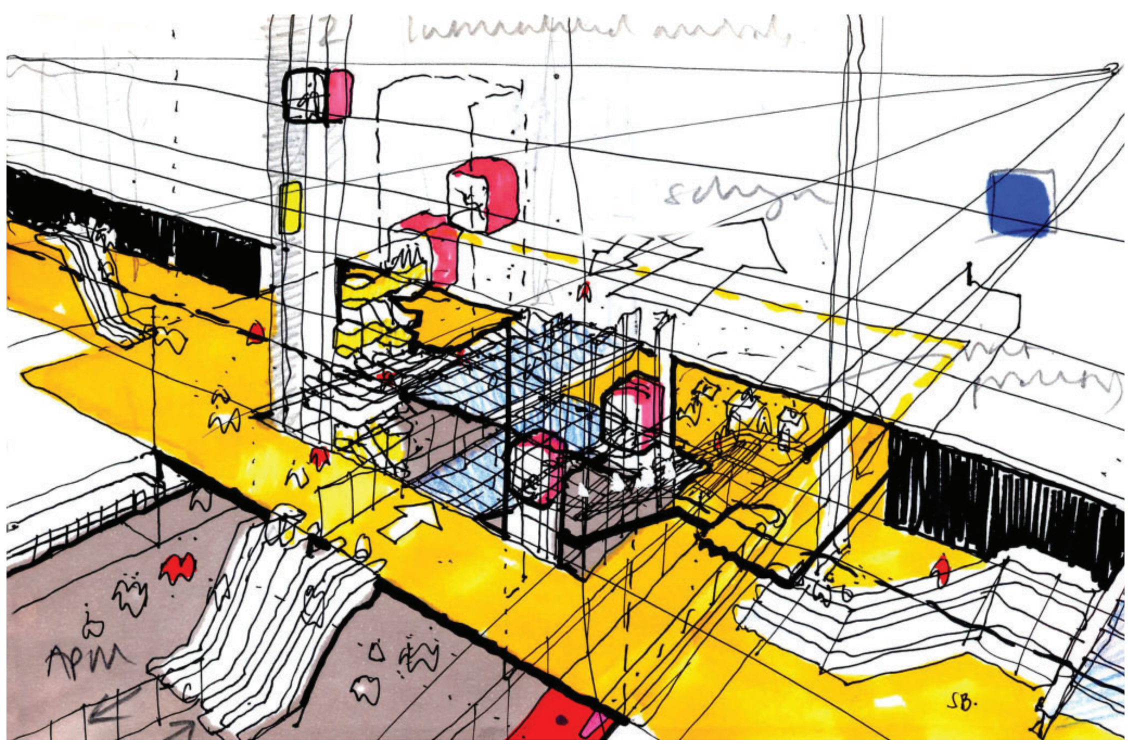


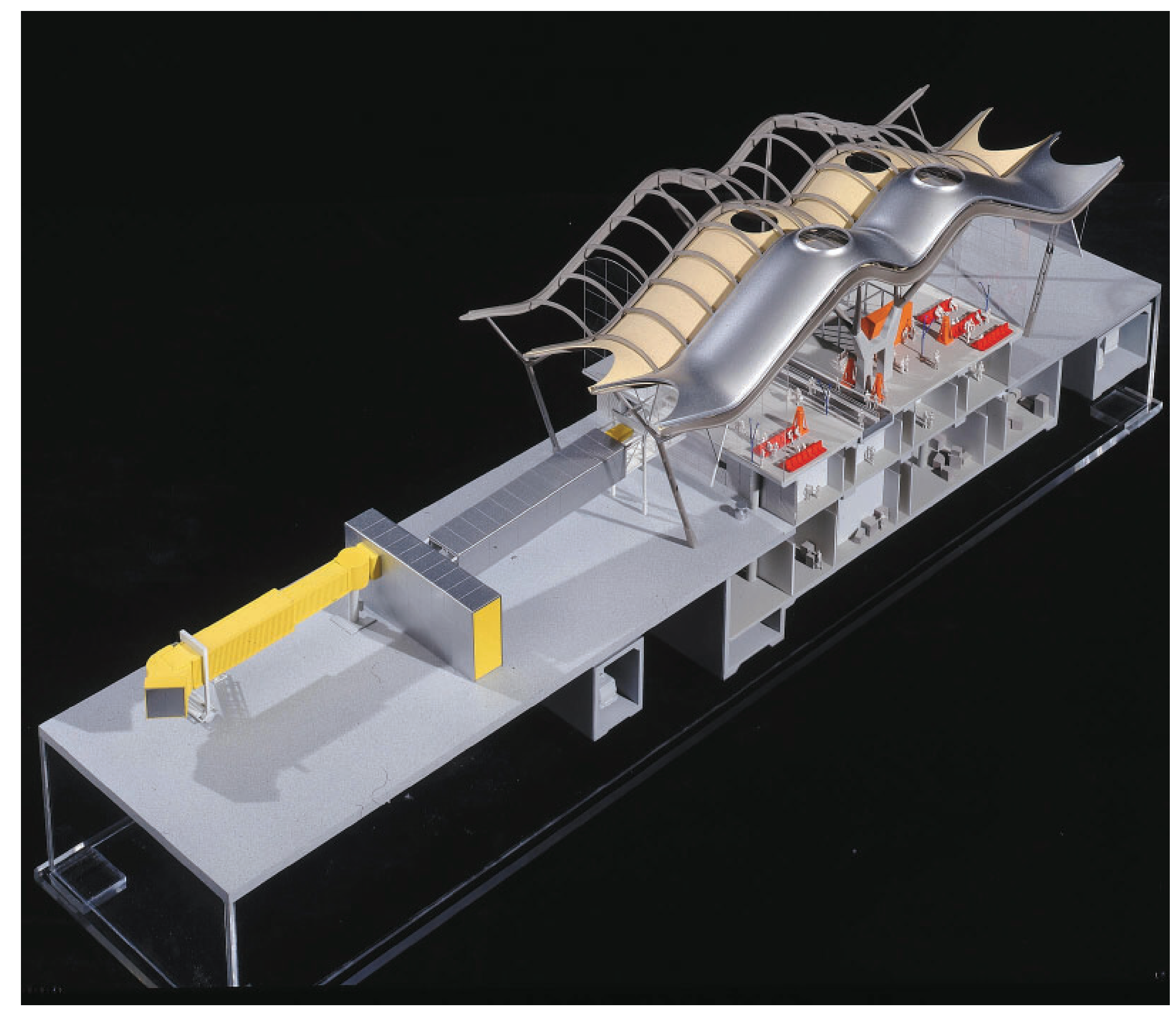
The Design

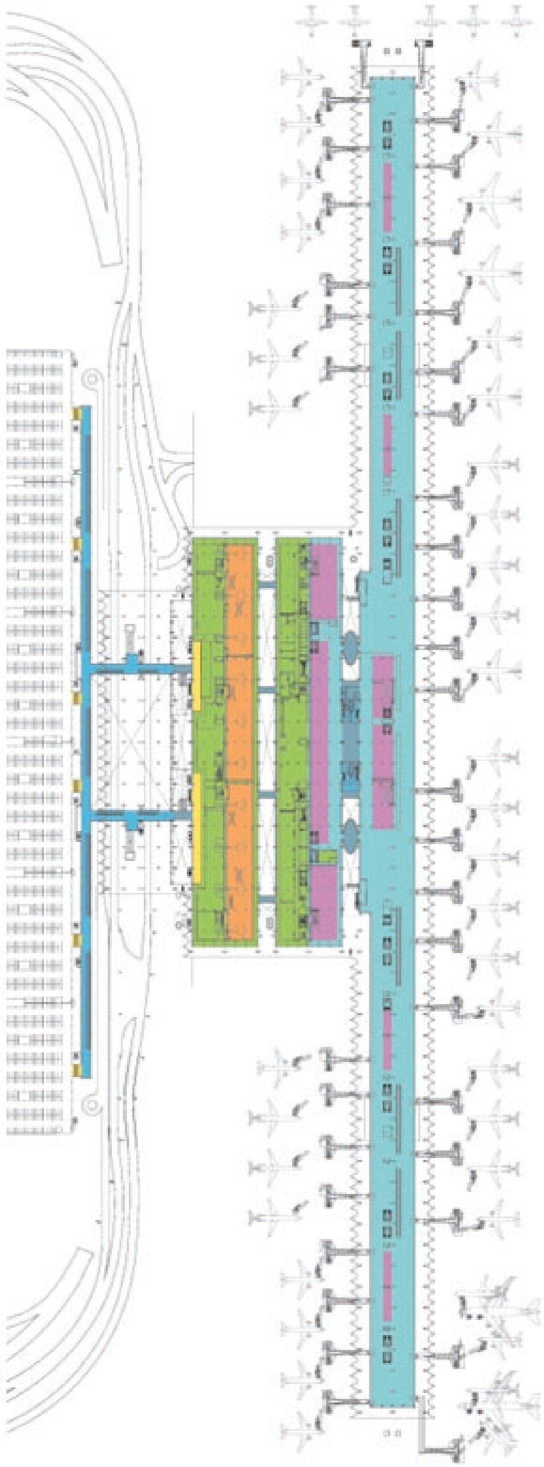
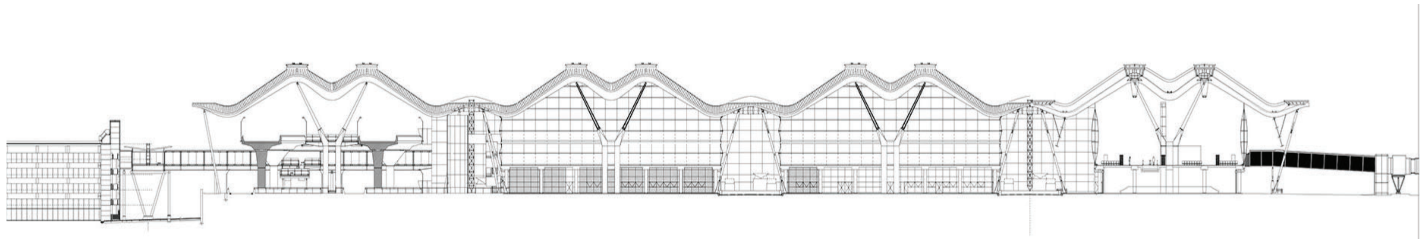
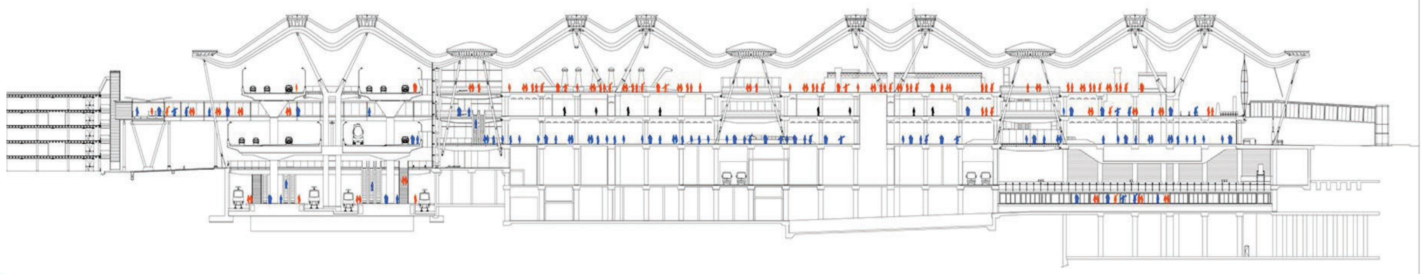
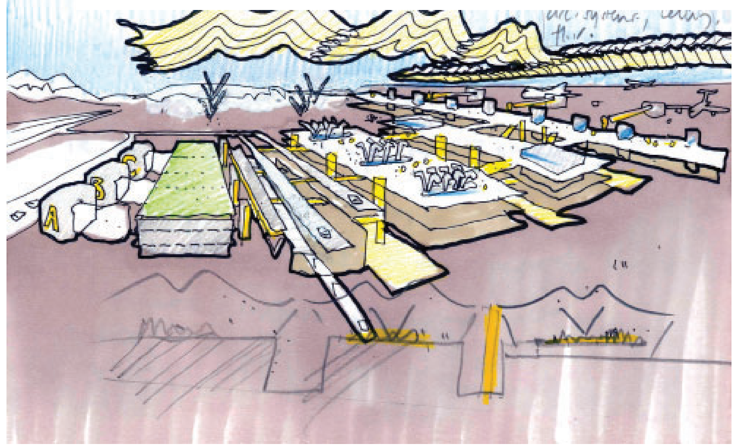
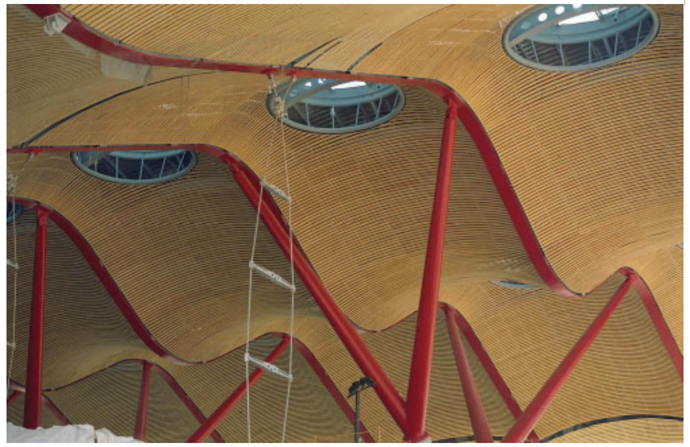
The design concept of terminal 4 is to allow for the ease of progression from the arrival point to the gate area. This design gives passengers an easy transition of spaces. The curved roof on the structure has *"light canyons ~ Wikiarquitura"* to direct natural light into the lower levels of the building. The use of natural lighting in the interior spaces greatly reduces the amount of artificial lighting that is needed for the building and ultimately reduces the buildings carbon footprint. The buildings orientation on the site is also an important piece of the design. The building faces east - west so its solar orientation limits the amount of direct sunlight it receives, especially during the hot summer months.

The Structure

The structure of the terminal is primarily built from steel and concrete. The structure of the building was designed with the future of the airport in mind. Meaning that if needed the terminal could be expanded on either end because of its repetitive composition. The structure is designed on a 60' by 30' grid to accommodate the uses of the interior spaces.






Kuala Lumpur International Airport

Location	Kuala Lumpur | Malaysia
Architect	Kisho Kurokawa
Year Complete	1998 (Terminal 1)
Floor Area	405,930 sq. m.
Construction Cost	766.5 Million USD (1998)
Type	Airport Terminal + Site

Kuala Lumpur Terminal 1

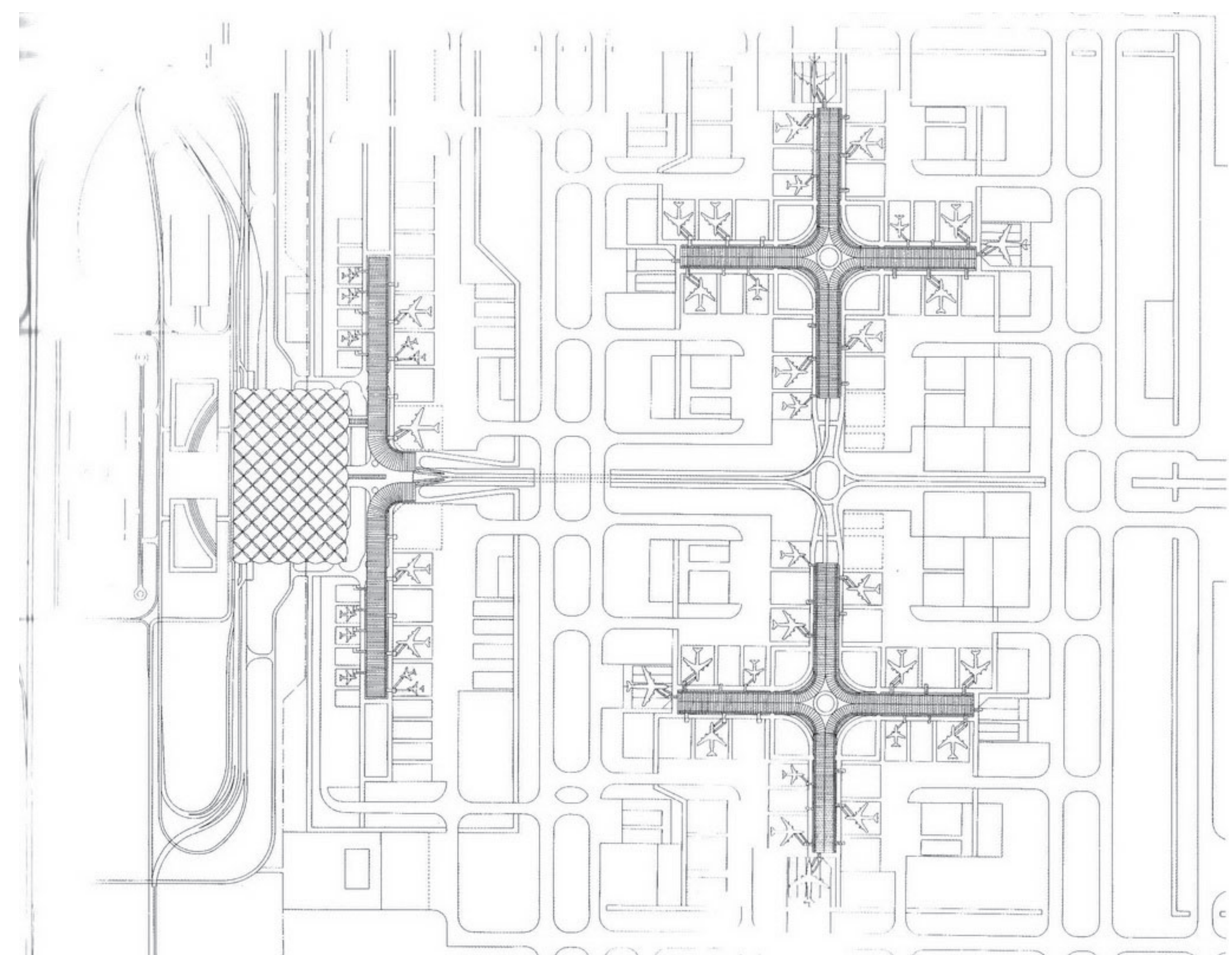
Kuala Lumpur opened in 1998 and is currently one of busiest airports in Asia. In 2016 the airport served over 52 million passengers and is expected to increase. Designed by the Japanese Architect Kisho Kurokawa the terminal during its construction was very advanced for its time. In 2008 the airport has expanded to meet the ever increasing rate of travel in Asia and the rest of the world.

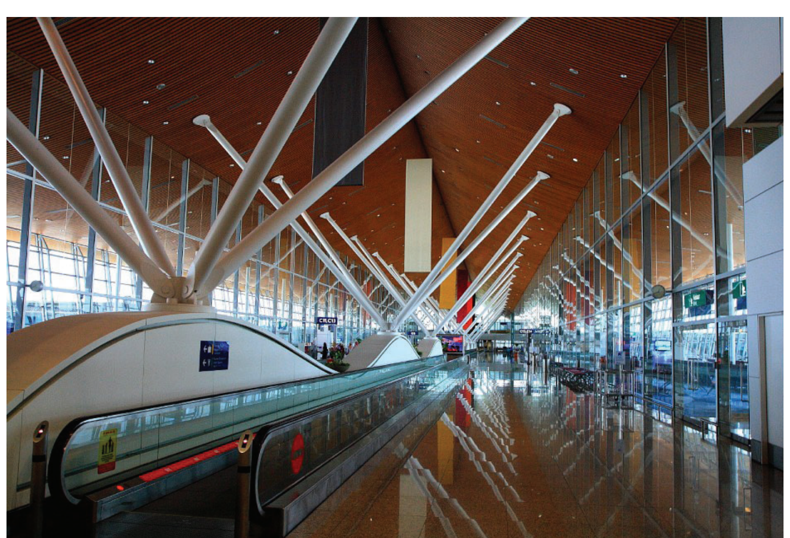
The Design

The design of terminal 1 was thought to incorporate as much natural lighting as possible into the interior spaces to reduce the carbon foot print of the building. The curved roof structure is symbolic of Islamic geometry while providing views to the exterior of the Malaysian rain-forest. The center piece of the design is the large atrium space that is home to over 4000 native plant species to Malaysia. This small rain-forest inside of the terminal building is thought to connect passengers to nature and provide symbolism that the natural rain-forest environment is very important to Malaysian culture. The airport facilities are surrounded with native plants and small pieces of rain-forest.

The Structure

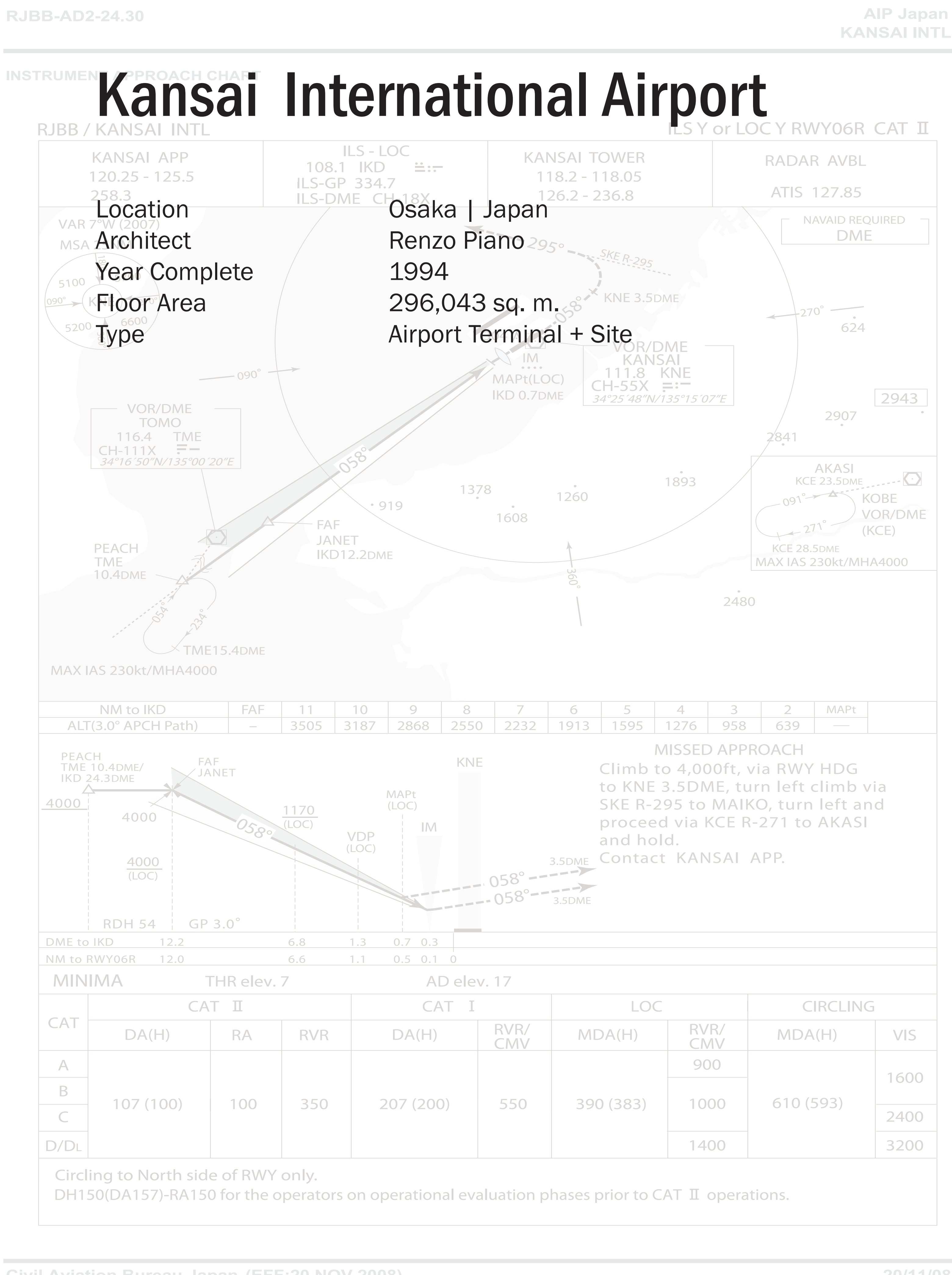
The structure of the terminal is primarily built from steel and concrete. The interior spaces have large tube steel tree columns and the roof is cladded with natural wood finish. The use of natural lighting throughout the entire terminal is very important to the design of the roof structure. The roof structure are concrete parabolic shapes that mimic the top of the rain-forest tree canopy. When originally designed the terminal was laid out on a structural grid so future expansion could be possible.





Kansai International Airport

Location	Osaka | Japan
Architect	Renzo Piano
Year Complete	1994
Floor Area	296,043 sq. m.
Type	Airport Terminal + Site



Kansai International Airport Overview

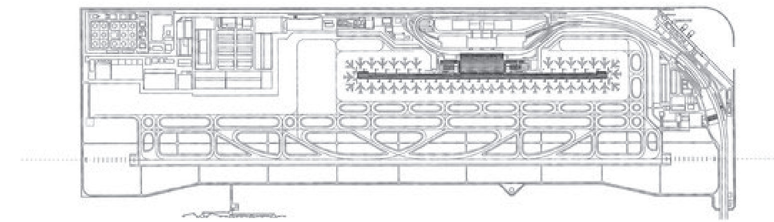
One of the largest civil engineering projects to ever completed the Kansai International Airport near Osaka, Japan is built on a man made island. The island was constructed over 4 year period and is connected to the main land with an almost 4km long bridge. There are over a million columns that hold up the island and terminal. Because the airport is in an area where earthquakes, typhoons, and tsunamis are present special considerations had to be made to the design of the terminal and the site.

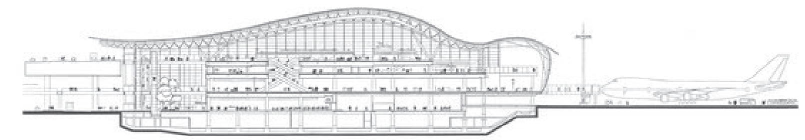
The Design

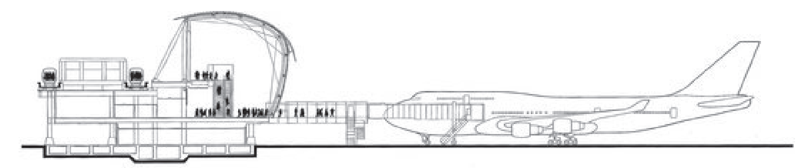
Being one of the longest airport terminals to this day the Kansai International Airport is just over 1.5 km long. Renzo Piano's vision for the terminal was a very light and open design to help passengers navigate the space with ease. The center and wing like design is thought to mimic a glider's fuselage and wings. The airfoil shape of the terminal wings is closed off and one end and opens towards the airplanes sitting on the tarmac. This design also allows for natural air circulation from the smaller closed end to the open end of the terminal.

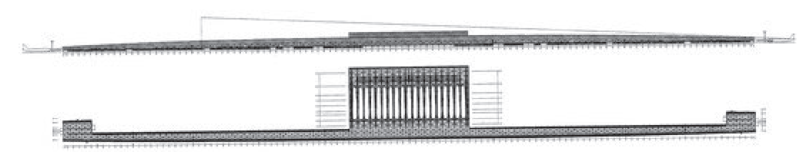
The Structure

The structure of the terminal is primarily built from steel. These steel beams are over 80m in length yet light enough and flexible enough to absorb earthquake forces. One interesting fact that I found out for this case study is that the over 82,000 steel roof panels are identical to each other. From a design standpoint this is very smart because if the building is ever damaged the panels can easily be replaced.



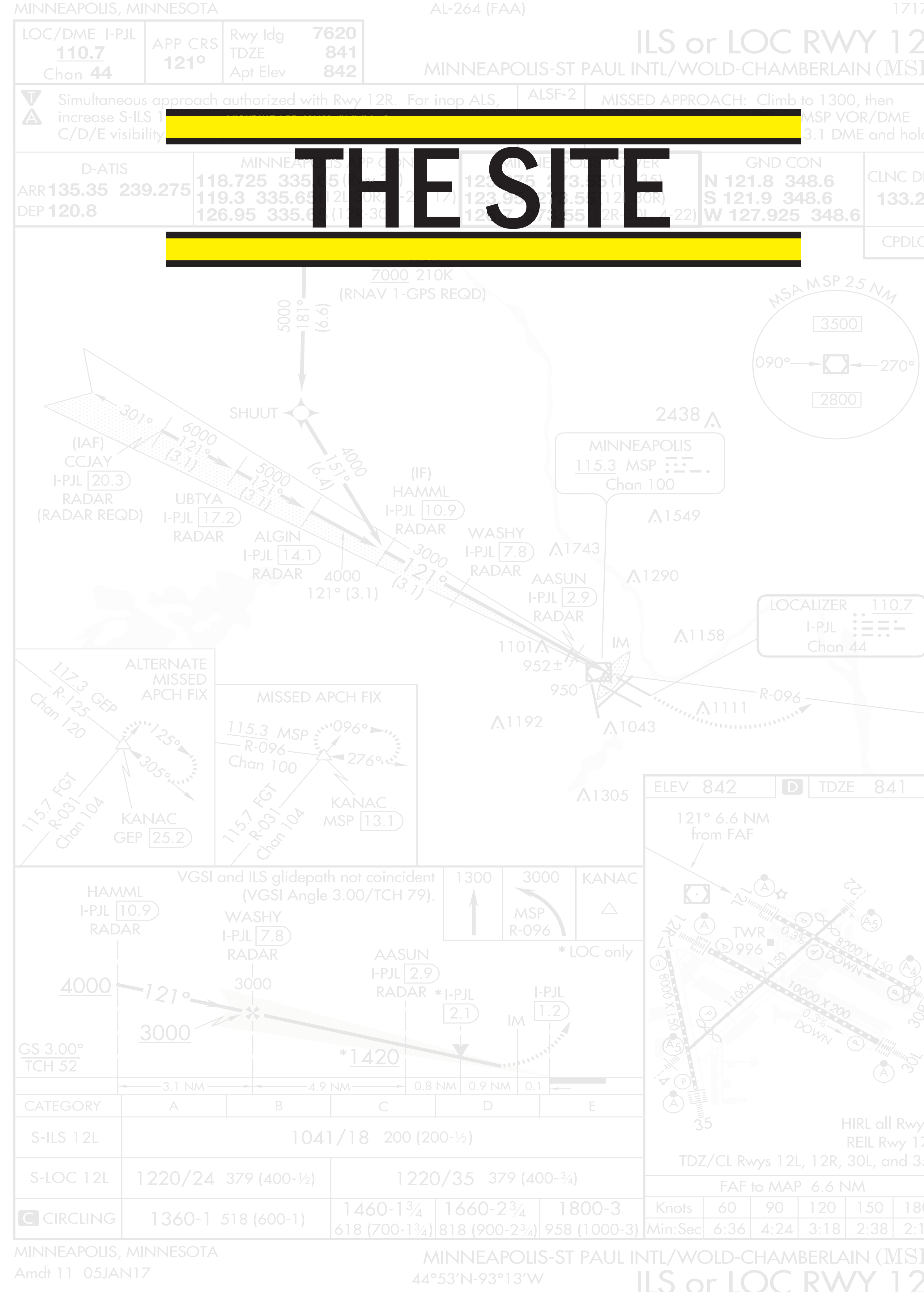






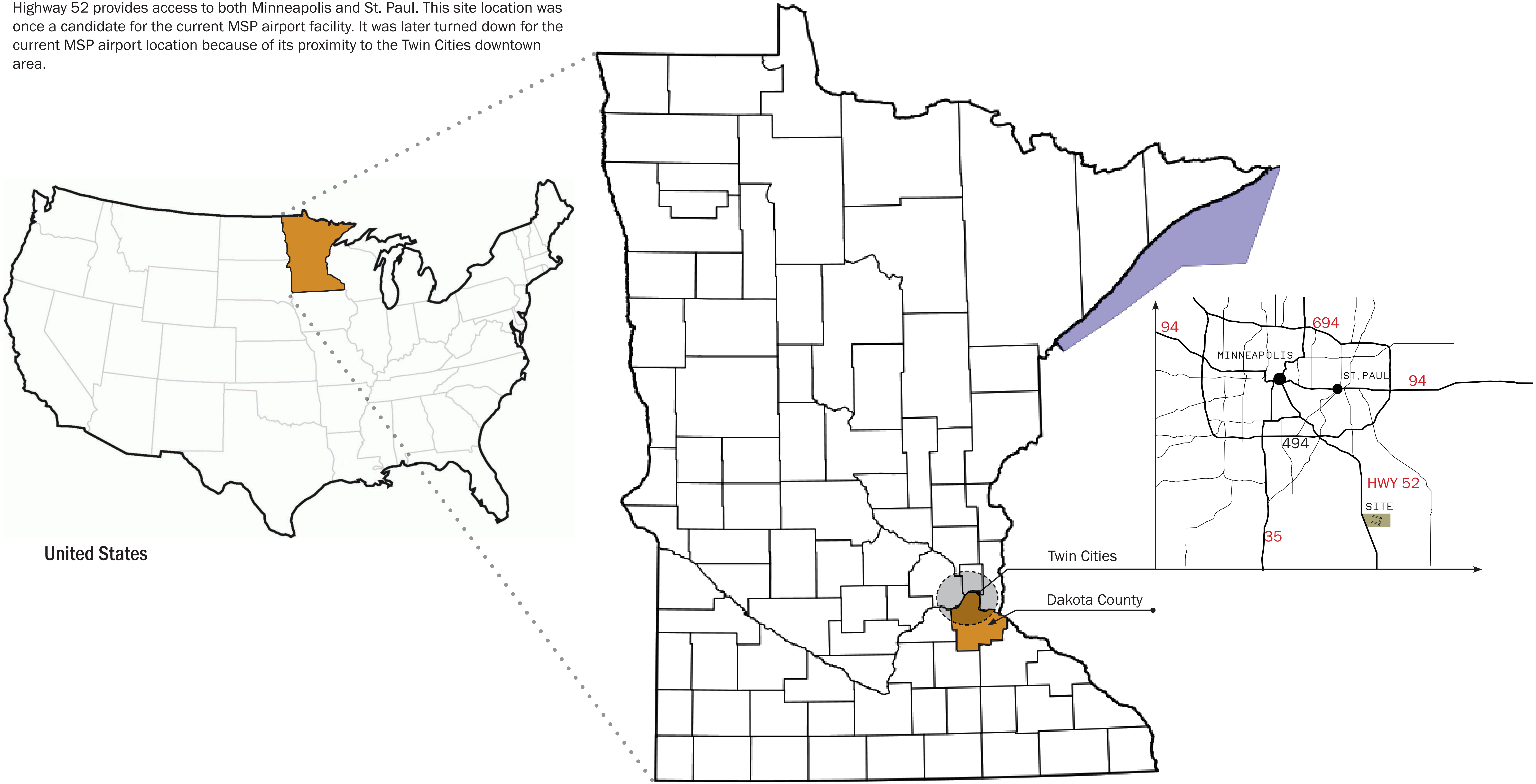

B2

THE SITE


MINNEAPOLIS, MINNESOTA
AL-264 (FAA)
17173
ILS or LOC RWY 12L
MINNEAPOLIS-ST PAUL INTL/WOLD-CHAMBERLAIN (MSP)
LOC/DME I-PJL 110.7 Chan 44
APP CRS 121°
Rwy ldg 7620
TDZE 841
Apt Elev 842
MISSED APPROACH: Climb to 1300, then
D-ATIS
ARR 135.35 239.275
DEP 120.8
GND CON
N 121.8 348.6
S 121.9 348.6
W 127.925 348.6
CLNC DEL 133.2
CPDLC
SHUUT
(IAF) CCJAY
(IF) HAMML
UBTYA
ALGIN
WASHY
AASUN
MINNEAPOLIS 115.3 MSP Chan 100
LOCALIZER 110.7 I-PJL Chan 44
ALTERNATE MISSED APCH FIX
MISSED APCH FIX
KANAC
ELEV 842
TDZE 841
CATEGORY
S-ILS 12L
S-LOC 12L
CIRCLING
HIRL all Rwys
REIL Rwy 17
TDZ/CL Rwys 12L, 12R, 30L, and 35
FAF to MAP 6.6 NM
Amdt 11 05JAN17
44°53'N-93°13'W

Site Information

The site is located twenty five minutes from the busy Minneapolis | St. Paul downtown area, just east of Highway 52 near the city of Hastings, Minnesota. I choose this site location because of the connectivity to the Twin Cities area. Highway 52 provides access to both Minneapolis and St. Paul. This site location was once a candidate for the current MSP airport facility. It was later turned down for the current MSP airport location because of its proximity to the Twin Cities downtown area.



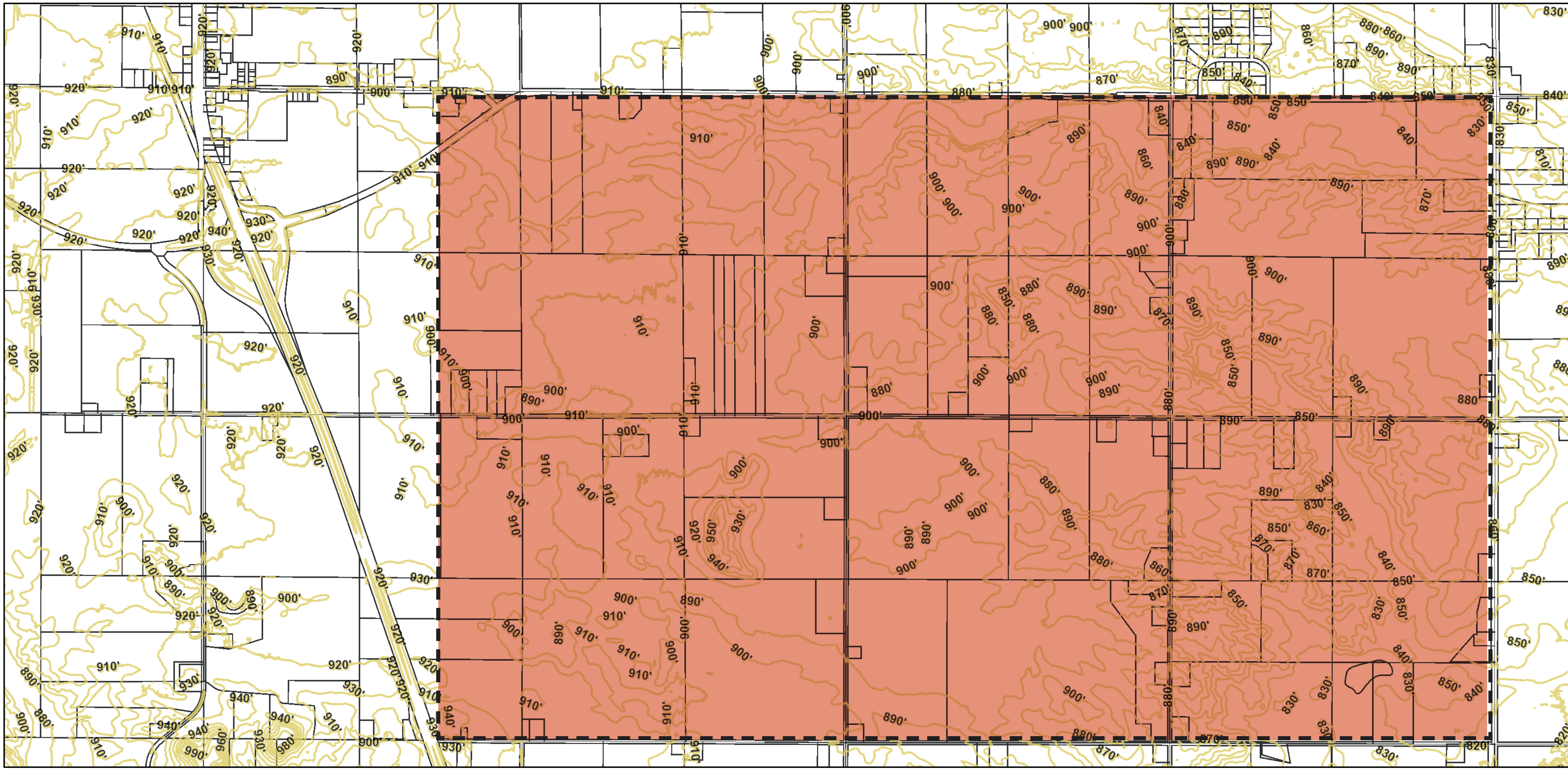
State of Minnesota

Site Aerial Photo

The approximate site area shown in red is approximately 2 miles by 3 miles. This area will serve as the primary site location.

Site Aerial Photo With Contours

The approximate site area shown in red is relatively flat area with little elevation change. This location will be ideal for an airport facility.



SITE ANALYSIS

Site Visit First Impressions

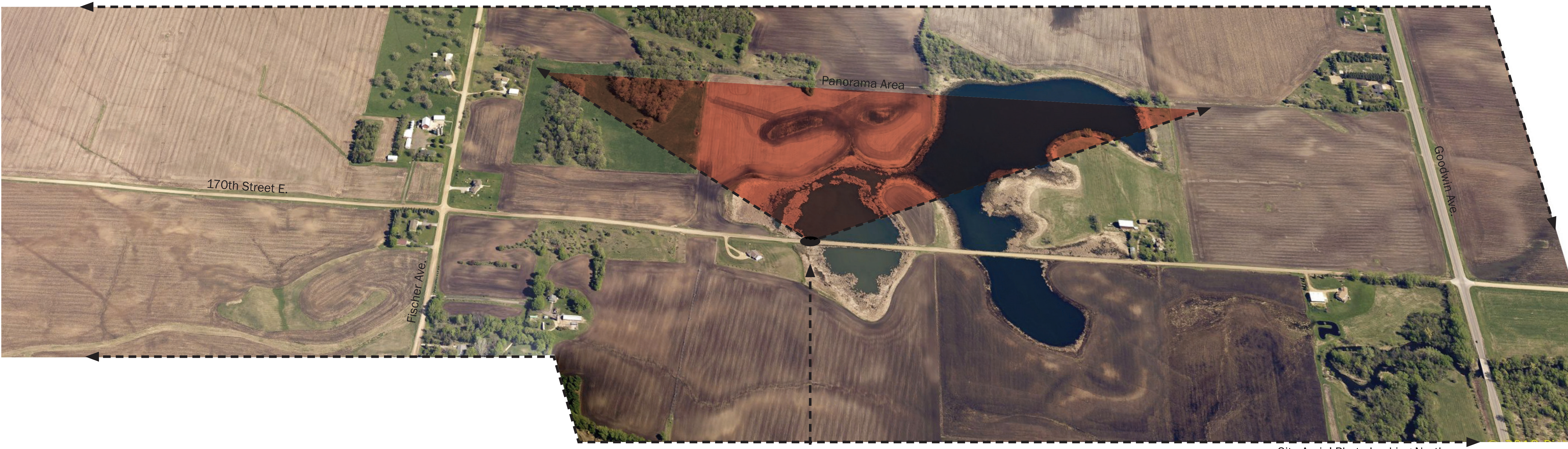
I was finally able to visit my thesis site on October 13, 2018. Currently the site is primarily farm land with a few small businesses and homes scattered through out the site. There is also a variety of large mature trees on the site in large clusters and a wetland area that will be incorporated into the final design solution. Since the site has little change in elevation the views of the surrounding area were excellent.

During my Visit I took account for the following items:

- Views of the surrounding site context
- Noise and Vehicle Traffic
- Plants & Vegetation
- Natural Lighting
- Natural Wetlands
- Natural Winds
- Buildable Areas
- Topography

Site Aerial Photo Looking North

Site Panorama Photo Looking North



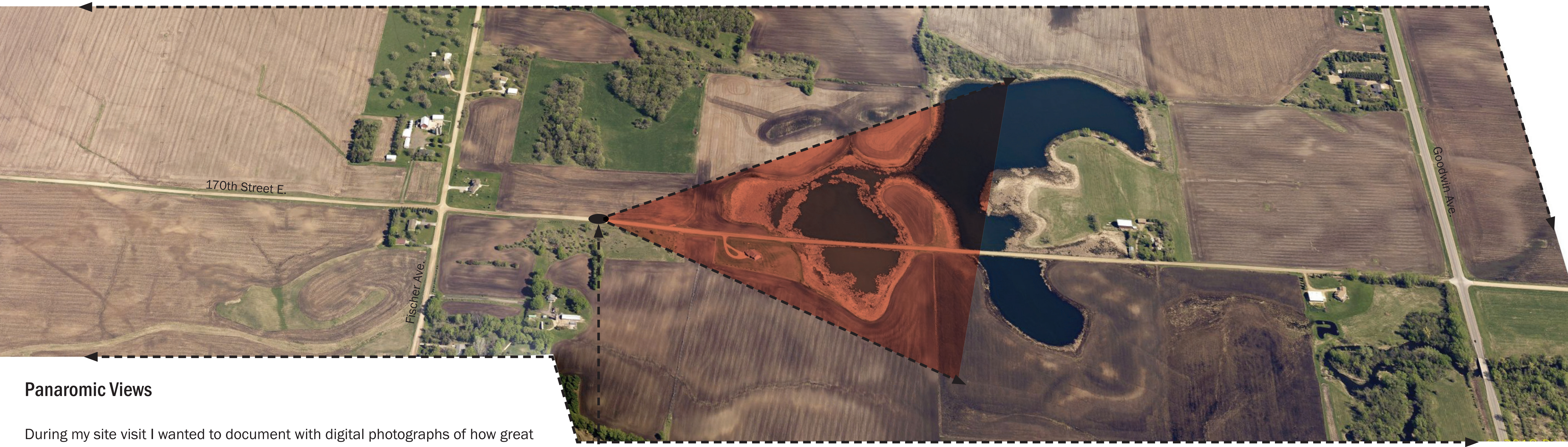
Site Aerial Photo Looking North

Natural Wetland

There is a large natural wetland on site that will be incorporated into the final design solution. These ponds will serve as the final destination for the cleaned rainwater and site runoff. There will be a series of cleaning ponds on site for the natural cleansing of waste water. This area of the site is the lowest in elevation and the best possible place to collect rain water into the existing ponds.

Mature Trees

After viewing the entirety of my site there are many groups of mature trees in large clusters. These trees will be preserved into the final design as some appear to have been around for decades. These large trees can also provide for natural views outside of the terminal facility.



Site Aerial Photo Looking North

Panaromic Views

During my site visit I wanted to document with digital photographs of how great the views of surrounding site truely are. For the final design solution I want to incorporate views to the outdoors as I believe this is very important to the comfort and well being of passengers and employees of the facility. Having a strong connection to nature can help ease the burden of travel and help improve the overall feel of the space.

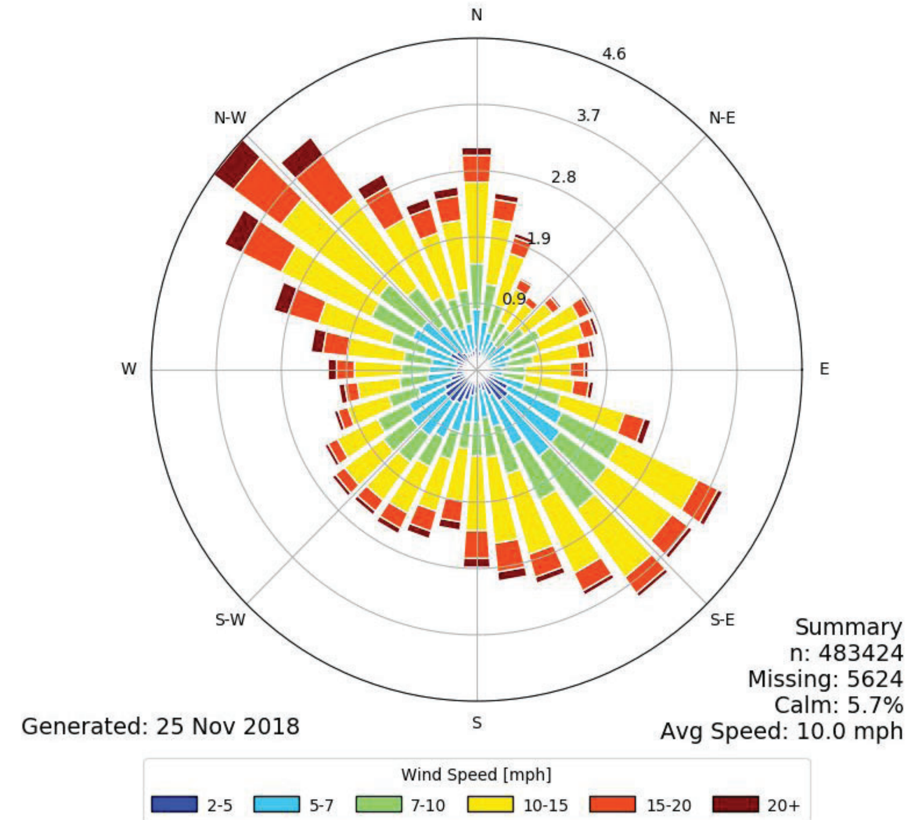
Site Panorama Looking East

Climate

The graph below gives the average high and low temperatures and the average precipitation for the city of Hastings, which is the closest city to the site with available climate data. The average January temperature is 23°F and the average July temperature is 82°F. The highest percipitation average is in July with an average of 4.3 inches for the month.

Wind Analysis

Because wind speed and direction are critical for flight, wind analysis for my proposed site needs to be considered for the design of the runways. Since Minnesota has such a wide range of climates through out the year, it will be important to design the site to take advantage of the prevailing winds for both the runway design and the building orientation for natural ventilation during the summer months.



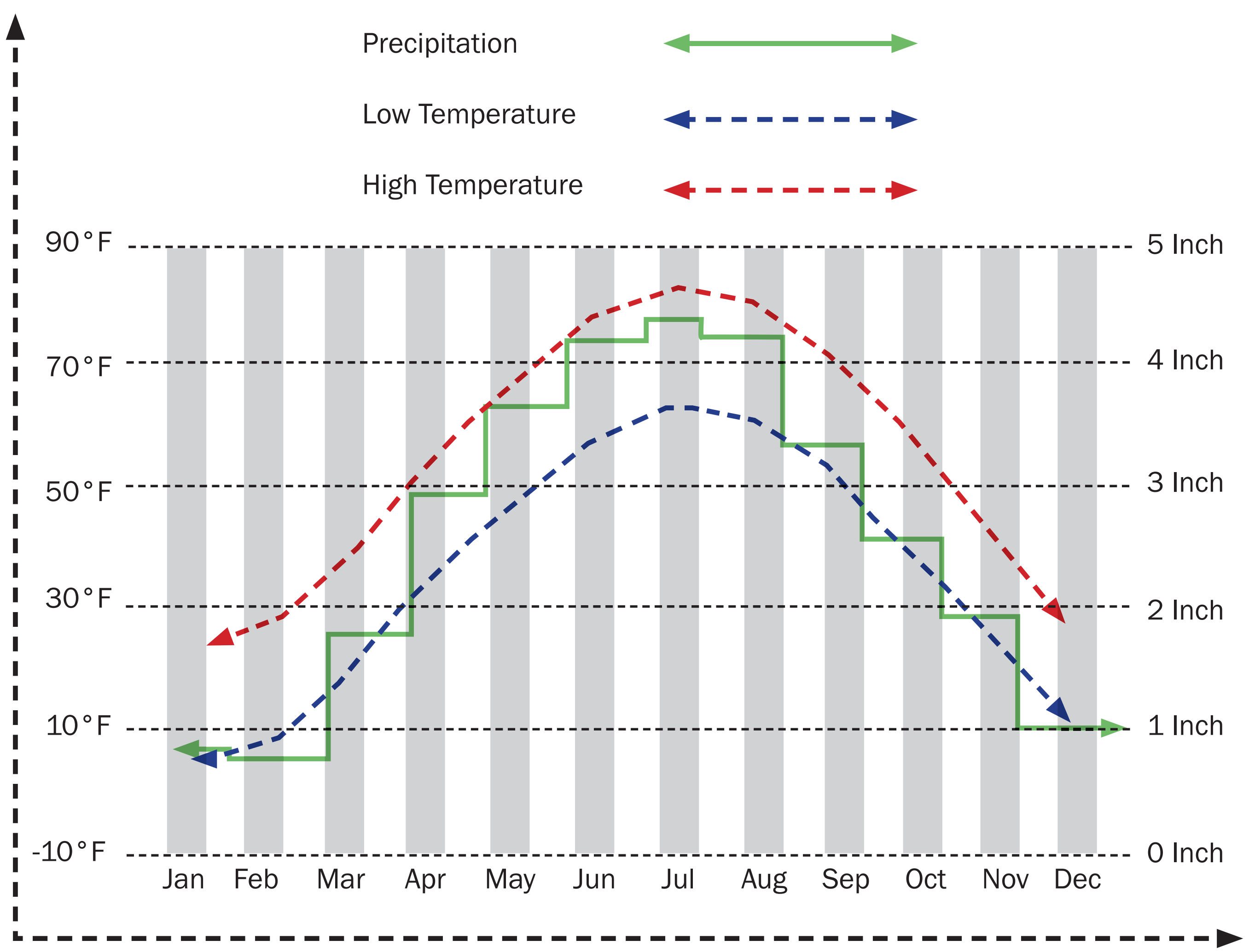
Rain Water Collection

1 Inch of Rain over 1 square mile yields: 17,380,000 gallons of water.

The site being approximately 6 square miles could yield 104,280,000 from a 1 inch rainstorm!

The site alone in one year could collect and retain 547,470,000 gallons of water.

Hastings, Minnesota Climate Graph



Climate

Location: Hastings, Minnesota

Hastings weather averages:

Annual high temperature:	**54.3°F**
Annual low temperature:	**35.8°F**
Average temperature:	**45.05°F**
Average annual precipitation - rainfall:	**31.49 inch**

Average Temperatures:

	Jan	Feb	Mar	Apr	May	Jun
Average high in °F:	23	28	40	56	68	78
Average low in °F:	5	9	22	36	47	58
Av. precipitation in inch:	0.87	0.75	1.77	2.95	3.66	4.17

	Jul	Aug	Sep	Oct	Nov	Dec
Average high in °F:	82	80	71	58	41	27
Average low in °F:	63	61	52	39	26	11
Av. precipitation in inch:	4.33	4.21	3.31	2.56	1.89	1.02

SCHEMATIC DESIGN

SPACE ALLOCATION

Below is a list of the main spaces that will be included in the terminal design. I am proposing that the airport facility has a yearly passenger traffic of 50,000,000. This is an average of 25% more passenger traffic then the current MSP airport. The table also shows the average square foot per person in certain spaces through out the airport. These numbers are slightly more then the required minimum to maintain the maximum level of passenger comfort and airport efficiency.

Approxmiate Passenger Traffic Numbers

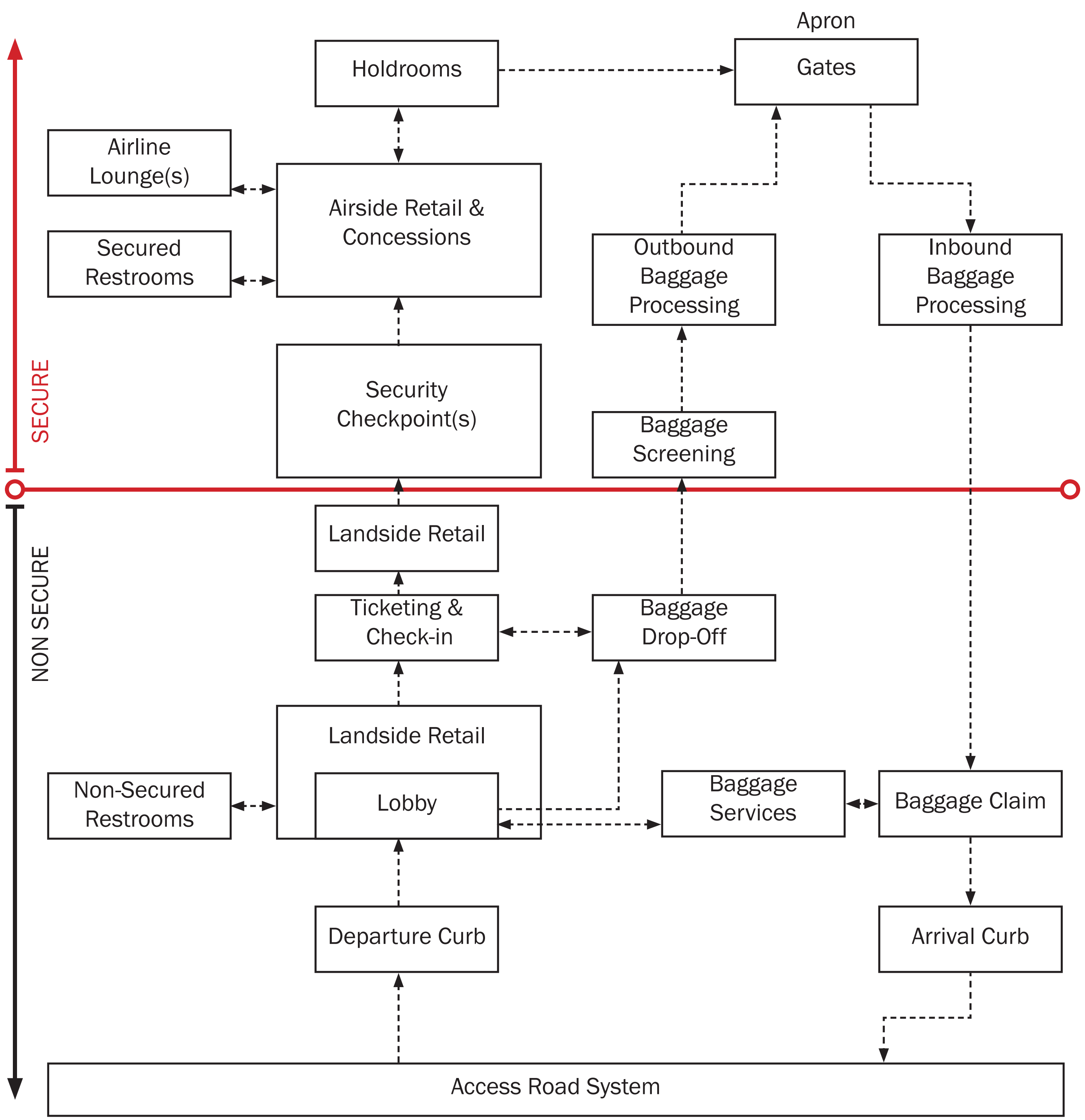
Passengers Per Year →	50,000,000	
Passengers Per Day →	50,000,000/365 →	136,986 Day
Passengers Per Hour (24 hour period) →	136,986/24 →	5707 Per Hour
Passenger Sq. Ft. Per Person	8 Sq. Ft. x 136,986	1095888sq. Ft.

Sq. Ft. Rounded to Nearest 100 Sq. Ft.

Terminal Building	Level of Service A in Sq. Ft. Per Person	Square Footage	% of Building Space
Land Side			
Drop-Off Area	15 Sq. Ft. Per Person	50,000	1%
Pickup/ Arrival Area	15 Sq. Ft. Per Person	50,000	1%
Entry	10 Sq. Ft. Per Person	50,000	1%
Circulation	8 Sq. Ft. Per Person	1,100,000	30%
Ticket Counters/ Check-in	10 Sq. Ft. Per Person	20,000	0.05%
Retail Space	8 Sq. Ft. Per Person	500,000	11%
Adminstration Offices	150 Sq. Ft. Per Office		1%
Security Offices	150 Sq. Ft. Per Office		1%
Security Checkpoints	8 Sq. Ft. Per Person	100,000	2%
Air Side			
Retail Spaces	8 Sq. Ft. Per Person	800,000	18%
Gate Areas	15 Sq. Ft. Per Person	500,000	11%
International Waiting Areas	15 Sq Ft. Per Person	100,000	2.00%
Customs Checkpoint	10 Sq. Ft. Per Person	50,000	1%
Baggage Handeling		500,000	11%
Baggage pickup	15 Sq. Ft. Per Person	550,000	12%
		4370000	1.03
		Total Sq. Ft.	Total % of Space

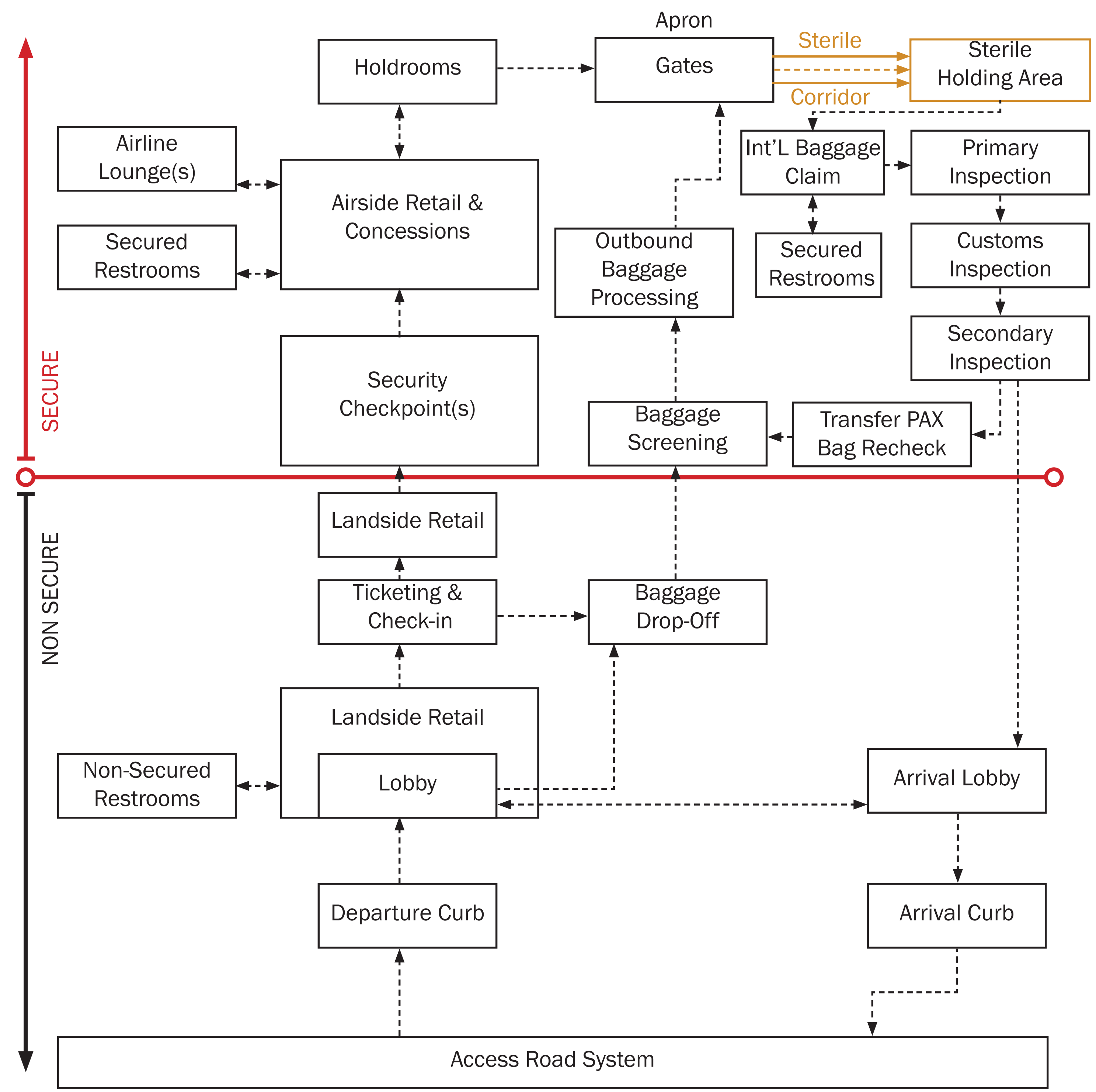
Domestic Passenger Flow Diagram

The following diagram shows a typical progression of a domestic flight departing and arriving passenger within the terminal space.

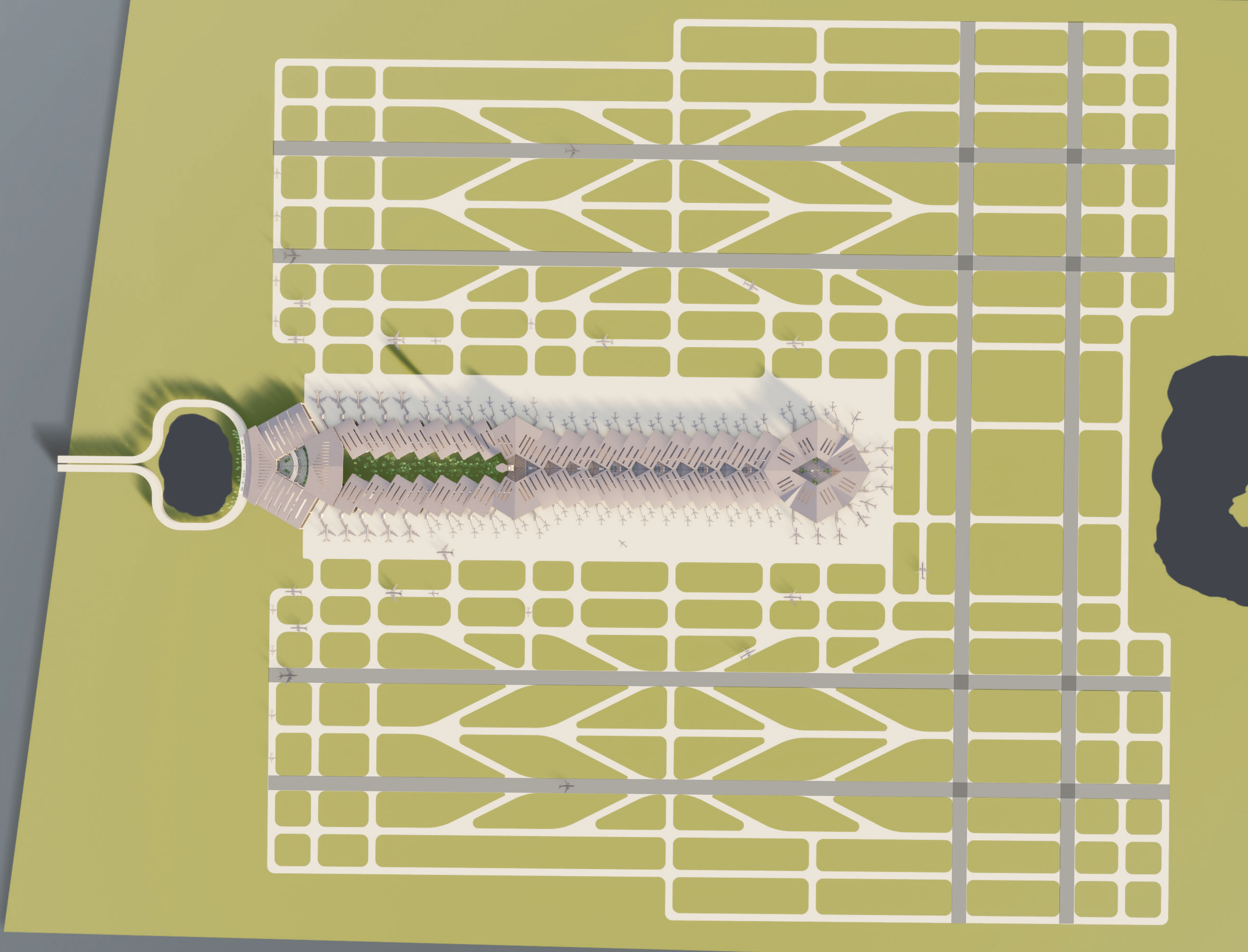


International Passenger Flow Diagram

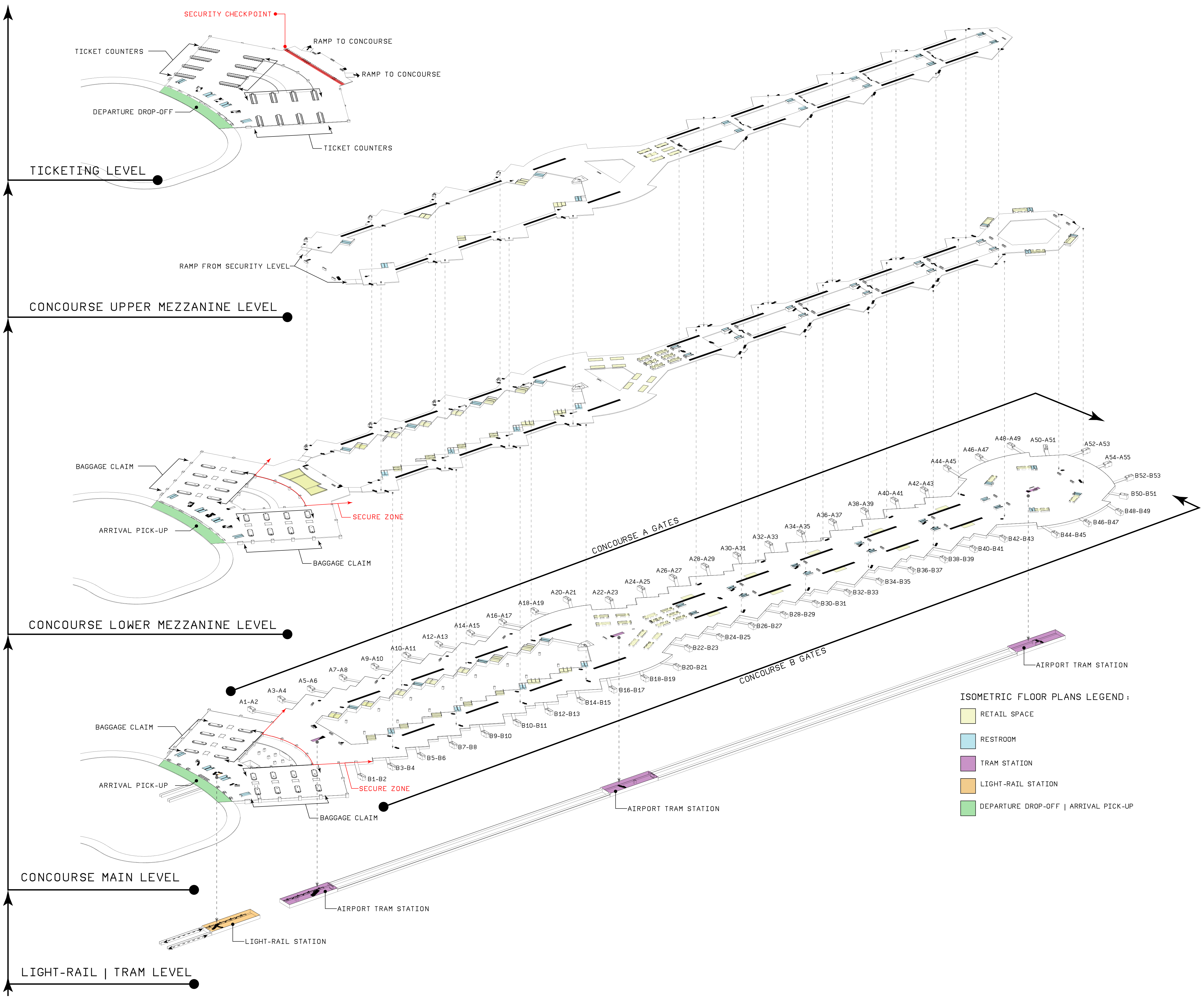
The following diagram shows a typical progression of a international flight departing and arriving passenger within the terminal space.



SITE PLAN



FLOOR PLANS


SECURITY CHECKPOINT
RAMP TO CONCOURSE
TICKET COUNTERS
RAMP TO CONCOURSE
DEPARTURE DROP-OFF
TICKET COUNTERS
TICKETING LEVEL
RAMP FROM SECURITY LEVEL
CONCOURSE UPPER MEZZANINE LEVEL
BAGGAGE CLAIM
SECURE ZONE
ARRIVAL PICK-UP
BAGGAGE CLAIM
CONCOURSE LOWER MEZZANINE LEVEL
CONCOURSE A GATES
A1-A2
A3-A4
A5-A6
A7-A8
A9-A10
A10-A11
A12-A13
A14-A15
A16-A17
A18-A19
A20-A21
A22-A23
A24-A25
A26-A27
A28-A29
A30-A31
A32-A33
A34-A35
A36-A37
A38-A39
A40-A41
A42-A43
A44-A45
A46-A47
A48-A49
A50-A51
A52-A53
A54-A55
B52-B53
B50-B51
B48-B49
B46-B47
B44-B45
B42-B43
B40-B41
B38-B39
B36-B37
B34-B35
B32-B33
B30-B31
B28-B29
B26-B27
B24-B25
B22-B23
B20-B21
B18-B19
B16-B17
B14-B15
B12-B13
B10-B11
B9-B10
B7-B8
B5-B6
B3-B4
B1-B2
CONCOURSE B GATES
BAGGAGE CLAIM
ARRIVAL PICK-UP
SECURE ZONE
BAGGAGE CLAIM
CONCOURSE MAIN LEVEL
AIRPORT TRAM STATION
AIRPORT TRAM STATION
AIRPORT TRAM STATION
LIGHT-RAIL STATION
LIGHT-RAIL | TRAM LEVEL
ISOMETRIC FLOOR PLANS LEGEND:
RETAIL SPACE
RESTROOM
TRAM STATION
LIGHT-RAIL STATION
DEPARTURE DROP-OFF | ARRIVAL PICK-UP

CONCOURSE MAIN LEVEL PLAN

LONGITUDINAL BUILDING SECTION

PROJECT STATISTICS:

PASSENGERS PER YEAR: 50,000,000

NUMBER OF GATES: 110 - MULTIPLE APRON RAMP SYSTEM (MARS)

TERMINAL LENGTH: APPROX. 8600'

TICKET COUNTERS: 16

BAGGAGE CLAIM CAROUSELS: 32

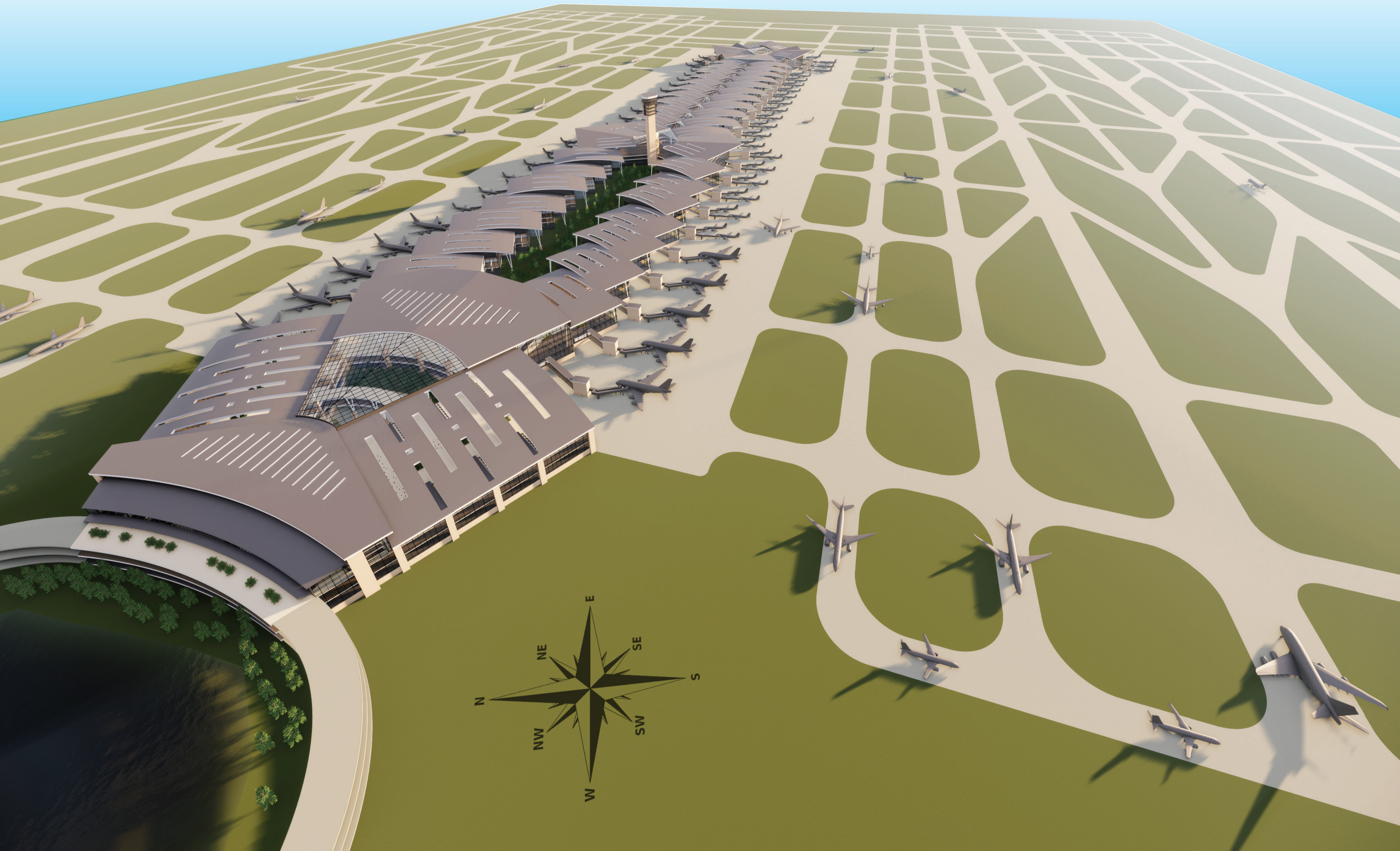
RESTROOMS: 74

MOVING SIDEWALKS: 50

BUILDING SYSTEMS DIAGRAM

FINAL RENDERINGS

TERMINAL OVERVIEW



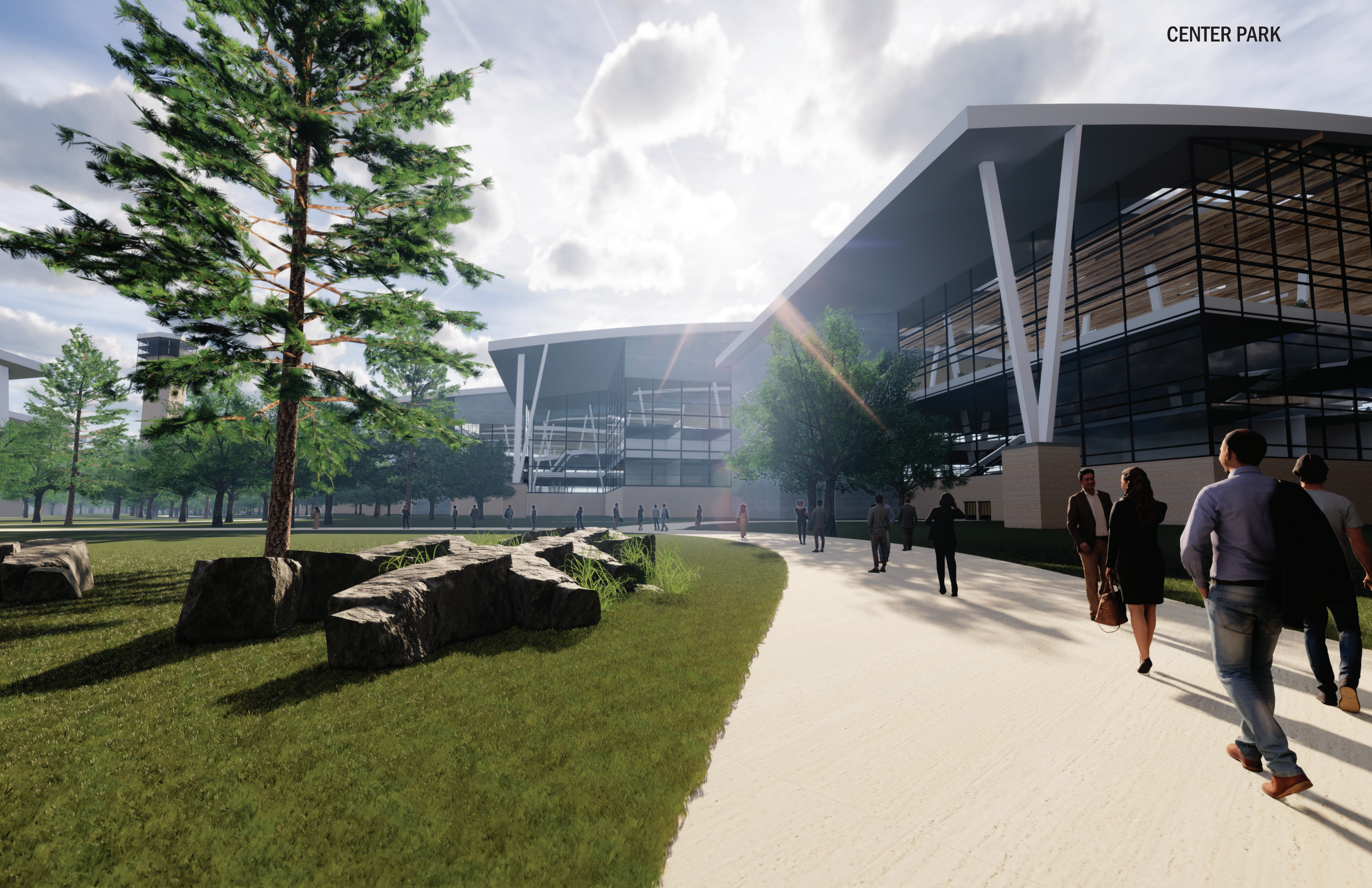
DEPARTURE DROP-OFF

TICKETING


CONCOURSE B

GATE WAITING AREA

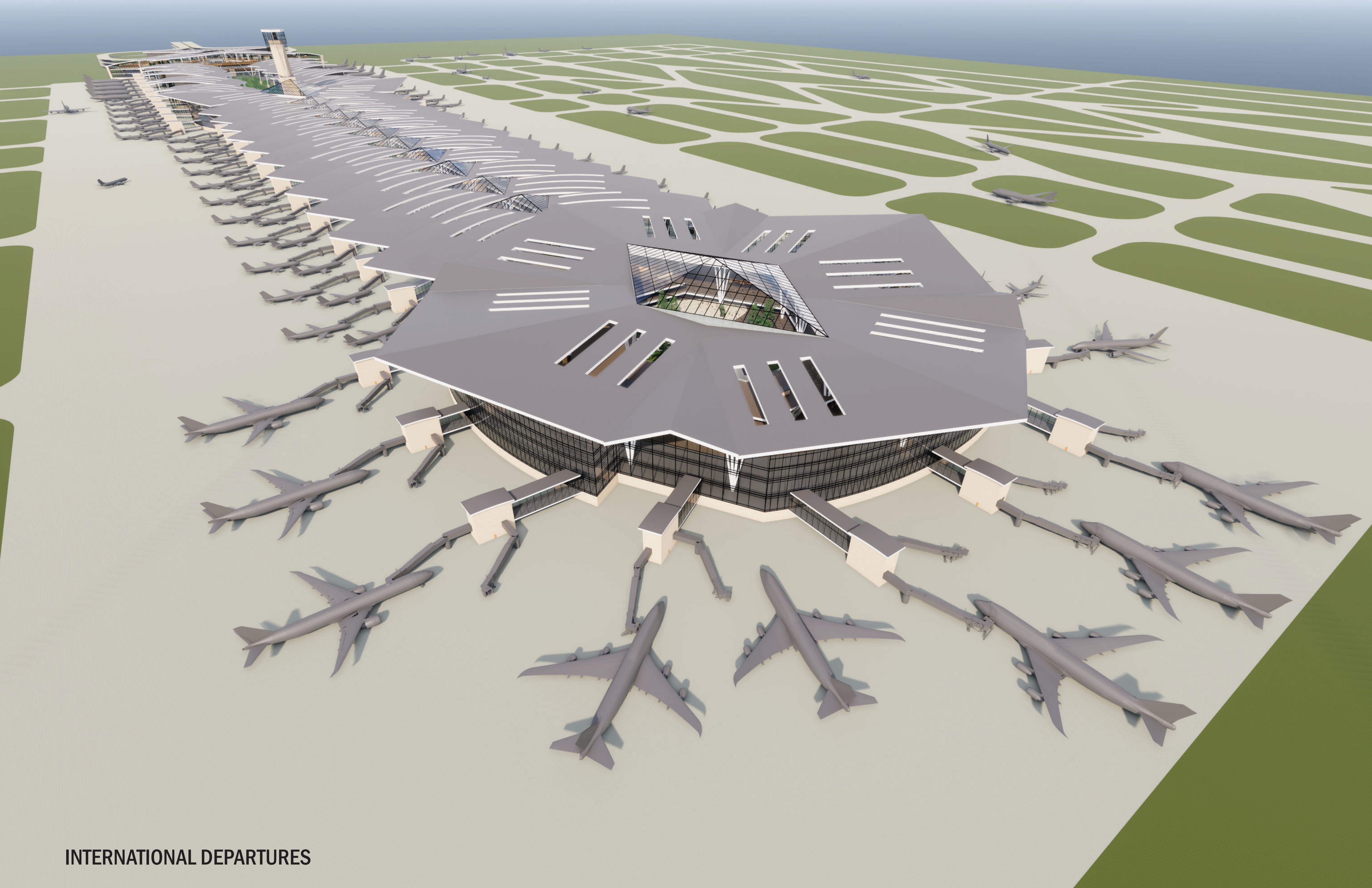
CENTER PARK



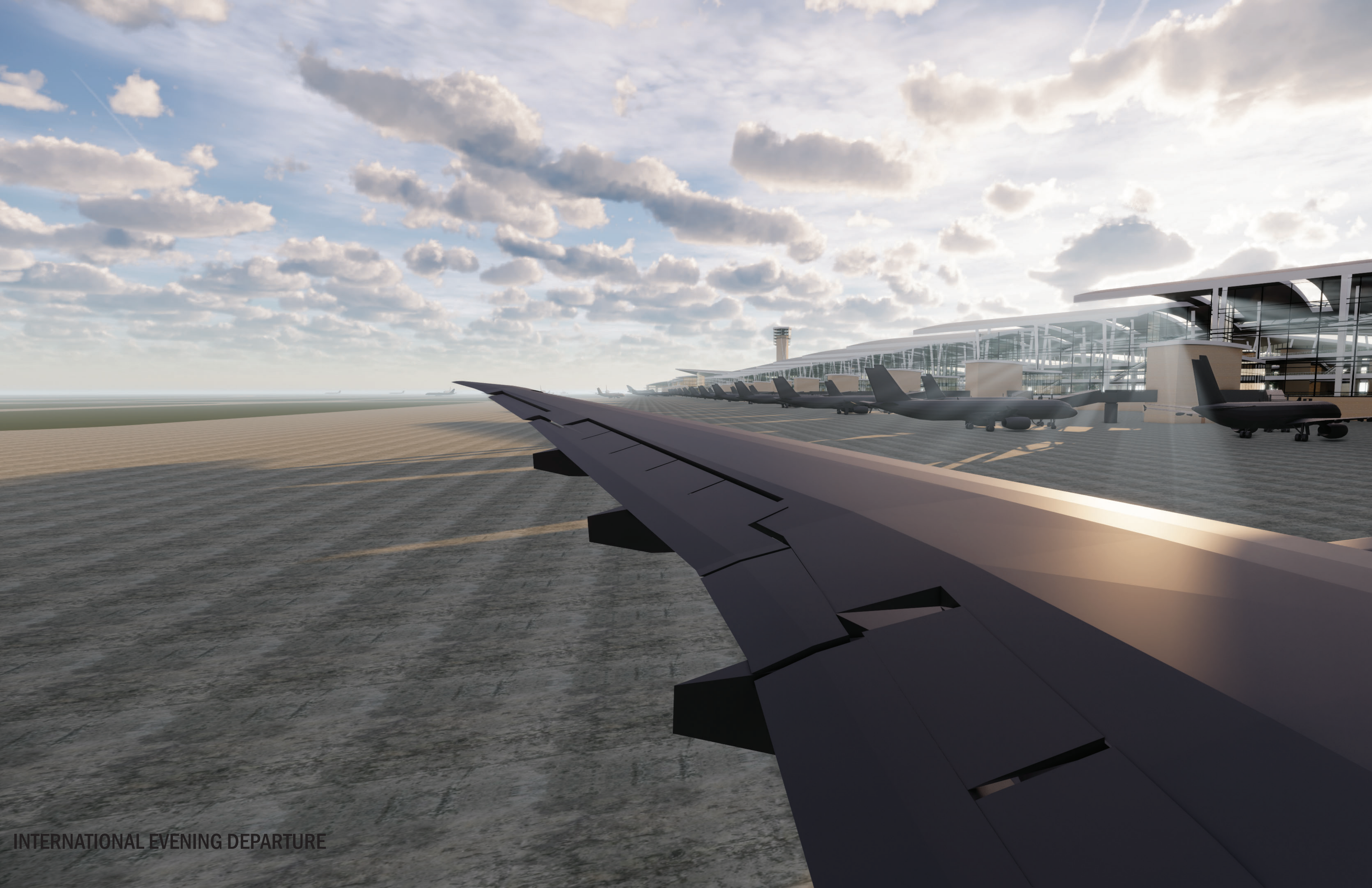
CONCOURSE INDOOR PARK

INTERNATIONAL DEPARTURES ATRIUM

INTERNATIONAL DEPARTURES ATRIUM



INTERNATIONAL DEPARTURES



INTERNATIONAL EVENING DEPARTURE

"Once you have tasted flight, you will forever walk the earth with your eyes turned skyward, for there you have been, and there you will always long to return".

- Leonardo da Vinci

QUESTIONS?