From Airport to Spaceport:
Designing for an Aerospace Revolution

by

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DEDICATION

To the most understand and supportive fiancée in the universe: Marc S.A. Glasgow – may he rest in peace. He inspired me to take on the world and conquer it. His consistent faith in me carried me through the rough times and gave me the strength to persevere even after his death. I will love him always and miss him dearly.

This is for you.

Marc S.A. Glasgow

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ABSTRACT

"Airports will shape business location and urban development in the 21st century as much as highways did in the 20th century, railroads in the 19th and seaports in the 18th."
- John D. Kasarda, Ph.D. Kenan-Flagler Business School, University of North Carolina
http://www.aerotropolis.com/author.html

I say, spaceports will shape the urban development of the 21st century, more than airports, bringing about an aerospace revolution. Just as new technologies triggered the global revolutions of the past, so the invention of reusable spacecraft will revolutionize transportation.

The invention of such spacecraft suggests the need for a different kind of transportation hub: a spaceport. Not unlike an airport, a spaceport would be a center for transportation, but both terrestrial and extraterrestrial. Commercializing space travel would improve the efficiency of world travel and impact the cultural perspective of the world at large. This new transport nexus would not only need to accommodate new modes of operation, but would need to respond to the emerging global society. An all-inclusive spaceport, it would become a city unto itself.

A study of the changing world and the spiraling correlation between technological advancement and cultural development, in relation to the architecture of transport facilities, is the focus of the following thesis investigation.
A correlative study of airports, airport terminals, and the evolution of airports into aerotropoli due to globalization, provides the groundwork for the development of an urban spaceport. Restrictions and opportunities relevant to spaceport and aerospace terminal design are explored.

An extensive investigation in the field of urban planning, transportation, and space travel, along with some speculation, reveals the implications that a commercial space program might have on society and architecture.

Then, research into the programming and design of spaceports acts as a spring-board for the design process. Though no commercial spaceports exist as of yet, a conceptual study provides insight into the extraterrestrial side of the operations.

Finally, a spaceport masterplan and aerospace terminal that responds to the needs and concerns of the global community, as well as attempts to fulfill its dreams, is proposed as a precedent for redevelopment and implementation in the near future.
Figure 1: Diagram Showing Project Research Subjects
INTRODUCTION

BRIEF HISTORY OF TRANSPORTATION TECHNOLOGY: CAUSES AND EFFECTS

For as long as humans have inhabited the Earth, a spirit of innovation and exploration has driven the evolution of civilization. The invention and use of hand tools can be traced as far back as human history. The Stone Age, Bronze Age, Copper Age and Steel Age each signify a time period that new types of tools were invented and used. The significance of such inventions is their corresponding effect on civilization; just as the advent of cutting tools gave way to new techniques for hunting, cooking and building in ancient times, the advancements in transportation technology have inspired exploration and cultural exchange. Beginning with the advent of the boat that primitive humans forged in order to cross rivers to the cruise ships of today, boats are still the primary means of transporting great quantities of goods and people across the ocean.

Seafaring Vessels: Begin of Cross-Culturation

The boat is the earliest known form of transportation vehicle, predating the wheel. The discovery of a preserved canoe, carved out of the wood of a tree trunk, dates back 10,000 years. With a manned floatation device, humans could transport themselves and their belongings to new lands, cross large bodies of water to explore and hunt, and move goods to trade with neighboring tribes. The boat as a tool was extremely useful to ancient
peoples and played a great part in the spread of civilization and cultural around the world. Tribes began to mix and cross breed, cultures traded traditions and populations expanded. As the human population grew, so did the size of boats and the technologies that propelled them. When boats became large enough to transport gangs of men over vast bodies of water, the need for docking stations arose. These seaports were the centers for trade, so it was only natural that cities grew up around them.

![Port Scene with the Embarkation of St Ursula 1641 by Claude Lorrain](http://www.oilpaintingshop.com/lorrain/6.jpg)

The development of seaport architecture evolved over time into the busy harbors of today. Aside from large warehouses to store imported goods for distribution, major seaports gained popularity as places for shopping and entertainment. Pier 39 in San Francisco (Figures 4-6) is a good example of how the modern harbor has been adapted as a sort of outdoor shopping mall, with produce stands, restaurants, bars and the like. The harbor is also the place where cruise line passengers pass the time when the ship is at berth, therefore places to explore and relax are located at this waterfront for convenience.

Even after the creation of the wheel in ancient times, boats/ships remained the primary form of transportation. Not until the Industrial Age and the invention of the steam engine, did the wheel gain significance on a global level.

![San Francisco Harbor 1908](http://www.hellosanfrancisco.com/Images/Panoramic/8172006San_Francisco_from_Air_Ship_c1908.jpg)
Figure 5: San Francisco Harbor Today
Same long warehouse depots exist today.
(http://image50.webshots.com/50/5/18/17/487551817yXNIsr_fs.jpg)

Figure 6: Pier 39, San Francisco Harbor
Historic harbors now offer shopping and dining that attract crowds of people.
(http://upload.wikimedia.org/wikipedia/commons/d/db/Pier_39_San_Francisco_CA.JPG)

LOCOMOTIVES: INDUSTRIAL REVOLUTION PRIORITIZES EFFICIENCY

The first use of the wheel on a transport device is said to have occurred many years after its invention. Its original use for cooking and spinning clay pots was simple, but the assembly of a wheeled vehicle was slightly more difficult. Its roll as a wheel didn’t begin until around 4000 B.C.E., when wagon carts pulled by animals were used to move people short distances. The animal driven carts were fine for traveling long distances too, as long as frequent stops were made for the animals to rest. Later, when the need to move large amounts of goods long distances came about, the wagonway was formed – a set of wheel carts linked together set on tracks and drawn by animals (Figure 7).
There is even evidence that a sort of wagonway track system existed during the Roman Empire some 2000 years ago. Still, the animal power was limited, and far too slow for the ever growing capacity of the human race. As civilization progressed, populations grew, and the spread of villages and farms dotted the landscape, so too grew the need to transport raw materials and goods long distances in a more efficient manner. Hence, the steam powered cart system, known as the locomotive was invented.

In Britain, at the onset of the Industrial Revolution in the 18th century, when machines were created to replace man-powered operations in manufacturing, others were adapting these machines to transportation. The steam engine, originally a machine to pump water and turn geared factory machines, was adapted to propel a set of wheeled carts along a track – thus, the locomotive was born. Of course, many modifications and improvements were made to create the modern day train system, but the motive and function behind it still apply – to move large amounts of goods and people long distances more efficiently. People no longer needed to live near the seaports to exchange goods. The ability to travel the country over land, allowed the population that lived far from the
coast to exchange goods with those near the ports. As long as there was access to a rail line or depot, they could get the supplies they needed and trade wares. Just as the demand for exploration gave birth to sea-faring vessels in ancient times, so the demand for efficient transportation led to the railroad system in the 19th century.

In North America, during the 1800s, train use exploded with rail lines running clear across the continent in every direction. The improved socio-economic conditions that resulted from this transportation system boosted America to the top of the world commerce list. Subsequent effects on the urban environment and architecture also stemmed from the development of the railroad. The ability to move goods from ships inland via train (and vice versa) was of great benefit to the trading industry. Therefore, rail lines were located at seaports to increase the efficiency of moving products between ships and trains. A new architectural typology, the warehouse, was designed to house the goods before being loading onto trains or ships to be transported. The warehouse depot had a large open plan and high roof lines that allowed quantities of goods to be stacked up until they could clear customs and be delivered.

Figure 9: North American Rail System created by Radical Cartography
(http://www.radicalcartography.net/?rail)
Passenger train stations, on the other hand, were generally located in the middle of the city. As a symbol of economic power, passenger stations were designed to impress by their monumentality. These elaborately designed oversized buildings, such as New York’s Grand Central Station, incorporated passenger service areas, railroad operations offices, convenient stores and vast circulation halls. The integration of services at these early train stations were the beginnings of the all inclusive transport facility. Even though its popularity as a long distance people mover has waned over the last century, in lieu of faster modes of transportation, the rail system continues to transport goods across the country, and its monumentality is preserved in the architecture of its many stations.

AUTOMOBILES: PRIVATIZATION PROMPTS URBAN SPRAWL

Shortly after the development of the modern railroad, came the invention of the automobile – a vehicle made for private conveyance. Initially, only the wealthy could afford such a vehicle, making it a status symbol to simply own one. However, the exclusiveness of private transportation diminished with the advent of mass production.
The first automobile was based on the same steam engine as the locomotive. This steam power vehicle, however, wasn’t so successful. Not until the gasoline powered motorwagen, built in Germany by Karl Benz in 1885, did the general public start to take notice. Benz began selling his three wheeled version in Europe in 1888, and later a four wheeled version. Aside from the Benz motorwagen, other self-propelled vehicles of all means and methods were being developed throughout the late 1800s, none of which seemed to capture the market. The first affordable automobile began production in the United States in 1914 by none other than Henry Ford, the leader of mass production. He realized that a machine run assembly line would increase the efficiency of automobile production, and thereby decrease the cost in terms of time. As a result, the purchase price of the automobile, his Ford Model T, was low enough that almost anyone could afford to own one. Once word of the production method got out, manufacturers across the world began revamping their factories to accommodate assembly line production. New automobile production companies started popping up everywhere. Competition fueled the machine, so to speak, and automobile technology saw rapid growth in the years following.
The growing population of automobile owners in the early 1900s increased traffic on public roads so much that planners saw fit to create a highway system that accommodated the increase. Thus began the paved interstate system of roads that connects cities and their surrounding suburbs. This interstate highway system allowed citizens to live just outside the city, but still within driving distance to work inside the city – all that was necessary was a short commute in their personal automobile.

From an urban planning viewpoint, this highway system opened the door to urban sprawl – a 20th century building trend where people who wanted to escape the hustle and bustle of the city, would establish sustainable neighborhoods further and further away from the city center. The new neighborhood developments created a whole new architectural perspective; one that decentralized the city and redistributed the various live, work and play services throughout the surrounding lands. As populations grew, the city grew wider and wider. The result of this trend still affects us today, as populations continue to spread into the countryside, transforming the natural land into hundreds of suburban neighborhoods, like the one shown in Figure 14.
AEROPLANES: INTERNATIONAL COMMERCE DEMANDS EFFICIENCY

Somewhere in the mist of all the locomotion and automotive hoopla, there loomed a dream of flying. The desire to fly can be traced back to ancient times. Much evidence has been discovered in the drawings and writings of the ancients that reveal a desire to fly: illustrations of bird shaped devices and descriptions of self propelled flying machines. Documents, dating as early as the 15\textsuperscript{th} century, show that Leonardo Da Vinci was designing a winged aircraft. Nonetheless, the first successful motorized aircraft didn’t fly until the early 20\textsuperscript{th} century. Many potential designs were tested in those early years, but the ones that actually succeeded were drafted into military service, along with their designers, to fight in World War I and World War II. Aircraft became weapons of war and the designs that came out of the era reflected it. The jet fighter plane, for instance, materialized during World War II. During war times, the majority of air service in the states was limited. Because of the focus on the military, the commercial side of air travel didn’t really take off until the end of World War II. Thereafter, with an excess of pilots and aircraft at hand, the commercial business of air travel began to explode. The designs of aircraft turned to passenger planes, like the Boeing 707 shown in Figure 15. Though it was considered the first commercially successful jet airliner, it was not the first jet airliner to ferry passengers. The de Havilland Comet, takes the title as the first jet airliner to fly passengers for profit in 1952.

![Figure 15: World First Commercial Jet Airliner A Boeing 707](http://commons.wikimedia.org/wiki/File:Travolta707.JPG)
By the 1970s, airlines multiplied and airports sprang up in every major city. (Actually, most were located just outside the city due to the noise output of the aircraft and the lack of available land within the city). As the demand for air travel increased, and aircraft and airports grew in size, the costs of the tickets decreased. Like automobiles, what was initially available only to the wealthy became affordable to the masses. More people began flying to their destinations, rather than driving or taking the train, because it was faster and more efficient.

Figure 16: Tampa Airport 1948 (Originally Name Drew Airfield)
(http://upload.wikimedia.org/wikipedia/commons/9/93/Drew_field_tampa_11-060p.jpg)
As the fashion of flying wore off and became commonplace to the typical vacationer, the business commuter population arose as the primary consumer. Business men and women began to take advantage of the convenience and economy of air travel to conduct national and international business in person. The ability to increase the client base of one’s company beyond the local vicinity proved a great advantage over non-commuter competition. Manufacturers took advantage by employing airlines to transport their products to a number of international distribution areas. Even the government exploited air travel to improve the efficiency of mail delivery.

Thusfar, no other invention has had such a great impact on global commerce as the airplane. It is only in the past couple of decades, however, that its full potential as a transportation device has been realized. Initially, considered somewhat of a nuisance, airports were built on the outskirts of the city away from residences and businesses. However, as businesses realized the benefits of air shipping, they began to relocate their offices closer to the airport to gain more direct access to the aircraft. Express delivery services, like FedEx®, as well as many distribution firms base their success on the ability to transport products as quickly as possible. Efficient delivery has become a very important aspect for the success of many businesses worldwide, and not just for the delivery of goods, but people as well. In this age of international commerce, where time is money, doing business face to face is often critical to gaining a client’s trust, and there
isn’t always a lot of time in which to do so. Therefore, faster means of trans-continental transportation are always sought.

**REUSABLE LAUNCH VEHICLES AND SPACEPLANES: INNOVATION SAVES TIME**

What does the future hold for world travelers? For some, the thrill of flying is just as exciting as the destination. For others, the hours spent flying in an airplane can prove to be frustrating and exhausting – a waste of time. Well, imagine if the time it took to fly to around the world was ten times shorter. Better yet, imagine the intended destination wasn’t even on Earth, but outer space. Technology to do just that is well on its way.

In the past several years, great strides in the field of private space travel have been made. Research and development into reusable launch vehicles (or RLVs) is showing promise towards being the next generation of transportation. Combining the technology of aircraft with the technology of spacecraft, a more efficient vehicle for space travel is being constructed – one that is not only faster, but is completely reusable and operates on far less natural resources than the NASA space shuttle. Several privately owned companies have already begun fabricating prototypes of reusable space vehicles, such as the SpaceshipTwo®, Rocketplane®, EADS Astrium’s Space Jet, and the Xerus® Spaceplane (see *Figures 18-21*).

![Figure 18: Virgin Galactic’s Spaceshiptwo](http://www.spaceportamerica.com/news/photo-gallery.html)

![Figure 19: Rocketplane XP](http://www.rocketplaneglobal.com/press/20071026a.jpg)
Like the transportation vehicles of the past, these reusable launch vehicles will initially have a rather limited scope. The first space vehicles being designed are single-stage-to-orbit vehicles that will take tourists on short trips to the edge of space to experience weightlessness and return them back to the same location. However, others are working on single-stage and multi-stage-to-orbit vehicles to shuttle people to low Earth orbit (LEO) and the International Space Station (ISS). Even NASA is attempting to redesign a more efficient space shuttle to get their astronauts into space (Figure 22). Still others are focusing on super high-speed suborbital spaceplanes (a type of RLV) to ferry passengers across the planet in far less time than aircraft. At any rate, the full potential of each of these vehicles waits just over the horizon. “If the development of space tourisms
was made an immediate priority, within as few as 30 years it could evolve into a large-scale international industry” – one that encompasses a wide range of applications and customers (Collins 2000, 20).

“Just 100km, the distance between London and Oxford, separates the earth’s surface and the threshold of space… 100km is the smallest of small steps – only 10 times higher than the flight paths of commercial airliners” (Wade 2006, 29). A spacecraft capable of flying beyond the atmosphere into the nearest reaches of outer space and returning to Earth spells great potential on multiple levels. Since it only takes a few hours to blast off, circle the Earth, and glide back down to land, it is possible to utilize these space vehicles for point-to-point travel as well as Earth-to-orbit transport. Until recently, spacecraft and space travel have been reserved for the select trained astronauts employed by the various governments of the world. These privileged few have gotten to experience things that no common man has been allowed. Because RLVs and spaceplanes are more efficient, reusable, and have fairly quick turn around times, means that soon lay people (those with no previous astronautical training) will be able to experience the weightlessness of outer space, catch a breath taking view of the Earth’s surface curving miles beneath them, and return safely to their intended destination. Plans of LEO space hotels are also in the works, which would allow people to stay longer in zero-gravity space.

Other commercial opportunities also exist that utilize the space vehicles to transport materials to and from orbit and around the world, such as delivery of biomedical supplies and emergency courier service for those companies who simply can’t wait. Many privately operated RLVs would likely be employed by the U.S. government and other corporations to lift satellites into orbit, and deliver payloads and crew to the International Space Station. The spectrum of possibilities surrounding these reusable vehicles and their
transport efficiency are enough to suggest that aerospace travel will be the next era in transportation history.

![Figure 24: Correlation between Technology and Cultural Developments](image)

**ON THE EDGE OF AN AEROSPACE REVOLUTION**

**HOW SPACECRAFT AND SPACEPLANES MIGHT EFFECT CIVILIZATION**

An Aerospace Revolution awaits! Although many of these new space vehicles are being commissioned primarily to allow private citizens access to space, there is no stopping the socio-economic pressures of international commerce from taking control and exploiting the technology to improve worldwide transportation. In fact, speed and efficiency are the two major benefits that space travel technology can offer; they are also the two constant demands of modern society. There simply is no such thing as too fast. Modern society has acclimated itself to the increasing speed of life. For this reason, efficiency and convenience are the keys to successfully living in the 21st century – from farming to eating meals, from buying a car to washing a car, from building a house to cleaning a house – all aspects of modern life are speeding up, as is expected. The premise of supply and demand applies – the spiraling correlation between cultural developments, societal desires and technological advancement is clear – demand drives innovation. In the case of space travel, space tourism “could spur the development of space transportation systems in much the same way that modern fleets of transport aircraft were spurred by the tourist and business traveler” (Rogers 1998, 35). Thereafter, the international commerce market will drive the progress and the flood gates will open.
Spaceplanes that ferry “people to and from space… will transform the whole culture of space transport into that of an airline business” (Ashford 2000, 14). In an Ad Astra article, Eric Anderson of Space Adventures said he sees space tourism as a progressive step… as more and more people do it, it will become more accepted. “Fifty years from now, we’ll look back on space tourism as something that really opened up space to the public” (Carey 2006, 34).

“This revolution is comparable to that in aeronautics 100 years ago, when the invention of the aeroplane led to the rapid replacement of balloons for most purposes, and to an explosive growth in demand. Balloons cannot fly into wind. Ballistic missiles cannot fly more than once. In each case, aeroplanes provide the solution” (Ashford 2000, 17). Well, in this high-tech, fast-paced, space-age, where conservation of resources is of utmost importance, the more efficient reusable space vehicles are the solution; and they have arrived just in time. It is a known fact that our planet’s resources are diminishing, so every effort that we can put forth to conserve resources is a step in the right direction.

The use of RLVs instead of the current space shuttle, and spaceplanes instead of traditional aircraft would significantly reduce the amount of resources consumed to get to space or transverse the planet. First, these new RLVs and spaceplanes use hybrid solid/liquid propulsion engines that already consume less fuel than the space shuttle.

Second, and which may not seem like much, suborbital spaceplanes save fuel by flying at altitudes 100km or more above the Earth’s surface, where the density of the air is so low that drag (the slowing down of the plane due to friction across its surface) is insignificant. At these heights, engines can be shut off and the spaceplane can simply glide back down to Earth until it needs power again to either land or launch into space for another round.

Figure 25: Layers of Earth’s Atmosphere
(http://www.kowoma.de/en/gps/additional/atmosphere_02.jpg)
To reach the maximum efficiency in point-to-point (PTP) suborbital transportation, a spaceplane would fly a parabolic trajectory or series thereof (see Figure 26). The engines would only need to be on at the low points of the trajectory. The number of parabolas performed would depend on the distance of the flight.

Once the private space travel companies are established – meaning they have tested the safety of the spacecraft and repeatedly put passengers into space with no major disasters – that is when the aerospace revolution will begin. The price to fly will decrease and more people will take advantage of the aerospace technology for a variety of activities. “What might now be viewed as adventure or sport for the barnstormer and the risk-taker is what leads to yet one more giant step for mankind. The advent of greater access to space, more efficient travel, greater opportunities for exploration, and the chance at expanding the limits of human experience are there for the taking” (U.S. 2005, 10). Besides the typical activities of space flight such as, courier service, passenger transport and cargo delivery, there are some more ambitious space bound activities that have been proposed in the fields of solar power collection, entertainment, manufacturing, R&D, and maintenance.

Figure 26: Parabolic Trajectories of Suborbital Flights
(Davis et al. 2008, 6)

Figure 27: Suntower Concept
(http://upload.wikimedia.org/wikipedia/commons/8/84/Suntower.jpg)
One such proposal is to build a solar tower (Figure 27) with hundreds of photovoltaic panels designed to collect solar energy and transmit it to the Earth’s surface for use. Another suggests round trip tours to the moon, along with overnight stays at space hotels are being planned for the future. Manufacturing products in microgravity, or the vacuum of space, that can’t be made on Earth, as well as mining the moon for resources to bring back to Earth are other activities. One of the more important activities involves building space laboratories, like SpaceHab, to conduct biological experiments that might lead to the development of new medicines. And to maintain all of the space structures, space robots that could be rented are another possibility. The development of these other space bound activities “depends on the development of low-cost access on demand, which in turn depends on the development of mature spaceplanes” (Ashford 2000, 13). Therefore, progress in the field of space travel technology and its infrastructure should be a top priority. “It is unquestionable that the development of a space-tourism industry [and space travel in general] as described above will be extremely beneficial for world economic growth”– not to mention the millions of jobs created to operate the various entities associates with the space travel industry (Collins 2000, 20).

One entity, in particular, which is the focus of this master’s thesis, is vital for an aerospace revolution to occur, and that is a spaceport. “Just as conventional airplanes cannot operate without airports, spacecraft that may one day provide PTP [point-to-point] suborbital transportation will require a similar infrastructure of spaceports” (Davis 2008, 63).

WHAT IS A SPACEPORT?

Put simply, a spaceport is a site for launching spacecraft; similar to a seaport for ships and an airport for aircraft. A NASA Vision Spaceport Partnership Report on spaceports defines it as, the “facilities, equipment, personnel, and vicinity required to prepare space-bound craft for flight, initiate and manage the flight, and receive the craft at the end of the flight. For Earth-based spaceports, ‘vicinity’ refers to the land occupied by the facilities and equipment” (McCleskey 2000, 15). Spaceports will be “a vital architectural element of a new age of spaceborne commerce” (McCleskey 1999, 1).
**Spaceports Today**

In the U.S., the vicinity is dispersed over multiple spaceports facilities. These spaceport facilities, such as the Kennedy Space Center (KSC) and Cape Canaveral Air Force Station, have traditionally been reserved for government or military operations. Established in 1962, the Kennedy Space Center on Merritt Islands in Florida has remained the launching operations center for the National Aeronautics and Space Administration (NASA). The KSC site, which lies adjacent to the Cape Canaveral Air Force Station, only uses about 6,000 acres of its 140,000 acre site to launch its spacecraft. A variety of missiles, rockets, and shuttles have been launched from the KSC and Cape Canaveral sites over the last 50 years. The combine site includes 48 missile/rocket launch pads, of which only seven are actively used, and two active shuttle launch pads. The other federal spaceports – Edwards AFB, Reagan Test Site, Vandenberg AFB, Wallops Flight Facility, and White Sands Missile Range – are used mainly for landing, testing and tracking operations.

Traditionally, launch sites have been located near the coast, so the pieces that separate during multi-stage launches can drop into the sea where they cause less damage and can be reclaimed. However, this feature will be less necessary with the new single stage and two-stage space craft since there is nothing that drops away.

![Kennedy Space Center VAP and Pads 39A & 39B](http://picasaweb.google.com/robertadibble/SpaceShuttles#5015013354329134770)

**U.S. Space Activity**

The NASA KSC has been actively operational since its inception in 1958 and remains a leader in scientific research in the U.S. However, budget cuts and other factors that have occurred over the last decade have diminished the operational activities of the
space program at large. With only 13 shuttle missions scheduled before the retirement of
the space shuttle Endeavour in 2010, current opinions of NASA held by of those in the
space science and engineering fields are less than optimistic. Lately, questions have risen
concerning what NASA plans to do for the five years between the decommissioning of
the space shuttle in 2010 and the launching of the new shuttle Constellation in 2015. The
options are limited to relying on the Russians for access to space (and the ISS), or
continue to use the derelict old shuttle past its expiration. There is another alternative,
however, that NASA officials are considering. If, no when, the private space travel
companies begin steady operations of their launch vehicles, which is likely to happen in
the next two years, the government could utilized them to get the NASA crews and
supplies into space. With federal government funding, the private sector companies could
be operational much quicker. In 2006, the Commercial Orbital Transportation Services
(COTS) program of NASA plopped down a half a billion dollar prize for a competition to
the firm who could design and build a vehicle that would deliver crew and supplies to the
ISS. Two companies emerged as the winners and split the prize money: Space
Exploration Technologies (SpaceX) and Rocketplane Kistler (Berger 2006). If the
companies can prove that their spacecraft will work reliably, then NASA may begin
utilize the private sector vehicles and facilities to continue their space missions.

EMERGENCE OF COMMERCIAL SPACEPORTS: A NEW PERSPECTIVE

In the realm of spaceports, there are currently only a few privately owned and
operate spaceports in the U.S. Most are abandoned air force bases or airports with ample
space, hangers and runways that have been converted for use as testing sites for
spacecraft. According to the Federal Aviation Administration (FAA) 2008 registry, there
are seven non-federal spaceports (see Figure 29). These non-federal spaceports, with the
exception of the Blue Origin Launch Site, are primarily intended for vehicle testing. The
Blue Origin Site, which received the first FAA permit for reusable suborbital rockets, is
intending to offer passenger service in the near future.
The concept of a spaceport designed for the purpose of space tourism is rather new. Eight requests for proposed commercial spaceports have been received by the FAA in the past year. “Two common characteristics of many of the proposed spaceports are inland geography” – a contrast to the coastal location of present-day U.S. spaceports – and interest in RLV passenger operations (FAA 2008, 60). No commercial spaceports such as this have ever existed, though plans of one in New Mexico are already in the works. Spaceport America, designed by Foster + Partners (see Figures 30, 55, 57-61), will be the first commercial spaceport facility designed specifically for passenger space tourism. Located in the middle of the New Mexico desert north of Las Cruces, Spaceport America is designed around the astronaut experience and the Spaceshiptwo® vehicle technology. The Spaceshiptwo® vehicles operated by Virgin Galactic, the spaceliner company operating out of the spaceport, will carry paying customers to the edge of space and back. Only a hand full of companies have begun conceptual designs for spaceports: Space Adventure’s® Spaceport Singapore and the United Arab Emirates’ Spaceport in Dubai. Since the architects designing these new commercial spaceports have already consulted with the space travel companies involved, their designs provide much needed insight into the programming of spaceports. Being an inspirational model for this thesis, an investigation into the technologies, materials and functions of Spaceport America is conducted and discussed later.
In order to keep up with the private sector, NASA is now looking into organizing a private commercial spaceport of their own, where they will offer aerospace engineers and various space vehicle developers a launch site on which to test their vehicles. NASA plans to utilize the extra space at the KSC to build a test bed launch site complete with hangers, launch pads and runways to accommodate a variety of space vehicles. An artist rendering of what the spaceport might look like can be seen in Figure 31, from aeroplane runways to vertical launch pads. Of course, there will be a minimum fee associated with the use of the site, but their hoping it will stimulate the aerospace engineering arena and provide funding for their own research and development.
SPACEPORTS: VISION OF THE FUTURE

The scope of this research, however, is to provide a view of the future where space travel is common and commercial spaceports are the new centers of transportation. This view deviates from the uni-modal spaceports described in the last section. “This approach assumes this capability is needed to satisfy visionary commercial markets, such as space solar power and public space travel, as well as human exploration enterprises” (McCleskey 1999, 1). In the new era of aerospace transportation, say 50 years in the future, space flight is the primary means of transcontinental travel, as well as for regular scheduled trips to orbit. This does not suggest that other forms of transportation would be obsolete. Quite the contrary, space travel would just be another dimension to the transportation system. To say that people would regularly visit the ISS, stay in space hotels, commute to other countries for work, or to orbit for that matter, is not so far fetched; neither is the idea that people will want to ride in spacecraft as an alternative to conventional air travel. It will be as commonplace as flying in a Boeing 747 today. There would be RLVs taking small groups of people and cargo into orbit, and suborbital spaceplanes designed to take loads of passengers around the world to far off destinations.

Figure 32: Diagram of Suborbital Point-to-Point Travel
(Davis et al. 2008, 2)
The new suborbital transportation would operate much like today’s commercial aircraft, except it will be faster and much more exciting (Rogers 1998, 34). People would arrive at the spaceport, board the spacecraft, fly around the planet, land at another spaceport, deboard, and go on their merry way. (Well, it might be slightly more complicated than that, but it’s the simplest explanation.) “Just as conventional airplanes cannot operate without airports, spacecraft that may one day provide PTP suborbital transportation will require a similar infrastructure of spaceports.” “Point-to-point suborbital transportation, in particular, may drive the proliferation of spaceports, as the vehicles will require facilities worldwide for takeoffs, landings, and maintenance” (Davis et. Al. 2008, 63, 65). Katie Roberts, a spokeswoman for the New Mexico Economic Development Department agrees, that “the sustainability of this industry is point-to-point service… so there would be spaceports all around the world. It’s going to be the new generation of Fedex, or when you can get from Paris in two or three hours” (Iannotta 2006, 40). Unlike the isolated uni-modal spaceport concepts discussed earlier (like Spaceport America), this implies that the commercial spaceport of the future is integrated into a city and capable of handling vast numbers of passengers, as well as multiple forms of transportation – it will be a transportation hub. “Master planning of spaceports will involve synthesis of many different modes of transportation, such as ground transportation (road and rail), sea, and air travel” (McCleskey 2001, 17).

Another assumption is that because spacecraft and the infrastructure to operate them costs more, only major cities around the world will have spaceports. Therefore, a spaceport would act as a hub in a hub-n-spoke system. Intercontinental travelers arriving by spacecraft or spaceplane would need to catch a short air flight to their final destination and vice versa. This is another reason why spaceports would need to be multi-modal.

In addition, the location and urban context surrounding the spaceport is important in terms of support systems available to sustain it, including human resources and infrastructure. This is not to imply that isolated spaceports, such as Spaceport America, would not be useful, but to gain the most benefit from a commercial spaceport, it must coexist with an urban community. A spaceport must be in a location where the local labor force is large enough to handle it. “Spaceports and space transportation maturation must
necessarily evolve the technological capability to operate much as airports do today” – at the edge of or in the city. “This means improvements in reliability and safety will apply” (McCleskey 2000, 14).

A spaceport as such would be more than a simple launching facility; it would be a transportation nexus. The infrastructure involved in a spaceport of this nature would be very similar to that of a hub airport. It would need multiple runways to accommodate take off and landing of spacecraft and aircraft; it would need hanger facilities, storage warehouses, fuel depots, a control tower, a fire station, access roadways, train station facilities, and parking garages. Mostly importantly it would need terminal facilities that provide passenger access to the craft, and a tram system to connect them all. There may also be vertical launch facilities on site, which would require additional support structures, such as tracking centers, launch pads, assembly buildings, and gantries. Overall, the infrastructure would be much the same as an airport. One major difference, however, being the separate aerospace terminals giving passenger access to the various spacecraft and spaceplanes.

An aerospace terminal would be unique, not just in appearance, but in function. Because of the added risks taken by passengers flying into space, the aerospace terminal would house the necessary facilities and equipment needed to train them for the space experience. It would also include a medical center to conduct physical exams of passengers prior to and after flights. The boarding and deboarding method of spacecraft might also be different from aircraft, making the interface between building and spacecraft unique. Because there would be a wide range of people visiting the spaceport, and the aerospace terminal specifically, it would likely have an abundance of amenities for not only passengers, but guests. It might also possibly have a large educational and entertainment area for families and visitors to explore while they wait, or during a leisurely afternoon outing. Considering that the technology would be fairly new, the aerospace terminal(s) would be a sort of marketing tool in and of itself to encourage people to take the leap into space flight. Above all, it would be designed to get people interested in space science and space travel. Therefore, the aerospace terminal would be
more than just a connection point between passenger and spacecraft, but a sort of space themed recreation center for all to enjoy.

The most important feature of the aerospace terminal is the space flight training center. During space flight, the body is subject to additional stresses and sensations that it is not use to here on Earth, such as high pressure g-forces and weightlessness. These forces can pose health risks or cause panic in an unprepared passenger. Therefore, novice passengers would be required to attend a space flight training program prior to their first space flight. This training would involve classroom instruction, simulators and sensory stimulation tests designed to prepare the passenger for space flight conditions. Visitors, not intending to fly, might also participate in training activities. An experienced passenger, on the other hand, would not need any training; they will have gone through the training some time before and be familiar with the effects of space flight.

The training center would likely be an entity within the terminal building, along with a medical center designed to provide physical examinations to potential passengers. Since the health risks of space flight are higher than those of air flight, especially for sick passengers, each passenger would need to undergo a physical examination to ensure that they are healthy enough to endure space flight conditions. Eric Anderson, CEO of Space Adventures believes anyone “able to ride a roller coaster… should be able to fly in a suborbital space vehicle” (Carey 2006, 32). This may be true, but common sense requires that the health of passengers be assessed in case they do not realize they are sick. This means that the physical exam would be rather intense. Just as pilots must obtain a medical certificate validating their good health every year, so a space flight passenger would get a certificate of good health perhaps every five years. Examinations of individual passenger prior to every flight during the five year period would be limited to a basic physical. The certificate of good health could be issued by a family doctor, or by a doctor at the medical center in the terminal. Either way a certificate of good health would be presented prior to any training or ticketing.

For those passengers staying longer in orbit, more intense training would be required, as well as a post flight medical exam to check that no health problems have resulted from the lack of gravity or exposure to radiation.
These additional procedures will affect the standard passenger process through the terminal (see Figure 115 for an example of passenger flow through the aerospace terminal). A first time passenger navigating through these procedures would likely spend more time in the terminal prior to space flight than he/she would on the flight. The major benefit of this new space transportation, however, becomes evident when an experienced passenger flies half way around the world for a meeting, and returns the same day. An experienced passenger would spend about the same amount of time in the terminal as a passenger does for an air flight today, but the time spent on the flight is far less. The overall travel time for an experienced passenger on a suborbital PTP flight ends up being only a matter of minutes; significantly less than it would be on a traditional aircraft (see Table 1).

<table>
<thead>
<tr>
<th>Route</th>
<th>Distance (km)</th>
<th>Aircraft Duration (hr)</th>
<th>Concorde Duration (hr)</th>
<th>Suborbital Duration (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>London – New York</td>
<td>5,900</td>
<td>7 h 30</td>
<td>3.5</td>
<td>66 - 71</td>
</tr>
<tr>
<td>London – Singapore</td>
<td>9,560</td>
<td>11 h 30</td>
<td>8*</td>
<td>75 - 78</td>
</tr>
<tr>
<td>New York – Tokyo</td>
<td>10,900</td>
<td>12 h 50</td>
<td>9*</td>
<td>81 – 85</td>
</tr>
</tbody>
</table>

Table 1: Travel Time Comparison for Different Modes of Transportation (Davis et. al. 2008, 14)

The culmination of these suppositions results in a vision of the future that thrives on space travel. A vision that shows people from all walks of life becoming astronauts, businesses relying on space transport, and international commerce depending on it to succeed. It shows space commerce beginning to emerge and the spirit of space exploration revived. A vision of an aerospace revolution!

This vision, which supports the argument of an aerospace revolution, establishes a basis for a line of inquiry that involves research in the fields of airport design, urban planning, terrestrialism, government regulations, space architecture, astronaut training, and spaceport programming. The research that follows and this vision combine to form the very essences of this project, and leads to the design of a spaceport and aerospace terminal that responds to the needs and concerns of the global community, as well as attempts to fulfill its dreams.
As building types go, airports are probably the most similar to commercial spaceports. On a basic functional level, they are identical in that they connect the public to a particular mode of transportation, be it air travel or space travel. In lieu of an existing commercial spaceport, an airport is the obvious precedent to examine. Remembering that a commercial spaceport, like an airport, would accommodate a variety of transportation means, including aircraft and spacecraft, the main functional systems, program spaces, design features and concepts of the typical airport apply. These systems, as well as the latest trends in airport design provide the basis for the development of a commercial spaceport.

AIRPORT TYPOLOGY

In analyzing the airport typology, the first step was to identify the basic infrastructural components and define any unfamiliar terms (many of which are included in the Definitions section at the end of this document). The typical layouts of airport components – the main terminal building, airside(s), roadways and runways – are shown in Figure 33. The main terminal building acts as the main entrance and staging area for all passengers and guests visiting the airport facility. The airside(s) are the restricted areas that allow passenger access to the aircraft. There are three types of roadways at airports: public roads that provide passenger access to drop-off and pick-up areas, service roads for employees and delivery/service vehicles that connect directly to the terminals, and access roads that allow airport authorities and emergency vehicles to access the runways. The runways, used for take offs and landings, are the most critical since they must be situated according to local climate, aviation regulations and site limitations. These four
main components are the first to be laid out on the site. Of course, a variety of layouts stem from these basic four, depending on site limits, use level, scale and scope.

![Diagram of Typical Airport Component Relationships](Adapted from Blow 33)

Elaborating on these basic layouts, airports terminal buildings have five basic schemes (see Figure 34), which can be combined to create a variety of organizational patterns. The *linear* terminal scheme is the simplest and has the most straightforward circulation. Circulation along its length provides access to gates along the perimeter. The disadvantages are that the amenities are often duplicated, and transfer passengers can have extremely long walks from gate to gate. The *remote* terminal scheme is the most flexible in that the apron stands may or may not be fixed. This scheme can utilize mobile lounges to transport passengers to and from airplanes, which makes for short walking distances. However, mobile transporter breakdowns and weather can slow processing greatly and inconvenience the passenger. There is a need for greater security in this arrangement as well.
Figure 34: Standard Airport Typologies
The terminal with *piers* or *fingers* has a main terminal building with sterile airsides extending from it. The centralization of amenities within the main terminal is very economical and produces a clear relationship between the public landside and the sterile airside. The apron stands and gates typically line the perimeter of the airside piers providing added security. The piers can be arranged in a number of ways to fit the site or any other organizational criteria. The piers scheme is, however, prone to congestion due to long walking distances for passengers, especially those transferring from one airside to another, as well as long conveying distances for baggage. The terminal with *satellites* scheme has a stand alone main terminal that functions as the public staging area. The main terminal is connected to satellite airsides via train, tram or travellator. This scheme can be easily expanded with additional satellites, but expanding the main terminal is limited. The satellites scheme can also have long walking distances depending on the arrangement of the airsides. The *unit* terminal scheme allows each terminal to operate autonomously with its own amenities. Each unit terminal has its own form (usually linear or pier style) and is connected to the other unit terminals via train, tram, or roadway. Transferring between the unit terminals is oftentimes confusing and difficult.

Each of the standard layouts and schemes has advantages and disadvantages that suggest the appropriate type and scale of airport for which it is best. For the purposes of a large, multi-modal commercial spaceport that caters to airplanes and spaceplanes, a unit terminal arrangement with a separate aerospace terminal seems to be the most appropriate. Given that space flight would be the newest form of transportation offered, the aerospace terminal should become an icon of the spaceport. In this configuration, the aerospace terminal stands apart from the rest of the facility, allowing it to have a distinct appearance that dominates the entire spaceport.

In any event, the organizational layout established at the beginning of the design process should be flexible and expandable, so that any future alternations or additions can easily adapt to the existing geometry. As a result, the masterplan becomes a “flexible, spatial diagram of a strategic nature” (Edwards 2005, 55). This geometry should also manifest itself at all scales of the terminal buildings. “The architect has the primary task
of finding clear organizing patterns which can regulate development over time. Such patterns expressed as structural layouts are best evolved with a clear sense of geometric progression” (Edwards 2005, 55). In this sense, the organizational pattern serves a dual purpose, (1) it clarifies the functional order of the plan through the structure and spaces and (2) it arranges the spaces into a perceivable journey for passengers to follow (Edwards 2005, xv). There is no other building type quite as complicated and demanding as an airport, therefore, simplicity and order are critical.

Typologically, an airport terminal is a unique building, one that speaks of space, speed, light and flight (Edwards 2005, xi). A well ordered, spacious terminal allows for the influx of passengers to move about the terminal with ease. However, it can be uncomfortable with only a few occupants. A well designed airport terminal gives meaning and identity to an otherwise alienating environment by striking a balance between function and drama (Edwards 2005, 84). An architectural expression of flight, symbolic of its function, along with the play of volumes and light, can add dimension and often soften a harsh, utilitarian feel of a terminal. So, “if order and organization are to be found in the plan of terminals, then beauty and event are created by the different applications of structure, space and light in section” (Edwards 2005, 128). “The initial simplicity of design gives way to plurality. Order… erodes into romantic confusion (Edwards 2005, xv). This dichotomy between an ordered plan and a dramatic section corresponds to the dichotomy between the necessary function of the terminal, with its emphasis on circulation, and the theatrical experience desired by its users.

The aerospace terminal design in this project needs to perform in the same manner, if not more towards the dramatic. The novelty of space flight during this nascent period, calls for a bold expression that draws attention. Though not literal, the aerospace terminal would be a sort of billboard advertising what it offers to passersby. The dichotomy of its function and expression would be most evident when seen by approaching viewers on the ground, but it may also exhibit this duality to the sky for those fly over to enjoy.

Other dichotomous relationships present in the terminal must also be handled with as much intentness, such as between landside and airside, public and private, accessible and sterile, and arrivals and departures. However, due to the amount of security required in
airports, these relationships are necessarily separate. In small to medium airports, they are usually distributed horizontally. But, in large airports, the arrivals and departures are oftentimes vertically separated on different floors for added control, and so that the flow of passengers doesn’t collide. Together, the vertical and horizontal distribution of these relationships helps organizes the passengers, and aids in security management. Examples of vertical distribution within the airport terminal are shown in Figure 35. Horizontal distribution follows the typological schemes discussed earlier in Figure 34.

![Diagram of Vertical Segregation within the Terminal](Edwards 2005, 125)

Passenger organization is the most important function of the airport terminal, therefore, “emphasis should be upon routes, movement and circulation” (Edwards 2005, xiii). The grouping and staging of passengers regulates the flow of traffic through the various check points. The flow chart for passenger arrivals and departures is shown in Figure #. The various check points should be strategically located to meet regulations, and large enough to accommodate the masses of enplaning and deplaning passengers.
Characteristically, the passenger route should be as clear and legible as possible, utilizing a variety of architectural elements – material, colors, textures, even structure – to signal the critical points in the passenger’s journey (Edwards 2005, 127). A geometric ordering at all scales, from the structure to the light fixtures, lends to the legibility and efficiency of the terminal. Eventually, these visual clues guide the passenger to their destination, be it landside or airside. “In this transitory environment, the architect creates a gateway to flight and in the opposite direction, a gateway to continents;” and in the case of an aerospace terminal, a gateway to space flight (Edwards 2005, xi). Therefore, whatever the ultimate destination, the passenger should understand that he/she has reached that threshold – arrivals should see the city or landscape, and departures should see aeroplanes (or spaceplanes) (Edwards 2005, xv).

Figure 36: Passenger Flow Chart
(Adapted from Blow 1996, 35)
Another important feature of a well designed airport, that of intermodality, contributes to the efficiency of the entire system – that, and well, people love options. Providing multiple ways for people to access and move about the airport and terminal facilities is a great way to reduce congestion. Most airports provide roadways for public vehicular access, but modern “airports are marked by intermodality, terminals which are huge in scale and often linked directly into rail systems” (Edwards 2005, xii). There should be a range of pathways and transport options for pedestrians within the terminals as well. In addition to stairs, elevators, and walkways, there should be the choice of using escalators, travellators, or trams that speed up movement and reduce walking distances. Maximizing dwell time while limiting the distance passengers have to walk is another balancing act. This is where the passenger priorities and the airport priorities collide. Regardless of any possible debate, the customer comes first. The opportunity to take a faster route should always be offered to those who do not have the luxury of time.

On the flip side, there are always non-flying guests, as well as passengers, who are perfectly willing and wanting to relax and enjoy their time in an airport. As previously noted, “transport buildings take on a role beyond the utilitarian: they celebrate physical travel and social connection” (Edwards 2005, xi). For this reason, they include a variety of gathering space and amenities. If someone is stranded in the airport for several hours waiting for a flight, they should be able to grab a bite to eat, watch a show, do some shopping, catch up on work and have a haircut, for example. No one should need to suffer from boredom. Aside from retail shops and restaurants, spaces for reading, reflecting and quite contemplation should also be offered for those passenger/visitors who wish to escape the hustle and bustle of the concourse.

Aside from facilitating circulation between transportation modes, processing passengers, handling cargo and baggage, providing passenger services, and organizing and grouping passengers, an airline terminal (or spaceport terminal) must create a sense of place.

Following the conventions set forth here for good airport and terminal design, virtually warrants a good, functional spaceport and terminal.
**Precedent Study Airport**

There are several examples of good modern airport design that incorporate these characteristics, such as: Chep Lap Kok in Hong Kong, Denver International Airport and Beijing Capital International Airport. The designs are innovative and captivating. They show just how the balance of function, structure and beauty can be made even in the most complicated of building types. One airport in particular is such a great example of airport design that it was studied as a precedent to this project.

**Kansai International Airport**

Kansai International Airport in Osaka, Japan designed by Renzo Piano was selected for its high-tech and thoughtful approach to airport design. Piano’s emphasis on making Kansai a multi-modal transportation nexus with all the splendor and beauty of a flight is what makes it a model for the new generation of airport design. Just looking at it from a distance, one can see that it is more than just a simply shelter for passengers.

![Figure 37: Kansai International Airport (Photo by Carpkazu 2006)](http://commons.wikimedia.org/wiki/Image:Finair_MD-11.JPG)

The architect’s use of technology and environmental design in a building of this scale and complexity is a feat in and of itself. For one, the entire airport terminal is
constructed on a man-made island (Figure 38) with some 906 hydraulic jacks supporting the foundation. As a separate island it can operate 24 hours a day, 7 days a week without disturbing the community. However, this means that any expansion will require more land to be created.

Figure 38: Aerial of KIA
(http://upload.wikimedia.org/wikipedia/commons/3/38/Kix_aerial_photo.jpg)

The clear order of Kansai can not be denied. The terminal is laid out in a linear pier configuration with pier arms extend out from the central terminal to reach an overall length of just over a mile. Possibly the longest building in the world, it provides frontage for at least 41 apron stands around its perimeter. The runways lay parallel to the terminal on the southeast side, while the main access road circulates on the northwest side.

Figure 39: KIA Siteplan
(Transportation 1997, 13)
The layout of the airport components and interior spaces inside the terminal produces a clear distinction between landside and airside. The main terminal in the center houses all the amenities, ticket counters, inspection stations, baggage carousels, etc., while the gate lounges reside in the arms. International passengers circulate through the main terminal and out through the pier concourses to the gate lounges for departure and vice versa for arrivals. The domestic departures proceed straight forward through the main terminal to the gate lounges on the opposite side.
Even within a multi-level terminal, such as this, the circulation is clear and legible. The design is thought to be the first to used light and structure to guide passengers through the terminal. This is accomplished through the strategic ordering of architectural and structural elements. “Columns, beams, lattice girders and sweeping lantern lights are guiding elements that direct, deflect and assemble weary passengers (Edwards 2005, 176). Kansai’s “architecture of space and light, and the design of structure and constructional details, seem to push at the frontiers of the tectonic experience” (Edwards 2005, 176). These elements combined with the form of the space allude to its function and create a sense of place. For example, the main public concourse with its wide walkway, heavy structure above, solid earthy tones, pedestrian bridges, and monumental rectangular form lit from skylights above, resembles that of an urban main street. The gate lounges in the airside wings, on the other hand, have thin, curving lattice girders, brightly colored details, large glass windows overlooking the apron and a rounded tubular form that hint at the idea of flight (see Figures 42, 44). The circulation spaces sandwiched between the floors are long and linear; and the upper level area is a large, open, airy park-like space.
Because Kansai International Airport sits on an island, it was important that it be a multi-modal facility. Within the terminal, a tram system runs the length of the pier arms allowing passengers to quickly get to their gates. Just outside the terminal, public light rail and high-speed rail lines terminate in the airport train station that lies beneath the parking garage. This structure is joined directly to the main terminal facility via several...
pedestrian bridges. One central bridge passes through the parking structure and connects with a luxury hotel on the other side (see Figure 48). A bridge that spans the gap between the airport island and the mainland connects the airport access road with the public thoroughfare, and carries the rail system across.

Figure 45: KAI Ceiling: Airfolds
(http://upload.wikimedia.org/wikipedia/commons/3/37/Kansai_International_Airport01n4272.jpg)

Figure 46: Airport, Train Station & Hotel Arrangement
(http://j-click.jtb.co.jp/info/ecw/img/88.gif)
Figure 47: KIA Station
(http://farm1.static.flickr.com/28/64965778_49dbc47372.jpg?v=0)

Figure 48: Hotel Nikko
(http://static.panoramio.com/photos/original/681355.jpg)
It is always important to consider other issues that might effect or be effected by the design. Two issues related to the design of a spaceport are discussed below. These issues influenced the development of the project and spaceport design.

**Aerotropolis Schematic**

![Aerotropolis Schematic](http://www.aerotropolis.com/aerotropolisSchematic.html)

Figure 49: Aerotropolis Schematic by Dr. John D. Kasarda

(http://www.aerotropolis.com/aerotropolisSchematic.html)
This investigation into the concept of an aerotropolis, a term defined by Dr. John D. Kasarda, is the backbone supporting the idea that a strategic masterplan is necessary to stitch a spaceport into the physical and social fabric of an urban environment, such as a city. Kasarda’s insight into the evolution of airports lends to the understanding and structuring of the urban context that surrounds airports. As he explains in his 2007 article for Airport Innovation “[an] airport city is really the urban core of the more geographically expansive aerotropolis… [which includes] extensive outlying corridors and clusters of aviation-oriented businesses and their associated residential developments” (Kasarda 2007, 108). Airports are practically becoming cities unto themselves surrounded by supporting infrastructure, businesses, housing, entertainment and shopping districts. This trend has emerged as a response to the fast-paced world in which we live where “greater efficiency is paramount, followed closely by agility; and that distance equals time.” “For every laptop order… a real 747” must carry it in its hold (Lindsay 2006, 80). Therefore, time, accessibility and location are key features of an aerotropolis. “Companies, increasingly reliant on air transportation to move people and goods quickly in a global economy, locate nearby” (Nasser 2003, 01A). Even service oriented businesses “that require executives and staff to undertake frequent long-distance travel” are moving closer to airports (Kasarda 2007, 108).
Thusfar, most airports “have evolved largely spontaneously” with development filling in around them “creating arterial bottlenecks of roadways. In the future, strategic infrastructural planning could reduce this congestion” allowing airports to mature into a city with the airport as the transportation node at the center (Kasarda, Aug/Sep 2006). In doing so, the terminal would act as the “‘town centre’… with promenades, parks, oases, inside and outside the buildings” (Edwards 2005, xiii). The shops and restaurants inside the terminal would form the main street, while the airport hotel would effectively be the central business district. The warehouses and hangars on the property would constitute an industrial zone (see Figure 50). Other business, residential and manufacturing districts would, of course, be filled in around it, establishing an aerotropolis. As the transportation node, the airport would be a multi-modal facility with “dedicated expressway links (aerolanes) and high-speed rail (aerotrails)” connected to businesses and residences in the vicinity, as well as to neighboring cities (Kasarda Aug/Sep 2006).

Figure 50: Airport City Diagram
Several aerotropoli are already emerging around the world. At whatever level of development, these airports are growing in a deliberate fashion just as Dr. Kasarda envisioned an aerotropolis would. A few up and coming aerotropoli worth mentioning are Dubai World Central, Hong Kong’s ‘SkyCity’, Beijing Capital Airport City and Denver International. These few have either already exhibited characteristics of aerotropoli or are intentionally planning to become one. Dubai World Central (DWC) is a perfect example of a planned aerotropolis at its conceptual stage. Designed completely from scratch, the masterplan shown in Figure 52, demonstrates how the land can be divided up and how each district would relate to the central airport. In DWC, each district is assigned a purpose and named accordingly: Aviation City, Logistics City, Residential City, Commercial City and Golf City make up the plan and are strategically arranged into the system. Each district is then zoned for a particular land use. Although it has not yet been built, it has already been deemed the largest aerotropolis in the world. The airport alone would cover 54 square miles, have six parallel runways and six concourses, and be able to serve 120 million passengers a year. It will have enough residences to house all the airport staff, a cargo facility able to handle 12 million tons of cargo per year, and plenty of leisure activities for the residents and visitors.
Denver International Airport is another good example of planning for the future. When Denver’s Stapleton International Airport reached its capacity in the 1990s, authorities decided it was time for a new airport. In 1995, the Denver International Airport was built to replace it. The airport is located some 25 miles outside the city of Denver in the plains overlooking the city. The reason for locating it in the middle of the open plains was “to avoid noise impacts to developed areas, to accommodate a generous runway layout that would not be compromised by winter storms, and to allow for future expansion” (Wikipedia). Planning for expansion is one of the main characteristics of an aerotropolis. Denver International is the largest airport in North America, having over 53 square miles of land, in which only 33,000 acres are occupied by the airport. The planners wanted to ensure that “it had to have enough room to add runways when business grew and enough land around it to accommodate industrial cargo facilities, commercial and residential space” (Nasser 2003, 01A). There is currently enough extra land to add up to 12 more runways and double the size of the airport. However, this additional land was intended to be use for commercial and residential development. If development continues as planned, it could very well grow into the first aerotropolis in North America.

Figure 53: Denver International Airport
(http://farm1.static.flickr.com/43/75748924_59e3a5385b.jpg?v=1135536635)

“One might misconstrue aerotropolis land uses as simply additional sprawl… In reality, the aerotropolis grows according to a rational system” (Kasarda Aug/Sep 2006). If left to grow haphazardly, the businesses and residences will expand around an airport and encroach upon it so that it can no longer expand itself to meet the needs of the growing city. But, if a rational system were established at the time the airport was built
and enough land was assembled to accommodate growth, then an aerotropolis would be formed. “The aerotropolis represents the logic of globalization made flesh in the form of cities” (Lindsay 2006, 80).

Spaceports, could, and should, be designed for the same type of expansion. A spaceport could easily be adapted to the aerotropolis model, whereby the spaceport, being the new transportation nexus, resides at the center of a greater urban environment. The information gathered about the aerotropolis model and its examples are used in the site analysis and master planning of the spaceport in this project.

**GLOBALIZATION AND TERRESTRIALISM**

Globalization is upon us, whether we like it or not. The Earth’s resources are depleting and world wide pollution stands to destroy life as we know it. It may not be tomorrow, or 30 years from now, but it is inevitable. As its most intelligent inhabitants we are honor-bound, if not for the sake of survival, to alleviate the problems with our environment. It is a huge task, but with 6.7 billion people (population of the world as of 2008) working, it could be done. The only way to make progress in cleaning up the world and finding better solutions to the energy problem is to be like-minded in our goals. “Globalisation reflects a political shift towards international politics, by definition a shift that allows people to feel part of a larger whole, with world trade and the reversal of pollution and the depletion of the Earth’s resources as the unifying goal” (Bartlett et al. 2000, 87).

![Figure 54: Symbolism for Global Community](http://www.thewayncc.org/images/Peace%20On%20Earth%20Hands.jpg)

“The conquering of space is a unique challenge the can help to unify the world and encourage us to collaborate as a species. In the emerging global society, the collective
project is essential not just as a symbol of human unity, but for future economic progress” (Armstrong Introduction 2000, 5). Finding solutions to preserve the planet should be this collective goal. As discussed earlier, many opportunities await in space that could greatly improve the state of the planet, like space solar power. It is our duty to explore these opportunities for the good of the planet.

Leveraging the realities of space flight, the global community will learn to transcend the artificial boundaries that separate humankind, including national and socio-cultural ones. Once people begin seeing the Earth as single sphere in space, as “home,” then this change will happen. “The iconography of the planet Earth as seen from orbit has become a powerful symbol of international harmony and peaceful collaboration between nations” (Bartlett et al. 2000, 87). The common dream of space flight that once unified the world, will again, as we enter this new era. The quest to fulfill a new dream – that of personal space flight – will unify the Earth’s cultures and bond us together into a single race. As terrestrials with a common agenda to save the planet, we shall succeed. Getting into space was the first step. Now it is up to us to push the limits of space until all boundaries disappear.

The spaceport, and more specifically the aerospace terminal, will be the first stop for anyone going into space. “Not only will space unify humans, it will perform the additional role of consolidating the relationship between technology and people” (Bartlett et al. 2000, 91). Therefore, the terminal design and program should reflect the unifying nature of its function, and shall become a metaphysical symbol of what the people see as its future. In doing so, it will explicitly become an icon of space flight and implicitly inspire global harmony. In his discussion about airport terminals, science fiction writer J.G. Ballard said that concourses are “where everybody briefly becomes a true world-citizen” (Edwards 2005, xv). It is not a place that belongs to a nation, a government or a culture, but a place that belongs to all people, collectively. In an aerospace terminal, where people gather before flying into space or after returning from space, this will be even more true, so its aesthetic and functional composition should convey its collective nature. In one direction, the aerospace terminal will be the gateway to space flight, and in
the other direction, it will have the grand purpose of being the gateway to all that is terrestrial.
In general, any investigation into the design of a spaceport should begin with the prescriptive regulations supplied by the government. These regulations, or lack thereof, are discussed here. Then, to further inform the project, the conceptual design of a commercial spaceport and an existing space flight training center are examined.

**Government Regulations**

Though the federal government will no doubt eventually control the entire commercial space flight industry within the United States, at this time, no strict regulations have yet been established for the design and operations of commercial spaceports. In fact, the only piece of legislation written so far has been the Commercial Space Transportation Act of 2003, which has a fairly general scope. According to the 2008 U.S. Commercial Space Transportation Developments and Concepts publication, the Federal Aviation Administration’s Office of Commercial Space Transportation (FAA/AST) specifically, “licenses and regulates U.S. commercial space launch and reentry activity, as well as the operation of non-federal launch and reentry sites, as authorized by Executive Order 12465 and Title 49 United States Code, Subtitle IX, Chapter 701 (formerly the Commercial Space Launch Act). FAA/AST’s mission is to ensure public health and safety and the safety of property while protecting the national security and foreign policy interests of the United States during commercial launch and reentry operations. In addition, FAA/AST is directed to encourage, facilitate, and promote commercial space launches and reentries” (FAA 2008, i). So far, no specific rules, laws and guidelines exist concerning the space launch vehicles, the operations, the infrastructure or design of the spaceport. In short, the FAA is currently only authorized to grant permits to the various *astropreneurs* to fly customers into space, and to license
those spaceports designated for space tourism activities. (Notably, only six spaceports have obtained licenses from the FAA to conduct commercial space travel operations; three of which are collocated with federal launch sites.)

“In many ways, the environment we are in is similar to the barnstorming days of early aviation (U.S. 2005, 8). Patricia Grace Smith, Associate Administrator for the FAA’s Office of Commercial Space Transportation, has said that there must be a period of time given before the government can regulate the space travel industry (David 2005, 16). Back in the days of the Wrights Brothers, there were no rules on when or where flights could be made or who participated. There was no FAA even, until after commercial aviation became a regular practice. “Those early fliers took great risk as part of the deal” and those “people who flew with the pioneers also flew because they loved the thrill” (U.S. 2005, 8). There are some who say that the aviation industry would never have happened if the government had regulated it during those critical years. The same can be said of the nascent space flight industry. Recognizing this fact, the federal government set an eight year trail period, which started in 2003, for the industry to complete its testing and begin initial operations. After this eight year developmental period, the space flight industry would be reevaluate based on progress, and the FAA/AST would either allocate more time or begin implementing rules and regulations.

In the Commercial Space Transportation Act, and in other congressional hearings on commercial human space flight, the concern is geared more towards the safety of the uninvolved public, than passengers at this point… this is compared to a similar era in the early days of aviation (David 2005, 16). Safety begins with those people on the ground who are completely unaware of what is going on above them. Since the FAA’s mission is to provide safety, it is only logical that they would start by protecting the public and property. After that other issues of environmental impact, labor laws, security of the facility (post 9-11), and impact on air traffic would come into play. Then, the safety of the passengers and crew would be addressed; most likely requiring some form of passenger preparations, such as space flight training and medical evaluations.
In lieu of any set regulations, the laws and guidelines assigned to airports in regards to their operations, infrastructure and design are applied to this spaceport and aerospace terminal design.

**SPACEPORT AMERICA**

As discussed previously, the few commercial spaceports presently being planned are strictly for the purpose of space tourism. Nonetheless, these spaceports offer plenty of information on the programming and design of spaceport terminal facilities.

![Figure 55: Spaceport America Site Plan (Foster + Partners)](http://www.fosterandpartners.com/Projects/1613/Default.aspx)

One example in particular, which has evolved the furthest with respect to its architectural design, is the inspiration for this thesis project. Spaceport America was conceived in the early 1990s by a group called the Southwest Space Task Force. Aware of the exciting discoveries in space flight technology, this group wanted to boost the already thriving space industry in New Mexico by building the first purpose-built commercial spaceport. They acquired a 27 square-mile piece of desert land, 45 miles north of Las Cruces, New Mexico to be the site of this inland spaceport. Currently in its schematic phase, the construction of the spaceport infrastructure and terminal facility is expected to be completed by the end of 2010.

In 2005, Sir Richard Branson announced that his space tourism company, Virgin Galactic, would make Spaceport America its world headquarters. Virgin Galactic aims to be the world’s first successful space tourism enterprise, and will be the first spaceliner operating out of Spaceport America. Aspiring to its CEO’s, Sir Richard Branson’s, desire to open space up to all people, Virgin Galactic will offer its customers a seat on one of their spaceship for a ride that’s out of this world. On these quick trips to the edge of space
and back, passengers will experience the power of a rocket hurling them through the atmosphere, the weightlessness of zero gravity, and the transcendent view of the Earth’s surface curving beneath them.

By 2006, Sir Norman Foster + Partners, in conjunction with URS Corporation and DMJM, were already working on designs for the spaceport (see Figures 55, 57-61). The initial concept of the spaceport was derived from the Virgin Galactic logo (Figure 56), where Sir Richard Branson’s eye became the form of the terminal building. From that, the design continued to evolve into what is now a grand symbol of space flight. Its form, scheme and structure all lend to the functional and metaphorical nature of the terminal.

“The sinuous shape of the building in the landscape and its interior spaces seek to capture the drama and mystery of space flight itself, articulating the thrill of space travel for the first space tourists” (Foster + Partners 2008). Craved out of the New Mexico desert, the circular terminal is sunken into the landscape not only to take advantage of the thermal mass for cooling, but to symbolize the bond humans have to mother Earth. The raised earth around the terminal protects it from the harsh New Mexico climate, while allowing the warm westerly winds to be pulled through the mass of earth and cooled to naturally ventilate the building. To add to the drama, the sculpted roof covering of the terminal building adulates as the desert surface, and from a distance seems to rise from it like the mountains beyond. The view of the terminal upon approach, prepares passengers for the excitement and mystery that awaits.
Passengers enter the terminal from the west by passing though a deep channel cut out of the landscape – its walls lined with historical information of the region and space flight. The passenger’s journey down to the terminal facility suggests a moving into the Earth, as if to protect and comfort the passengers before they are released out to the unknown and unfamiliar space. Schematically, the terminal is divided horizontally east and west and on two floors. The more private, sensitive areas, like the control rooms, are on the first floor of the west side, and have limited access and visibility. The public areas located on the second floor and east side of the terminal, are encased in glass that allow light from skylights to fill the terminal’s interior. Passengers and guests enter the terminal at the second floor on the west side. They are then taken across an air bridge, also encased in glass, over the super-sized spaceship hanger to east side of the terminal; suggesting a transition from Earth to space flight. This is similar to the transition that occurs in airline terminals when passengers move from landside to airside. The public viewing area, shown in Figure 58, lies at the end of the journey on the eastern most side of the terminal and offers a panoramic view of the runway and service deck through floor to ceiling glazing. This procession through the terminal is essential to the functional operations, but more it builds passenger excitement for space flight.
As the first to introduce personal space flight technology to the people, Virgin Galactic plans to immerse its passengers in the astronaut experience. These activities, besides ensuring passenger safety, health and comfortable, will allow them to get the most out of their trip by preparing them for the new sensations they will encounter. During the four days prior to flight, passengers will go through zero-g training, flight simulations, mission planning, spacesuit fitting, and medical examinations. In order to accommodate for these activities, the Spaceport America terminal is designed around this passenger experience, ergo it includes the physical spaces needed for these activities. In addition to the typical public spaces – lobbies, lounges, viewing gallery and restrooms – other passenger specific spaces are included, such as training classrooms, crew meeting rooms, dressing rooms, and simulation rooms. Even a cafeteria is included for passengers who will likely spend all day in the terminal during training. Since few passengers will be on these space flights, the experience will be rather intimate. For this reason, the spaces designated for the passengers are relatively small to encourage communication, fellowship and celebration. The public areas occupy approximately 18,000 square feet.
The other spaces within the terminal account for the administration offices, staff areas, service areas, and indoor hanger facilities large enough to fit two completely assembled spaceships (see Figure 59). Overall, the entire terminal facility is approximately 100,000 square feet.

![Figure 60: Spaceport America Interior Plan Section (Foster + Partners)](http://www.architectsjournal.co.uk/images/spaceport_fromabove_tcm23-1874723.jpg)

Finally, the sustainable construction methods and architectural details express the functional and metaphorical nature of the terminal best. Some of the construction details that have already been mentioned in the previous paragraphs are reiterated here, such as the ventilation technique. As mentioned before, the terminal building lies in a dug out section of the desert floor with an earth berm along the west side. As a passive cooling method, wind captured on the west side of the berm is drawn through channels embedded in the earth and subsequently cooled before it enters the building. Vents placed at the upper edges of the terminal draw the cool air in from these channels and expel warm air by convection. Under floor radiant cooling and heating is included to manage the temperature within the terminal during extreme weather. Passive day-lighting is also incorporated through skylights in the ceiling. Internally, the floor to ceiling glazing allows sunlight to reach down into the remote portions of the hanger. The roof itself is made of thin shell concrete that acts as a thermal mass trapping heat during the day and releasing it at night when the temperature drops. The smooth surface also releases heat as wind passes across it during breezy days. Photovoltaic solar panels are attached to the roof for added energy conservation. And finally, local material and construction techniques top off the sustainable features of the terminal. Figure 60 illustrates the various sustainable techniques proposed in the terminal design that give it a LEEDs Platinum accreditation. By simply incorporating these environmental friendly features
into the terminal design, the relationship of the terminal and its inhabitants to the Earth is reinforced.

**Figure 61: Sustainable Design Techniques**
(http://www.fosterandpartners.com/Projects/1613/Default.asp)

**Figure 62: Exploded Axonometric of Spaceport America (Foster + Partners)**
(http://www.fosterandpartners.com/Projects/1613/Default.asp)

**SPACE FLIGHT TRAINING: NASTAR CENTER**

Astronaut or not, all humans going into space on either orbital or suborbital vehicles will need some sort of training. The experience is so unlike anything on Earth, both physiologically and psychologically, that preparation is critical, not only for the safe and comfort of the passenger, but for their overall enjoyment.

An exact training program for such flights is something the industry has not yet standardized, though some have speculated what types of training might be required. Based on experience and the sensations the pilots underwent during test flights of their spaceships, Virgin Galactic has already devised a training program for its first passengers. This training will eventually be conducted within the Spaceport America terminal, however, until the spaceport is built the training is being provided by the Nastar Center in Philadelphia.

The Nastar Center specializes in training astronauts and air force pilots for the extreme sensations they experience during flight. When Virgin Galactic approached them about training their passengers, the Nastar Center group created a space flight training
course designed specifically to prepare their passengers for suborbital space flight. Knowing the physiological and psychological stresses the human body undergoes during space flight, such as g-force pressure, weightlessness, and disorientation, a training course involving simulator equipment and classroom instruction was established.

The equipment at the Nastar Center used for space flight training test human tolerances under various conditions. These conditions do not occur naturally on Earth, so they must be artificially created by various machines. Each training simulator is specially designed to induce certain sensations. The physical motion of the equipment combined with the visual display simulates the various conditions and situations that would be encountered during space flight. A few of these simulators are shown in the figures below. The spatial disorientation trainer (Figure 62), for instance, tests a person’s ability to remain conscious, relaxed and functional while being flipped around in multiple directions. These interactive simulators are programmed with flight exercises that trainees respond to during the test, while instructors monitor their vital signs and observe their reactions on a video screen. Another simulator, the hypobaric chamber (Figure 63), prepares passengers for emergency situations where a change in air pressure occurs. It involves pressure breathing exercises, use of oxygen equipment, and rapid decompression emergency procedures. This is slightly more involved than the pre-flight instructions passengers receive on airline flights due to the heighten risks of space flight.

![Figure 63: NASTAR Advanced Spatial Disorientation Trainer (ASDT)](http://www.nastarcenter.com/)

![Figure 64: NASTAR Hypobaric Chamber](http://www.nastarcenter.com/)
One of the most effective pieces of training equipment is the centrifuge (Figure 64). The high-g centrifuge is used to test g-force reaction. G-force is a measure of an object’s acceleration due to gravity. It is equal to the reaction force an object experiences as a result of this acceleration plus gravity. Positive gees produce the feeling of heaviness perceived by the body when rapidly accelerated upward during lift-off or vertical climb; similar to the feeling experienced when moving upward on a roller coaster. Negative gees produce the sensation of weightlessness when the body is accelerated down towards the center of gravity. Negative gees can only be achieved near a body of gravity, such as the Earth, which has a positive g-force of 1. Hence, a g-force above +1 must be maintained to escape Earth’s atmosphere. A centrifuge tests a person’s g-tolerance, which various tremendously depending on magnitude, direction, duration, location, body posture, health, and body type. Passengers on Virgin Galactic flights would need to be able to tolerate +3.5Gz (head to toe) on vertical climb and +6Gx (front to back) on reentry.

The centrifuge at the Nastar Center has a 25 foot arm capable of rotating at a speed necessary to simulate a maximum of 15G. The gondola at the end of the arm can itself rotate 360 degrees along two axes in order to simulate different body postures. Completely enclosed within the gondola, the participant sits in front of a simulated cockpit where they are prompted to perform flight task operations. These tasks are intended to keep the mind stimulated and to test whether the person can function under the physical and mental distress of g-forces. Of course, passengers would never have to perform such tasks during actual flight, but it helps to have some distraction from the physiological discomfort of g-force.
Outside Earth’s gravity field, the vacuum of space has a g-force of zero, which produces an actual weightless effect on objects. Virgin Galactic passengers will only experience 3-5 minutes of actual weightlessness during their space tours. First time floaters aren’t so graceful, so passengers will be shown various maneuvers, such as how to perform a zero-g somersault and move about the cabin, that will enhance their experience during this weightless period. Explanations of what others have experienced in zero-g, will also help prepare the passengers for their trip. This type of classroom instruction is included in the Virgin Galactic training as a way to ensure passengers get the most out of their trip to space.

The benefit of using simulators for space flight training is that if something goes wrong the test can be terminated immediately and any medical attention can be administer on the spot. Therefore, any training center, like the Nastar Center, or spaceport, like Spaceport America, that conducts space flight training on site, should be equipped to handle any medical emergencies that might occur. Space within the terminal should be allocated appropriately for the various training stations and medical facilities. The Nastar Center incorporates all of these major training stations with the necessary medical equipment to function safely. The 20,000 square foot facility is divided into thirds. The first third includes two classrooms, administration and staff offices, a meeting room and a lobby. The second third is a single training bay that houses a variety of training equipment including, among others, the altitude chamber, ASDT, gyrolab and training theater. The final third contains the human centrifuge, control room, observation area, VIP area, offices, medical station, research labs and a conference room. The facility is laid out so that multiple stations can be run simultaneously.
The program is basically a detailed description of the project in terms of architecture. It explains the reason for the project, the plan for designing the project, and the scope and extent of the project.

**Design Problem**

There is a call for change in the world of transportation that stems from a socio-economic need for faster, more efficient transportation, and an environmental need for energy conservative solutions in space travel. The technologies being developed today in the realm of personal and commercial space flight will very likely be the change that revolutionizes transportation. With space flight research and development on the rise, there is no time to waste in designing a facility capable of handing a commercial space travel enterprise. Fifty years from now, a commercial spaceport that operates much like an airport will be required to bring this technology to the masses. Certainly, no existing spaceport is equipped to handle the number of people who will want to participate in space travel once it is proven to be safe. According to Futron’s 2001 space tourism market study “by 2021, over 15,000 passengers could be flying annually,” and some 60 passengers could be on orbital space flights. (Beard and Starzyk 2002, 2-3). This isn’t much compared to the airline industry, but the prospect of suborbital point-to-point service could up those numbers drastically by 2060. At this point, no spaceports, current or proposed, are intending to offer space travel as an alternative to air travel; nor are any spaceports planning to commercialize space travel to the extent envisioned in this project. Because this technology is developing so quickly, there is an urgent need for planners and architects to begin preparing for this new transportation era by developing strategies
for handling the business of space travel in the form of commercial spaceports. The time to begin planning for this transportation revolution is now.

**Design Plan**

The design plan for this thesis project involves first developing a masterplan of a spaceport that supports a variety of aircraft and spacecraft; is multi-modal; is flexible and expandable; has a clear geometric order; and, functions efficiently. Aside from the basic components and infrastructure, these are the most important attributes drawn from the research that are integrated into the spaceport masterplan. Before beginning the master planning process, however, a location for the spaceport has to be selected. Then the infrastructure can be organized and the spaceport components arranged on the site.

Once the general layout of the spaceport is completed, the location of the aerospace terminal is determined. For a commercial spaceport to be successful in the future, it must function efficiently and safely, while presenting this new technology to the public in an appropriate manner. The venue suitable for introducing space travel to the public is an aerospace terminal. Similar to an airline terminal, which connects passengers to aircraft, an aerospace terminal connects passengers to orbital and suborbital spacecraft. The aerospace terminal is the central focus of the design portion of the project. The design of the aerospace terminal is one that specifically caters to intercontinental and orbital travelers; has clear, legible circulation; organizes passengers efficiently; is spatially flexible; balances function with dramatic expression; creates a sense of place; educates, entertains; provides a safe, comfortable environment; and, expresses its identity through architecture that is monumental and iconic. These objectives combine the basic principles of good airport terminal design with the desired qualities anticipated for a space travel terminal.

**Program Components and Spaces**

Prior to beginning the design of the spaceport masterplan or the aerospace terminal, a program had to be created that defined the components and spaces necessary to meet
these objectives and successfully achieve an efficient design. This program outlines the scope and extent of the design project as envisioned.

**SPACEPORT MASTERPLAN COMPONENTS**

As discussed previously, for a commercial spaceport to be efficient it must be multi-modal and act as a transportation hub. In doing so, it will allow people to commute from the surrounding urban community by train, bus or car, as well as throughout the region, around the world, and into space via airplane, spaceplane or spacecraft. Therefore, a spaceport would consist of the typical airport components, such as parking garages, service hangers, fire station, control tower, and airline terminal facilities; some atypical facilities, such as a train station, a hotel or museum; plus facilities specific to space flight, such as loading pods, longer runways and special aerospace terminal facilities.

**Components of the spaceport masterplan:**

2 three mile long runways for spaceplane and spacecraft operations - this length is an estimate based on the needs of future spacecraft
1 two mile long runway for airplane operations – average runway length on U.S. airports
Multiple taxiways/taxilanes
Airline terminal facilities: 3 domestic terminals with 44 gates each totaling 132 gates 2 international terminals with 25 gates each totaling 50 gates
Fire station
Control tower for local air traffic monitoring
Control room for space traffic monitoring
Area for fuel storage tanks
Area for service hangers
Area for warehouses
Security booths at entrances to airport property
Hotel/Conference facility
Parking garages/ lots for passengers, spaceport visitors, hotel guests, employees and the general public
Rail line and stations
Property Line Fence
Industrial, commercial and residential zones
Public roads to access the drop-off and pick-up areas of the terminals
Service roads for employees and delivery/service vehicles to access terminals
Access roads for airport authorities and emergency vehicles to access the runways

<table>
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<th>Number of Gates at Top Six U.S. Airports</th>
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<tr>
<td><strong>Airport Name</strong></td>
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<tr>
<td>Hartsfield-Jackson Atlanta Int’l Airport</td>
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<tr>
<td>Chicago O’hara Int’l Airport</td>
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<tr>
<td>Dallas-Ft. Worth</td>
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<tr>
<td>Los Angeles Int’l Airport</td>
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<tr>
<td>Denver Int’l Airport</td>
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<tr>
<td>JFK Int’l Airport in New York</td>
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Table 2: Airport Gate Statistics as of 2008

AEROSPACE TERMINAL SPACES

The spaces within the aerospace terminal building are determined by the functional activities taking place within it. These activities are either required by the greater function of space flight, or proposed as marketable amenities and attractions. The space allocations for the various terminal functions were carefully determined using the FAA Advisory Circular No. 150/5360-13 Planning and Design Guidelines for Airport Terminal Facilities with the assistance of Mr. Howard Klein, Airport Planner for URS in Tampa (and thesis committee member). First, a forecast for the number of passengers was calculated for the different terminals. Then those estimates were used to calculate the square footage of the program spaces within the aerospace terminal.

Programs Spaces for the Aerospace Terminal based on approximately 2 million enplanements per year and 20 gate stands: (SF = Square Feet, LF=Linear Feet)

- Ticketing Lobby incl. Counter Length, Queuing and Lateral Circulation ~7,000 SF
- Ticket Counters Frontage ~130 LF
- Ticketing Offices ~2,750 SF
- Waiting Lobby ~2,570 SF
- Concourse (Effective Corridor Width) 24-36 LF
Security Station (2 incl. weapon check & x-ray at 600 SF per station) ~1,200 SF
Departure Lounges (675 SF for Spacecraft, 1,500-2,000 SF for Spaceplanes) ~25,875 SF
Jetties
Gates: 5 for orbital spacecraft seating up to 10
15 for sub-orbital spaceplanes seating 150
Service Aprons and Stand Positions 20
Immigration/Passport Control Area (INS) ~4,770 SF
Public Health Services ~910 SF
Customs (USCS) ~4,710 SF
Animal & Plant Health Inspection Service (APHIS) ~2,260 SF
Baggage Claim (2 Oval Devices at 100 LF, 200 LF of Frontage) ~6,286 SF
Airline Operations Offices ~3,753 SF
Airport Management Offices ~2,800 SF
Airport Security/Police ~10,000 SF
Truck Service Docks
Building Maintenance & Utilities Areas ~1,900 SF
Storages Rooms ~500 SF
Dressing Rooms for Orbital Travelers ~256 SF
Food Services ~28,000 SF
Coffee Shops 35-40 SF/coffee shop seat ~14,000 SF
Snack kiosk 15-25% of coffee shop space ~6,500 SF
Bar Lounges 25-30% of coffee shop space ~7,500 SF
Retail Shops ~14,415 SF
News & Tobacco (min. 150 SF, 600-700/million enplanements) ~1,424 SF
Gift Shops (min. 150 SF, 600-700/million enplanements) ~1,424 SF
Drug Store (min. 700 SF, 600-700/million enplanements) ~1,424 SF
Barber Shop/Shoe Shine (150 SF/chair) ~244 SF
Auto Rental Counters (350-400 SF/million enplanement) ~814 SF
Flower Shop ~400 SF
Displays (min. 50 SF, 90-100 SF/million enplanements) ~203 SF
Insurance Counter/Machines (min. 50 SF, 150-175 SF/million enplanements) ~356 SF
Public Lockers (70-80 SF/millions enplanements) ~163 SF
Public Telephones (100-110/millions enplanements) ~224 SF
Automated Post Office ~125 SF
Vending Machines (min. 50 SF, 150 SF/millions enplanements) ~305 SF
Toilets (1800 SF/500 peak hour enplanements) ~6,168 SF
USO/Travelers Aid ~203 SF
Nursery (with private toilet) ~122 SF
Transportation Museum ~10,000 SF
Space Science Museum ~10,000 SF
Theater ~1,500 SF
Simulation Ride Room 300 SF x 2 ~600 SF
Observation Deck/Viewing Undefined
Training Center Lobby/Reception Area ~400 SF
Classrooms 300 SF x 2 ~600 SF
Meeting Room ~400 SF
Centrifuge Room incl. Control Room, Observation Room (35 ft radius) ~5,148 SF
Disorientation Room & Control Room (20 ft radius) ~1,757 SF
Hyperbaric Altitude Chamber & Control ~800 SF
Medical Center: Lobby, Reception, Offices, Break Room, Exam Rooms ~1,560 SF
Control Room ~20,000 SF
Control Tower ~8,400 SF

**Total Gross SF** 240,508 SF
Building Mechanical (3% of total gross area) 7,215 SF
Circulation (Corridors, Stairs, Elevators, etc. 30% of total gross area) 74,317 SF
Building Structure (5% of total gross area) 16,102SF

**Total Gross SF** 338,143 SF
**Gross SF Per Passenger** 197 SF
As a precedent for commercial spaceport design, it is important to consider all the factors that contribute to and effect the overall spaceport operations. Of these factors, the most critical one and also the first to be determined, “is where the initial spaceport facilities will be located.” Foremost, the site location must reinforce the efficiency aspect of space travel. “A primary goal of [point-to-point/suborbital] transportation is to significantly reduce the amount of time that it takes cargo and passengers to reach long distance destinations” (Davis 2008, 65). Efficiency is the number one benefit of space travel, so a spaceport must reinforce this concept in its design and location.

**SITE CRITERIA**

Selecting a site for the spaceport involved first researching the basic design standards and guidelines for an airport. It was determined in a previous section that because there are no such guidelines to date for spaceports, and since this spaceport will offer air travel as well as space travel, using the Federal Aviation Administration airport guidelines was the logical place to start. In addition to these standards, other factors generated out of the speculations made for the project were also applied. From this information, a set of prioritized criteria were formulated and each potential site evaluated accordingly. The following list defines the ten criteria.

Prioritized Site Criteria:

1. **Target User Base:** Since this project centers on providing a more efficient method of transportation to the public, the spaceport should be located near an area where those users who will benefit the most are located. According to the aerotropolis research, those that rely heavily on transportation are distribution
companies and those frequent travelers involved in world commerce. Although there will be the occasional vacationer participating in space travel, the target market for this type of travel would be individuals and companies involved in world commerce or orbital enterprises. Therefore, the majority of customers would be business men and women taking suborbital point-to-point flights, or researchers and engineers bound for orbit. As the number one driver, this criterion indicates a spaceport location near an existing business center – a metropolitan area where the business population can take advantage of the reduced travel time that suborbital flight offers. The anchor city, outside of which the spaceport would be located, should be one that will benefit from an additional transportation hub to service the area. In other words, the existing airport serving the anchor city is at maximum capacity, and would welcome the additional air travel service of the spaceport to the area.

2. Population Density: The population of the service area, including the entire metropolitan area, should be enough to sustain the spaceport’s operations, both the transportation and entertainment related operations. The spaceport will also need to employ a large number of workers, with a variety of skills, and will therefore need a large labor pool from which to draw. This condition implies a site located near a city with a metro population in the millions.

3. Latitude: According to various space travel sources, orbital travel is most efficient along an equatorial path. The closer the launch site is to the equator, the less atmosphere must be penetrated for a spacecraft to reach orbit. It is for this reason that the NASA launch facility is located in Florida. For a U.S. based commercial spaceport providing regular scheduled trips to orbit, a site located in the southern region of the country is best.

4. Climate: Climate can severely hamper the operations of a launch facility. Airports are often closed, or flights delayed, due to bad weather conditions. So, the general climate of the selected site area should not be too harsh, especially in terms of wind. Wind is an important factor in the launching of space vehicles, as well as the take off and landing of aircraft. Runways are generally aligned in
the direction of the prevailing wind. Therefore, data must be collected to
determine its direction and the direction of any crosswinds that may exist.
Crosswinds require more land for additional runways, so a site location that has
unidirectional wind is better than a site with constant wind changes. In places
where it snows, additional facilities and services are required to clear runways
and maintain operations, which can be costly. Thus, to reduce the cost of the
building infrastructure and minimize complications during operation, a location
with a rather temperate climate and calm, steady winds is best for a spaceport.

5. Access: Just like airports, access to and from the spaceport is just as important
to the efficiency of the transportation system as the spaceplanes. Direct access
to major roadways, rail lines and tramways is necessary for a facility of this scale to function. Passengers should be able to utilize a variety of transportation means, to get to and around the spaceport. The spaceport should also be linked to the anchor city in such a way as to reduce congestion and allow faster connections. This calls for the site to be located within reasonable driving distance to the anchor city center. The site should also have access to an existing rail line, so high speed trains can be implemented as another means of connecting to the city. If possible, tram or subway routes should connect to the site as well. In this way, the spaceport becomes a multi-modal facility – an attribute that is extremely important to its overall efficiency.

6. Expansion Area: The trends described in the aerotropolis research suggest that a transportation nexus, such as a spaceport, would draw urban development to its perimeter. It is even possible to have designated areas of development within the spaceport property, such as business districts, residential parks, shopping areas and industrial/manufacturing zones. For this type of development to occur though, the site must be located in a sparsely populate area where the potential for growth is possible, and within proximity to the anchor city for all the reasons mentioned in 1, 2 and 5 above. The site should also encompass an area large enough for the spaceport to expand and urban development to fill in around it.

“Cities are always shaped by the state-of-the-art transportation devices present
at the time of their founding,’ observes Joel Garreau, author of Edge City…
Because of the airport [and the internet], it’s possible to imagine a world capital
in a place that was once an absolute backwater” (Lindsay 2006, 80). Therefore, a
vacant stretch of land in the middle of nowhere that meets all the previous
criteria would be perfect.

7. Site Area: Aside from being large enough to accommodate for growth, the
initial site area for the spaceport alone needs to be sufficiently long to
accommodate runway lengths at least three miles (15,840 feet) in two
directions; the direction of the prevailing wind and the crosswind. The FAA
guidelines recommend that the length should provide for the longest runway
needed for the largest/heaviest craft to take off and land, plus some extra for
safety. Depending on the direction of the wind(s), multiple runways may be
required in more than one direction. Given the assumption that vertical launch
vehicles will improve in safety and reliability, does not eliminate the required
safety buffer needed around the launch pads. Therefore, space should be allotted
for them if they are included.

8. Environmental Impact: All airport designers must submit an environmental
impact report to the Federal Aviation Administration for approval. Because of
their size and function, airports damage the environment on a much greater
scale than most structures. Such impacts include: water and air pollution,
ecosystem disturbances, noise, traffic, and cultural impacts. The goal of the
impact report is to show how the area might be disrupted and what mitigation
techniques will be implemented to limit the impact. In the real world, outside
the scope of this thesis project, a spaceport designer would likely have to deal
with the same sorts of impact mitigation and submit a similar report. The
selected site can greatly reduce how much the designer must content with in
terms of initial impact. The selected site would be evaluated in terms of
potential environmental impacts to the natural land and surrounding
neighborhoods. Completing an environmental impact report would involve
market research, traffic surveying, soil testing, ground water surveying,
ecological studies, pollution generation testing, cultural studies, etc. Without getting bogged down with this research, the scope of this project will include locating a site with as few superficial environmental factors with which to deal.

9. **Airspace:** Airspace is the volume of air through which air borne device fly. Airspace is divided into classes (A,B,C,D,E, & G) that define its vertical range, shape, and type (controlled and non-controlled). Typically, commercial airliners operate in controlled Class E airspace during flight. At landing and takeoff, however, airplanes pass through another class of airspace that revolves around the airport. Airports are assigned a class of airspace based on their size, instrument capability, traffic and purpose. Large commercial airports are generally assigned Class B controlled airspace. The controlled volume of airspace extends out for about 30 miles from some central point at the airport, and up to 18,000 feet, forming an upside-down cake like shape in the air (see Figure 65). The traffic control is responsible for controlling any and all fly objects inside its airspace. A spaceport would have a similar type of controlled airspace that would extend even higher for space vehicle operations (see Figure 32). To avoid conflicts and disruptions to the airspace of existing airports, the spaceport site should not be located within any airport’s 30 mile Class B airspace. Overlapping of airspace is permitted, but complicating the airspace too much or crowding the airspace should be avoided.

![Figure 66: Airspace Diagram](http://www.ultraflightradio.com/segmenthelpgraphics/AirspaceUFR.gif)

10. **Topography:** The topography of the site is important for the layout of the general infrastructure of the spaceport. Runways need to be fairly level for take off and landing. The FAA specifies approximately 2% maximum grade differential across the length of a runway. Minor leveling of the site by moving earth can be done, but only in cases where it is cost effective. The FAA
guidelines also state that runway lengths need to increase 10 feet for every foot of slope off dead level. (For instance, a three mile long runway with a 1% slope has a slope differential of 158.4 feet across its length, and therefore would need an additional 1584 feet making the total runway length 17,424 feet or 3.3 miles). So, the land of the site should be as close to flat as possible. The runway strength is also important to the take off and land of aircraft and spacecraft. The shear weight of an aircraft must be supported by the soil beneath the runways and taxiways; not to mention the impact force of landing an aircraft. The ability to add soil and compact it allows for some flexibility in site selection, but a site with solid, compact soil is preferred. Though no soil composition tests or research has been done for this project, the criterion for a flat site is observed.

Clearly, the city or cities near where the spaceport would be located is extremely important, as the first four of these criteria pertain to the selection of an anchor city; whereas the last six concern the physical site area of the spaceport. Therefore, selection of the anchor city is first in the task.

SITE ANALYSIS

The site analysis process began with determining which U.S. cities have an adequate target user base (criteria 1). First, an internet search was performed for the top business centers in the United States. The list below was compiled from the 2008 Mastercard Worldwide Centers of Commerce Index posted on their website:

Top 10 Business Centers in the United States according to the 2008 Index:

1. New York – 2\textsuperscript{nd} in the world
2. Chicago – 5\textsuperscript{th} in the world
3. Los Angeles – 17\textsuperscript{th} in the world
4. Philadelphia – 18\textsuperscript{th} in the world
5. Boston – 21\textsuperscript{st} in the world
6. Atlanta – 25\textsuperscript{th} in the world
7. San Francisco – 28\textsuperscript{th} in the world
8. Miami – 29th in the world

9. Houston – 34th in the world

10. Dallas – 35th in the world

Then, a second internet search was performed for the busiest airports in the United States. This list of Busiest U.S. Airports for 2007 was taken from the Federal Aviation Administration website: [http://www.faa.gov/news/updates/busiest_airports/]

Top 10 Busiest Airports in the United States in 2007 (by passengers count):

1. Hartsfield-Jackson Atlanta Int’l (ATL), GA
2. Chicago/O’Hare Int’l (ORD), IL
3. Dallas/Ft. Worth Int’l (DFW), TX
4. Los Angeles International (LAX), CA
5. Denver International (DEN), CO
6. Las Vegas/Mc Carran Int’l. (LAS), NV
7. Houston/G. Bush Intercont’l. (IAH), TX
8. Phoenix Sky Harbor Int’l. (PHX), AZ
9. Charlotte/Douglas Int’l. (CLT), NC
10. Philadelphia International (PHL), PA

The cities that appear on both these list were evaluated as possible anchor cities: Atlanta, GA, Dallas, TX, Los Angeles, CA, Houston, TX, and Philadelphia, PA. Philadelphia was immediately eliminated by criterions 3 and 4, due to its northern latitude and harsh winter weather. Each of the other four cities was analyzed and evaluated based on the rest of the criteria. Though their populations, latitudes, and climates fit the bill, both Los Angeles and Houston failed at criterion 1 and 5. These cities are so dense and sprawled out that no piece of land large enough could be found within close enough proximity to their business centers to efficiently serve the target market users. Only Atlanta and Dallas/Ft. Worth had vacant land, or nearly vacant land, that met this and most of the other criteria.

After narrowing the site options down to two anchor city locations, each area was compared and examined in Google Earth to find suitable plots of land that met the criteria. Multiple sites were reviewed around the Atlanta and Dallas areas. The best three
of these sites were then analyzed thoroughly according to the ten criteria. A variety of data was collected through the internet and used in this analysis including: area maps, climate charts, population statistics, windrose charts, topographical maps, soil maps, and airspace charts.

The following is the analysis of the respective cities and the data gathered on the three best sites based on the ten criteria:
Figure 69: Atlanta Population Density (from Google Maps)
Density of the City: 3,939 per Sq. Ft.

Figure 70: Dallas-Ft. Worth Population Density (from Google Maps)
City Population 2007: 1,232,940 Metro Population: 6,145,037, 2.5% Increase Since 2006
Density of the City: 3,605 per Sq. Ft.
Figure 71: Atlanta Global Coordinates (map from Google Earth)

Figure 72: Dallas-Ft. Worth Global Coordinates (map from Google Earth)
Figure 73: Atlanta Windrose Diagram
(http://home.pes.com/windroses/)
Prevailing Winds from the East and West with a Crosswind from the Northwest

Figure 74: Dallas-Ft. Worth Windrose Diagram
(http://home.pes.com/windroses/)
Strong Prevailing Wind from the South
Figure 75: Atlanta, GA Average Temperature
(http://www.rssweather.com/climate/Georgia/Atlanta/temp.png)
Coldest Month: January, Average Low of 33.5 F
Warmest Month: July, Average High 89.4 F
Mean Daily Average Temperature is 72 F

Figure 76: Dallas-Ft. Worth, TX Average Temperature
(http://www.rssweather.com/climate/Texas/Dallas-Fort%20Worth/temp.png)
Coldest Month: January, Average Low of 34 F
Warmest Month: July, Average High 95.4 F
Mean Daily Average Temperature is 76.3 F
Figure 77: Atlanta Site 1 Access Routes (map from Google Earth)
35 Miles to Downtown Atlanta
I-75 Borders the West Edge of the Site
Railroad Line Crosses to the North

Figure 78: Dallas-Ft. Worth Site 2 Access Routes (map from Google Earth)
36 Miles to Downtown Dallas, 32 Miles to Ft. Worth
I-35E & I-35W Junction at the Northeast Corner of the Site
Railroad Line Along the East Side

Figure 79: Dallas-Ft. Worth Site 3 Access Routes (map from Google Earth)
27 Miles to Downtown Dallas, 25 Miles to Ft. Worth
I-35W to the South, Hwy 287/Hwy 67 Junction to the North
Railroad Junction at the South Corner
Figure 80: Atlanta Site 1 Expansion Areas (map from Google Earth)

Figure 81: Dallas-Ft. Worth Site 2 Expansion Areas (map from Google Earth)

Figure 82: Dallas-Ft. Worth Site 3 Expansion Areas (map from Google Earth)
Figure 83: Atlanta Site 1 Area (map from *Google Earth*)
East-West Length of Site: ~3.7 Miles or 19,530 Feet, Available Site Area: Approx. 7,345 Acres

Figure 84: Dallas-Ft. Worth Site 2 Area (map from *Google Earth*)
North-South Length of Site: ~4 Miles or 21,120 Feet, Available Site Area: Approx. 9,030 Acres

Figure 85: Dallas-Ft. Worth Site 3 Area (map from *Google Earth*)
North-South Length of Site: ~3.6 Miles or 19,430 Feet, Available Area: Approx. 6,000 Acres
Figure 86: Atlanta Site 1 Areas of Impact (map from Google Earth)
Small River Runs Through the Site
Sparse Residential On and Around the Site

Figure 87: Dallas-Ft. Worth Site 2 Areas of Impact (map from Google Earth)
Small River Runs Through the Site
Dense Residential Lies to the East of the Site

Figure 88: Dallas-Ft. Worth Site 3 Areas of Impact (map from Google Earth)
Two Small Rivers Run Through the Site
Sparse Residential On and Around the Site
Figure 89: Hartsfield-Jackson Atlanta Int'l Airport Airspace
Site 1 Lies Just Inside the 30 Nautical Mile Airspace Ring of ATL Airport

Figure 90: Dallas-Ft. Worth Int'l Airport Airspace
Site 2 Lies Well Within the 30 Nautical Mile Airspace Ring of DFW Airport

Figure 91: Dallas-Ft. Worth Int'l Airport Airspace
Site 3 Lies Within the 30 Nautical Mile Airspace Ring and Along the Flight Path of DFW Airport
Figure 92: Atlanta Site 1 Topography
Site Area: 7,345 Acres
MSL: 837 Feet
Site Differential: ~70 Feet

Figure 93: Dallas-Ft. Worth Site 2 Topography
Site Area: 9,030 Acres
MSL: 642 Feet
Site Differential: ~60 Feet

Figure 94: Dallas-Ft. Worth Site 3 Topography
Site Area: 6,000 Acres
MSL: 666 Feet
Site Differential: ~70 Feet
SITE SELECTION

The site selected for this thesis project is very important to the underlining concept of efficient transportation. Each of the three sites has advantages and disadvantages, and
could potentially be the site for a commercial spaceport in the future. However, for this commercial spaceport based on all the criteria set forth in this document, only one of these emerged as the most appropriate.

The Atlanta, Georgia Site 1 not only met all the criteria, but the culture of the area is familiar, which will help in the design process. Site 1 lies 30 miles south of downtown Atlanta along the Interstate-75 corridor half way between Atlanta and Macon in the southwest quadrant of the greater Atlanta metropolitan area. The population of Atlanta is growing exponentially, to the point that the city now presides over 140 cities and towns in 28 counties in Georgia. Atlanta is the capital of Georgia and considered the ninth largest metropolitan area in the United States. The Atlanta site 1 lies at the intersection of five of these counties, thereby allowing the cost and benefits of the new spaceport to be shared. Currently, the combined population of the five counties (Clayton, Fayette, Henry, Butts and Spalding) is 525,090. However, with the current rate of growth it is likely to greatly increase over the next few years. The population of Atlanta has thusfar spread as far north and east as the mountains and protected forests areas allow. Now, it is beginning to spread to the south and west of the city toward the site area. Residents are already moving into the areas around the site and new residential developments are being established.

![Figure 98: Hartsfield-Jackson Atlanta Airport Hub](http://www.barnabu.co.uk/wp-content/uploads/usa-air-routes-google-earth.JPG)

It has already been said that Atlanta is a major business commerce center, so there is no doubt that the business population is sufficient to support a spaceport. Atlanta is also home to the busiest airport in the United States. According to many sources the Hartsfield-Jackson Atlanta International Airport has already reach its capacity and can no
longer expand to accommodate the increasing demand. The spaceport could easily support the additional air travel demand needed for the metro area.

The winds in the Atlanta area blow most frequently from the east and west, therefore runways are typical laid along an east-west compass direction. This is good for take off and landing of spacecraft since their flight paths typical follow the rotation of the Earth. The cooler Atlanta temperature, compared to Dallas, is also beneficial to the take off and landing operations of aircraft.

![Site Location Map Showing Rings of Impact](image)

Figure 99: Site Location Map Showing Rings of Impact

As far as access to and from the spaceport, multiple roadways border around the site. Interstate 75 runs along the west edge of the site and Highway 23 crosses just to the north; both provide direct access to downtown Atlanta to the north and Macon to the south. Highway 16 runs along the south edge of the site and connects the spaceport to the smaller suburban towns and rural areas. There is also a railroad line that follows Highway 23 north into Atlanta and terminates downtown. It could easily be adapted to a light rail system that connects to the Atlanta MARTA system, and allows cargo to be move from the city to the spaceport and back. In addition, a high speed rail system could be implemented along the I-75 route that connects to the ATL airport and downtown Atlanta. The multimodal aspect is completely covered.

All three sites have plenty of space for expansion and growth, however, the Atlanta site seems to be more apt to grow into the area and utilize the space around the spaceport as intended by the aerotropolis model.
The size and shape of the land available for the spaceport is completely appropriate for the infrastructure and urban development to fill in around it. The extended three mile long runways can be positioned across the east-west length of the site leaving plenty of space to the north and south for other spaceport facilities. The only obstacles within the site area that are of concern are the 100 or so residences and a small river. The river is fairly easy to contend with as most infrastructure can span over it. Unfortunately, if some residences need to be moved for the benefit of a spaceport, so be it. Besides, many more residences will likely fill in the surround areas to take their place as the spaceport area grows.

Amongst the three best sites, the Atlanta site was the furthest away from the city’s existing airport, causing the least amount of airspace disruption. As mentioned previously, airspace can overlap as long as it doesn’t cause too much confusion. The Atlanta site airspace would indeed overlap with the Hartsfield-Jackson Atlanta Int’l Airport’s airspace, but the flight paths would be parallel and would therefore not cause that many issues.
DESIGN RESTRICTIONS & OPPORTUNITIES

All design projects have parameters either inherent in the site or supplied by an external source. Those parameters limit the scope and scale of the project allowing the designer to focus on the elements of the project that can be freely manipulated.

SITE LIMITATIONS

In addition to the government regulations described earlier, the site itself restricts the design of the spaceport. Those same qualities, mentioned in the Site Selection section, that are benefits of the site also serve as limitations to guide the design. These site limitations drive the design decisions made for the master planning of the spaceport, and also serve as context to which the design of the spaceport facilities can respond.

Being the most restrictive elements of the spaceport masterplan, the runways are the first to be placed on the site. The overall site area and shape, topology, prevailing wind direction, surrounding land uses, flight path obstacles and FAA regulations are the initial factors considered in determining the number and layout of runways. Once the runways are laid out, they, along with other factors, such as the size of the spaceport facilities (grounds and buildings), type and location of access roads, and location of rail lines, influence the placement of the other spaceport components.

The masterplan describing the arrangement of runways and other spaceport components is revealed in a later section.

SPACE VEHICLE DESIGN LIMITATIONS

The designs of the space vehicles operating out of the spaceport restrict the design freedom of the terminal facility. Just as Spaceport America is designed around Virgin Galactic’s Spaceshiptwo® vehicle, a spaceport in the future would be designed around
the spaceships used then. There is no way to know absolutely what commercial space vehicles might be like 50 years from now, but based on current models, several assumptions can be made about their designs. First, there will be both spacecraft designed to transport people and cargo to orbit, and spaceplanes used for suborbital point-to-point travel around the world. These vehicles will most likely look and function differently. An orbital spacecraft would be designed to withstand the constant exposure to radiation in space and the heat of reentry. An orbital vehicle would also be configured to dock with space stations, like the ISS, or space hotels. From the passenger’s point of view, a spacecraft would be a whole different experience. An orbital spacecraft would be smaller than the typical airplane and seat fewer passengers. Since spacecraft would have the ability to dock with space stations, the portal through which people and cargo pass might be smaller, possibly round, and on the top, bottom or rear of the vehicle rather than the side like an airplane. This would imply a different method of boarding and deboarding that would affect the design of the terminal and passenger interface.

A suborbital spaceplane, on the other hand, would likely be very similar to an airplane in shape, size, capacity, and point of entry. The method of boarding and deboarding would be the same as that of the typical airliner. The design of the terminal and interface would, therefore, resemble that of an airline terminal. These similarities would prove beneficial to the passenger processing efficiency of the suborbital operations, because passengers would already be familiar with the interface method.

Whatever the design of space vehicles, the terminal facility should support it while still being flexible to changes. The aerospace terminal design for this project is based on the assumptions mention above, though any future spaceport terminal would necessarily accommodate both types of space vehicles in order to maintain the efficient multi-modal quality of a spaceport.

**DESIGN OPPORTUNITIES: FORM, STRUCTURE, MATERIALS AND CHARACTER**

The aerospace terminal form, structure, materials, and design characteristics combine to make up the final design. Each of these design opportunities should be explored to arrive at a suitable solution. The initial form of the building is the first step in designing
the aerospace terminal facility. As mentioned earlier, the form of the building should be monumental and iconic so that passersby will recognize and remember the building. First impressions are the grandest and most important. Along with the form, the structure is the next most expressive element of architecture. The development of the structure, whether it is hidden or exposed, and its design can greatly influence the perception of the space, as in Kansai International Airport, where the heavy beams anchored the space to earth and the light, thin beams seem to lift the space. Materiality is another design feature that makes a space. Information gathered about commonly used materials in space bound structures, such as the International Space Station, airports, conceptual spaceport designs, and other space related architecture can provide inspiration for the design of the aerospace terminal. The spaces created by the combination of form, structure, and materials give the space its character and sense of place. The idea would be to create a futuristic perception of space by bringing the sensations of space flight, in terms of visual and textural experience, into the design of the aerospace terminal. By having these elements reflect the passenger experience, the entire building becomes a standing advertisement of its function; not in a tacky way, but a subtle way that provides an entertaining and comfortable atmosphere for the passengers.

**TIME RESTRICTIONS**

Unfortunately, the time allotted for completing this thesis project restricts the extent to which these design elements can be explored. Therefore, there will be a narrowing the focus to that which can be accomplished with the intent that further research and development will occur in the future.
SUMMARY OF INTENT

TRANSFORMATION OF RESEARCH INTO A DESIGN

The goal of this master’s project is to transform the research into (a) a masterplan of a new spaceport with its supporting urban environment and (b) a design of an aerospace terminal, which includes its adjoining hotel and parking garages. A spaceport that responds to the needs of the community and demonstrates its ability to engage the urban fabric provides the context within which an aerospace terminal is designed. Considering the design opportunities and restrictions, the focus of the design is on the form of the terminal facilities, and the program and structure of the terminal. The character of the main concourse is also looked at in closer detail, rounding out this research project, taking it from the master planning scale to the spatial scale. As a precedent, along with the supporting research, this project is meant to open the door to further research and development in the fields of commercial spaceport planning and terminal design.

Figure 100: Diagram of the Spaceshiptwo Flight Path
(http://www.virgingalactic.com/multimedia/album/graphics-and-illustrations/)
INITIAL DESIGN IDEAS

After contemplating the research, determining the program and deciding a plan of action, the design development phase began. The initial ideas at the forefront of the process were based on assumptions made earlier in the Vision of the Future section: that there would only be a handful of spaceports around the world; that space flight would be commonplace and therefore, spaceports would be the new transportation hub; that the aerospace terminal would be unique in appearance and function because it serves additional functions other than just flight interface; and, that the passenger experience through the aerospace terminal would be different. Starting with these initial ideas and design began to form.

MASTERPLAN DEVELOPMENT

The first conceptual design that came to mind, before any research, was a masterplan of a spaceport (see Figure 101) with the main terminal in the center, long arms curling out from the center forming the airside concourses, and a circular building stretching out from the middle to form the aerospace terminal. The roadways (shown in green) would circulate in front of the main terminal and around two parking garages. As a basic concept it seemed efficient in its layout and put the aerospace terminal in the center of the spaceport giving it prominence. All of the components were there, however, it did not consider the spatial requirements of the program, which was developed later. It was a good beginning to the masterplan though.
Other diagrams, like the basic section through a terminal and the section through the circulation corridor (Figures 102-104) were made during the research as a study of the spaceport components. These were used to flush out how the spaceport components connected and related to one another.
Once the site was selected and the runways laid out, the location of the spaceport facilities was determined. The quantity of land available around the runways suggested three sites for the spaceport (shown in Figure 105). All three sites had plenty of room for the spaceport facilities, but site 3 made the most sense. Site 3 was the closest to the intersection of two major roadways, Interstate-75 and Highway 25, and allowed the spaceport to stretch out along the length of the runway. This aspect was good because of its expansion capabilities and its direct connection to the runways.
The land area of site 3, shown in red, encompasses approximately 3,360 acres. This is plenty of land for all the spaceport facilities, runways, and the accompanying urban infrastructure needed to support the spaceport.

Figure 106: Site 3 Area

After site 3 was chosen for the spaceport to reside, masterplan concepts were explored. The two masterplan concept diagrams (Figures 107 & 108) show the runways in green, the existing roadways in orange, and the spaceport facilities in purple. The aerospace terminal being the focal point of the spaceport it is shown as a star. Masterplan concept diagram 1 evolved from the initial concept diagram and shows the aerospace terminal in the center of the plan. Masterplan concept diagram 2 shows the aerospace terminal at the far west end of the spaceport. This location for the aerospace terminal building would put it in a prominent position to be seen from the interstate and at a focal point of the spaceport. The uniqueness of the aerospace terminal suggests that is should be located where it can be seen as an icon of the spaceport. The second diagram allows for the most exposure of the aerospace terminal, so it was deemed the most appropriate to proceed forward.
Circulation is a major factor in designing an efficient spaceport, so to ensure that the circulation to and around the spaceport worked, several traffic flow diagrams were made and studied (see Figure 109). These diagrams show the terminals along the north edge with roadways on the south directing traffic flow. The red lines represent departure traffic
flow on the 3rd level, the green lines represent arrival traffic flow on the 2nd level, and the black lines represent ground level traffic flow. In the first and third diagrams, the traffic flows in one direction along the departure and arrival level with two-way traffic on the ground level. The second diagram shows two-way traffic on all levels. The one-way traffic flow is safer and more efficient when it come to picking up and dropping off passengers, because the cars can stop and remerge with traffic in line – no turns or u-turns necessary. Creating a one-way loop road allows vehicles to keep moving passed the terminals without having to stop and wait.

Figure 109: Spaceport Traffic Flow Study
The diagram below shows how the various circulation paths would relate and connect. The light rail train, shown in blue, coming from downtown Atlanta would make a loop passing the urban area to the south of the spaceport then run underneath the spaceport terminals. The vehicular roadways, in orange, would make overlapping loops. The secondary roads would connect perpendicular to the main spaceport access road loop. The main access loop road would pass in front of the terminal(s) and loop back around. These are not closed loop system, of course, there are cross roads that allow entry to and exit from the loop roads. The terminal(s) would have an internal tram system to transport passengers between terminals and parking structures. The passenger themselves would form a traffic loop pattern as departing passengers travel towards the gates and arriving passengers return. Each of these pathways connects to each other and creates a continuous movement in and around the spaceport.

From the concept of how the traffic needs to flow combined with the conceptual masterplan diagram, a clearer masterplan started to take form. The schematic masterplan diagram (Figures 111) shows how the spaceport components could be arranged and related to each other to create a holistic plan – a plan that is multi-model, ordered, expandable and most importantly efficient. The roadway grid aligns with the airline terminal facilities creating a repetitive angled pattern directed toward the aerospace terminal facilities at the west end of the scheme. Each terminal along the south side of the runways connects directly to the taxi lanes allowing for shorter time on the ground before
take off. Land surrounding the runways can be utilized for fuel storage, service hangers, transport company warehouses, etc., while still having land available for the spaceport to grow in the future. The land directly to the south and west of the spaceport facilities could be filled in with commercial, industrial and residential. Planning for this supporting infrastructure, as well as the spaceport facilities, is what the aerotropolis model proposes. If growth is planned for ahead of time it will not happen chaotically and the spaceport will run the most efficiently.

Figure 111: Schematic Spaceport Masterplan Diagram

The schematic masterplan and aerial view of the scheme below clarifies more accurately the size, shape and arrangement of the spaceport facilities and surrounding urban environment. A revised final spaceport masterplan is shown later. The next step, since the location of the aerospace terminal has been determined is to design the aerospace terminal.
Figure 112: Schematic Spaceport Masterplan

Figure 113: Aerial View of Spaceport Schematic Masterplan
AEROSPACE TERMINAL CONCEPTUAL DESIGN

At this time, the idea of space travel is for most still a fantastic dream. Most don’t even realize that the technology is already available, or that commercial space travel is right around the corner. To most, the concept of space travel brings to mind such images as the ones pictured below from Star Trek, Star Wars, video games, and television. As a culture, especially in America, we have been fascinated with space, space technology, aliens, etc., for years because it was a mystery – the last place to explore. So fascinated, in fact that the government set up an entire entity (NASA) tasked to go to space and study it. Of course, in that realm only a select few have been able to go into space. But now, on the verge of an aerospace revolution, it is very nearly possible that all will have the chance to at least to visit space. The concept of the aerospace terminal begins by using those dreams, those images of what we imagined as inspiration to design a terminal that makes that fantasy a reality.

For the aerospace terminal design to accomplish this grand task, while reaching the objectives set forth earlier – to have clear, legible circulation, organize passengers efficiently, be spatially flexible, balance function and dramatic expression, create a sense of place that is safe and comfortable, educate, entertain, and establish its identity by being monumental and iconic – certain concepts had to be explored. Though several of these objectives can be accomplished with the program, the architecture is used to reinforce the concept.

To be monumental and iconic, the aerospace terminal design had to stand out from the other spaceport facility and urban context. A hierarchy starting with the land, to the urban context, to the spaceport facility, to the aerospace terminal had to be easily recognized visually in plan and in section. The aerospace terminal being the largest, most expressive, unique building on the premises makes both an impression that the viewer can recall and helps orient those in the visual area. If it is tall enough to be seen for miles, then it can stand as a landmark as well. A diagram showing the concept of hierarchy is shown in Figure 115.
The circulation and organization of passenger is the most important feature of a terminal in general. Therefore, establishing the circulation in a unique manner was the goal. Somehow, relating the circulation within the terminal to the flight path of the spaceships travel as they fly around the planet and into space seemed like a good starting point. A couple very basic diagrams of the flight paths for orbit and sub-orbit craft are shown in Figure 117. With the earth as the shaded ball in the middle, the sub-orbital route...
takes off from point A, flies around the planet and lands at point B. The orbital flight takes off from point A, goes into the space, either flies around the planet or docks with a space station, and lands back at point A. This concept helped to set up a general path a passenger might take through the aerospace terminal. It also influenced the general form of the building.

Next, the idea that the organization of the cosmos should somehow play a role in the ordering of the aerospace terminal facilities seemed appropriate. The sun lies at the center of our solar system with each planet circulating around it at various distances. The earth is set up the same way; it is round, with concentric rings of atmosphere surrounding it at various distances (refer to Figure 25). This cosmic ordering applied to the aerospace terminal design resolved itself into the form of the building and its spatial planning. The design becomes a metaphor of cosmic order.
Thinking more about the circulation and the desire to make it more interesting than a straight boring walk to the gate, the two diagrams below developed. The first circulation diagram explains how movement occurs from within a central core and radiates outward to a circular ring and then rotates around the ring. The second diagram explains how the movement could be shifted as it moves outward to create a sense of discovery and exploration. These two ideas also play a part in designing the circulation and spatial planning within the aerospace terminal.

With order and balance being such strong notions arising out of the research, from the general airport design guidelines, to the precedent study airport, to this conceptual exploration, it seemed most appropriate to use these terms to help drive the design of the aerospace terminal. Order, as defined in the Webster’s New World College Dictionary, 4th Ed., is “the sequence or arrangement of things or events; series; succession; a fixed or definite plan; a state or condition in which everything is in its right place and functioning properly, etc.” Balance, is defined as “a state of equilibrium or equipoise; the pleasing
harmony of various elements in a design; harmonious proportion; to bring into a state of equilibrium, etc.” The one symbol that illustrates both of these notions is the Chinese yin-yang symbol. In Chinese philosophy, two opposing forces are inherently interconnected and interdependent – one cannot exist without the other. They combine to form a complete unit. This symbol and the philosophy behind it greatly influenced the design of the aerospace terminal in terms of form, circulation, spatial organization, and structure.

Finally, the passenger flow diagram (Figure 121) was created to study exactly how passengers move through the aerospace terminal. With the additional spaces necessary for space flight training, medical examinations, and visitor’s entertainment, this helped in devising how the spaces were laid out inside the terminal, the proximity of the spaces to one another and the sequence of the spaces. A new traveler must visit more places within the terminal than an experience traveler. The space flight training and medical screening areas are only visited by departing passengers, so they should be located along their path to the gate. The concessions and leisure activities are patronized predominantly by passengers waiting to board their flights, so the majority of them should be located spaceside near the concourse.

These ideas of hierarchy, order, balance, cosmic circulation, and sequence, together with the program, were used to drive the design and reinforced the objectives and function of the aerospace terminal.
Figure 120: Aerospace Terminal Passenger Flow Diagram
EXPLORATION OF TERMINAL FORMS

With the conceptual ideas at the forefront, a series of vignettes were made to visualize the aerospace terminal complex in three dimensions (see Figure 121-123). They evolved over the course of a few weeks from the simple cylindrical disk in sketch #1, to the rather odd variations in sketches #7.1 and #7.2, to the sexy, curvaceous design in sketch #13; each design building on the qualities of hierarchy, balance, order and unity.

In each vignette, the round form is bisected by the main vehicular access road dividing the structure into the terminal side and the hotel side. Even though the scope of this project does not include designing the hotel, it is meant to serve the spaceport guests and is thereby a part of the overall form. The two opposing functions of the terminal and the hotel create a balance across the intersecting roadway. The terminal’s primary function is circulation and movement, while the hotel is a place to stop and relax. The terminal functions as a procession of spaces that most effectively begin and end at the same elevation, which suggests a linear, flat form. The hotel, on the other hand, is large blocks of small rooms that can be stacked on repetitive floors built up so as to allow guests a view out at the spaceport. In these designs, an attempted is made to balance the terminal and hotel in form and function to create a unified, holistic design.
Figure 121: Conceptual Sketches of Aerospace Terminal Facilities 1-6
Figure 122: Conceptual Sketches of Aerospace Terminal Facilities 7-11
Figure 123: Conceptual Sketches of Aerospace Terminal Facilities 12-15
Each of the sketches were analyzed and certain features, such as the separate orbital pods, hotel shape, parking structures, tower location, and terminal form were recombined to create the final design form, which is reveal in the following sections.

**EVOLUTION OF THE CONCEPT**

The ideas about circulation, along with the concepts of balance, order and unity are illustrated here in a parti diagram (Figure 124) of the aerospace terminal complex (i.e. from this point forward *aerospace terminal complex* refers to the terminal and the hotel and parking garage structures; otherwise, the terminal by itself will be called the *aerospace terminal*). This parti diagram represents the aerospace terminal as a solid circle with circulation arrows radiating outwards from the middle to points outside the outer circle, which would be the gates. The hotel is represented by the dotted circle and shows a direct connection to the terminal with the two-way arrow. The outer solid circle represents the unity of the whole form as it is contained with itself. The three circles – the two opposing smaller circles encompassed by the large circle is an abstract representation of the yin-yang symbol.

![Figure 124: Aerospace Terminal Complex Parti Diagram](image)
Evolving this parti further, a geometric order for the aerospace terminal complex became clear. The three lines bisecting the large circle is the roadway dividing the aerospace terminal from the hotel and parking structures. The two opposing, but equal, interior circles became the hotel and landside structures. These two circular structures stand separate from the outer large circular areas surrounding it, making a gap between the forms. The triangular forms facing the center create an entrance to the terminal and hotel structures, and funnel the pedestrian traffic towards their centers. The two triangles overlap the bisecting roadway making the connection between the two circle forms. The five small circles at the top become the orbital pods in the final design. The small circle in the center of the upper circle will become the control tower.

The degrees of enclosure of the aerospace terminal complex shown in the diagram in Figure 126 imply a central core that is completely private, surrounded by semi-private space, and an outer ring of almost open space. The location of windows and skylights throughout the terminal reinforce this concept.

The hierarchy diagram in Figure 127 clarifies the connection between the hotel and aerospace terminal, and shows how the two different forms balance each other in section as well as in plan.
The next two diagrams show exactly how the geometric forms come together and how they related in term of circulation and spatial organization. The upper half forms the aerospace terminal landside and spaceside, while the lower half forms the hotel and parking garages. In the exploded version of the form, one can see how the individual pieces relate and how the circulation filters into the center then radiates outward to the gates.

The entire complex functions together to create an efficient circulation system that accommodates pedestrians, cars, trains, trams, spaceplanes and spacecraft. The schematic circulation diagram of the aerospace terminal complex in Figure 130, illustrates the horizontal and vertical traffic flow through and around the aerospace terminal. The floor plates of each level of the terminal complex are shown in two dimensions to help clarify the vertical changes. A more detailed circulation drawing is included in the final graphics.
Figure 128: Aerospace Terminal Complex Form Sketch

Figure 129: Aerospace Terminal Complex Geometrical Forms
Figure 130: Schematic Circulation Diagram of Aerospace Terminal Complex
The following graphics represent the transformation of this thesis research into an architectural vision meant to act as a precedent for future spaceport concepts and designs. In other words, these graphics illustrate only one of many possible interpretations of this information, and is not itself necessarily the perfect solution. However, the diversity of information amassed in this document, including these graphics, will expand the compilation of literature that can be utilized by the next generation of spaceport designers. Therefore, keep an open mind, think about life as we know it, and just imagine what the future holds.

The final masterplan of the spaceport incorporates ideas of the aerotropolis as described by Mr. John Kasarda and complies with the general airport regulations and design principles as mentioned previously. The spaceport acts as an anchor for the urban community that is planned for and anticipated. The spaceport land area includes ample space for growth and expansion. There is a clear geometric order to the spaceport and the surrounding urban fabric creating an all inclusive urban plan for the future. The spaceport is multi-modal, which accommodates vehicular traffic, light rail trains, terminal trams, planes, spaceplanes, spacecraft, and pedestrian traffic. The layout of the spaceport and urban context form a functionally efficient transportation hub. Refer to Figures 131-135 for masterplan graphics.
Figure 131: Spaceport Masterplan and Surrounding Context, Scale 1:2000
Figure 132: Figure-Ground of Spaceport and Surrounding Context, Scale 1:2000
Figure 135: Aerial of Aerospace Terminal Complex and Context
As one approaches the aerospace terminal from the access road (View #1, Figure 154) the idea of balance becomes clear as the two opposing forms that stand apart – the aerospace terminal and hotel complex – begin to merge across the roadway to form a single unified complex (View #2, Figure 154). The complex itself as seen from a distance is so unique, compared to the surrounding structures, in that it resembles what most imagine a flying saucer to look like making it easily recognizable (see Figure 134). Once close enough to actually see the aerospace terminal in its entirety it seems to almost hover above the ground. Its’ curved outer skin folds around the second floor space then stops allowing the structural bends to penetrate through the floor and extend down to the ground. These exposed structural columns and bends support the second floor allowing the ground floor to remain open for easily transfer and loading of baggage (See Figure 147).

There is a clear geometric order in plan and in section. The aerospace terminal plan is laid out with the landside building in the center and the spaceside building surrounding it. There is a clear separation between the two structures forming a ribbon of open space. The only connection between landside and spaceside is through three tubular passageways, which a departing passenger must pass through after clearing security and an arriving passenger must pass through before entering immigration. The space in-between the structures is landscaped and contains underground water basins that collect rainwater runoff from the buildings’ drainage system. In section, the levels are fairly standard: the service/baggage handling area occupies the ground floor, the arrivals are on the second floor, the departures are on the third floor, and visitors/entertainment area inhabits the fourth floor. A train station is also incorporated underground with directed access to the terminal lobby. Vertical circulation within the lobby connects the various levels of the terminal with the train station underground and the pedestrian bridge on the fourth level that joins to the hotel across the roadway.

The program spaces of the terminal and the circulation of the passengers follow the same clear geometric order as the terminal itself. Passengers filter in through the wide
open lobby with floor to ceiling double story glazing that allows light to flood inside. Passenger converge toward the center of the landside building where they then radiate out to either the space training center, the medical screening area, or through the security check points, and out to the spaceside building through glass tubular passageways.

Inside the spaceside building, passengers land onto a catwalk that circles above the inside of the spaceside leisure area. The passengers circulate around the catwalk to one of the escalators or elevators that takes them down to the concourse level. Passengers then have the choice of roaming around the leisure area, or heading directly to their gate lounge to wait for their flight. Since this is an international terminal, the gate lounges are clearly indicated by color for easy identification. See Figures 136-142 for the layout of the program spaces, Figures 143-144 for the detailed passenger flow maps, Figures 147-150 for the terminal sections showing the floor levels, Figures 151-152 for the detailed floor plans of the landside departures and arrivals, and Figures 154-156 for the passenger journey through the aerospace terminal.

The concourse is the most expressive part of the terminal design and gives the perception of space flight. The structure of the main concourse and lounge area resembles that of a high-tech space station. The large columns extend to the roof where an oversized bolt secures the top point of a curved beam. The curved beams support the roof panels as they curve around to form the exterior walls of the concourse lounge. The beams then act like support columns as they pass through the floor to the ground. These steel bends and columns act as the primary supports structure for the concourse area. Curved glass beams are also used in the main concourse as secondary structure to support the paneling system. The composite panels that clad the exterior of the terminal cease at about 10 feet above the concourse floor and become glazing to allow passengers a view of the apron activities outside. Glass skylights are strategically placed above the circulation paths and around the gateway as a way of guiding passengers through the terminal by using daylighting.

The overall form of the aerospace terminal complex and the detailed structure of the concourse offer passengers a perception of space flight that prepares them for their journey into space. The clear geometric order of the terminal that balances form and
function provides passengers with an efficient, yet exciting, experience. Its unique design sets the aerospace terminal apart from the rest of the spaceport facilities allowing it to become an icon of the spaceport and a landmark for the area. Refer to Figures 136-157 for aerospace terminal complex graphics.

Figure 136: Underground Floor Plan, Scale 1:400
Figure 137: Ground Floor Plan, Scale 1:400
Figure 138: Second Floor Plan, Scale 1:400

SECOND FLOOR PROGRAM

- **LANDSIDE ARRIVALS LEVEL** ~80,000 SF
- **AIRSIDE CONCOURSE LEVEL** ~150,000 SF

- **ADMINISTRATIVE SPACE**
- **VERTICAL CIRCULATION**
- **ARRIVALS FIS SPACE & BAGGAGE CLAIM**
- **CONCESSIONS SPACE**
- **LOBBY/PUBLIC SPACE**
- **ATO SPACE & GATE LOUNGE SPACE**
Figure 139: Third Floor Plan, Scale 1:400
Fourth Floor Plan, Scale 1:400

Figure 140: Fourth Floor Plan, Scale 1:400
Figure 141: Observation Deck Plan, Scale 1:400
Figure 142: Roof Plan, Scale 1:400
DEPARTING PASSENGERS FLOW MAP

Figure 143: Departure Level Passenger Flow Map, Scale 1:133
Figure 144: Arrival Level Passenger Flow Map, Scale 1:133
Figure 145: Third Floor Landside Departures Level, Scale 1:80
Figure 146: Second Floor Spaceside Departures Level, Scale 1:80
Figure 147: NW to SE Section Perspective through Aerospace Terminal, Scale 1:100

Figure 148: SW to NE Section Perspective through Aerospace Terminal, Scale 1:100
Figure 149: East to West Section Perspective through Aerospace Terminal, Scale 1:100

Figure 150: East to West Elevation of Aerospace Terminal, Scale 1:100
Figure 151: Enlarge Second Floor Plan of Landside Arrivals, Scale 1:50
Figure 152: Enlarge Third Floor Plan of Landside Departures, Scale 1:50
Figure 153: Exploded Axonometric of Aerospace Terminal and Details
Figure 155: Passenger Journey from Drop Off to Take Off, Views 5-8
Figure 156: Passenger Journey from Drop Off to Take Off, Views 9-12
Figure 157: Aerial Views of the Aerospace Terminal
DEFINITIONS

Aircraft Gate Parking Positions: used for parking aircraft to enplane and deplane passengers. The passenger boarding device is part of the gate position.

Airline Operational Areas: areas set aside for airline personnel, equipment, and servicing activities related to aircraft arrivals and departures.

Airport Access System: This component is composed of the functional elements which enable ground ingress and egress to and from the airport terminal facility. They include all vehicular and pedestrian paths, parking and curbside.

Airside: (see also Connector) restricted area giving access to aircraft loading and unloading (apron).

Apron: The apron comprises the area and facilities used for aircraft gate parking and aircraft support and servicing operations. It includes the parking positions, service areas, taxilanes and service/fire lanes.

ASL (Above Sea Level): Elevation above sea level.

Channel: passenger route through the terminal.

Concourse: a passageway for circulation between aircraft gate parking positions and the main terminal building.

Connector: (see also Airside) The connector consists of the structure(s) and/or facilities normally located between the aircraft gate position and the main terminal building. At low activity airports, i.e., less than approximately 200,000 annual enplaned passengers; this component is often combined with the terminal building component. It normally contains the concourse, departure lounges, security inspection station, airlines operations areas, passenger amenities, and building maintenance and utilities.

Curb: platforms and curb areas (including median strips) which provide passengers and visitors with vehicle loading and unloading areas adjacent to the terminal.
**Customs:** *(see also federal inspection service)* security area where international passengers are processed and baggage inspected.

**Dwell Time:** time spend in the terminal.

**Federal Inspection Services:** *(see also customs)* a control point for processing passengers arriving on international flights.

**Hub-and-Spoke System:** System of transportation, where traffic moves along spokes, like those of a bicycle wheel, to a center hub, then are redistributed back out along other spoke paths. Most common organization for air transport.

**Inbound Baggage Facility:** The nonpublic area for receiving baggage from an arriving light and public areas for baggage pickup by arriving passengers.

**Intraline and Interline Baggage Facility:** a nonpublic area for processing baggage transferred from one flight to another.

**Jetty or Loading Bridge:** adjustable corridor connecting airside terminal to aircraft (2-3m wide).

**Landside:** non-restricted area of an airport accessible to the non-traveling public.

**LEO (Low Earth Orbit):** An orbit from 160-2000km above the Earth’s surface. The ISS revolves and most orbital and suborbital human space flights occur within this altitude range.

**Main Terminal Building:** public area that includes lobbies, counters, circulation, service areas, baggage facilities, administrative offices, inspections service areas and passenger amenities.

**MSL (Mean Sea Level):** Average elevation of the area above sea level.

**Multi-Stage-To-Orbit (MSTO):** a space vehicle that launches using expendable rockets that are detached prior to the second stage that boost the vehicle into orbit.

**Pier:** extension protruding from terminal building giving access to airline gates.

**Orbital Spacecraft or Spaceplane:** a rocket powered space vehicle that reaches space (above 100km) and can remain in space for at least one complete orbit. The altitude and speed of the vehicle at perigee factors into its ability to remain in orbit.

**Outbound Baggage Facility:** a nonpublic area for sorting and processing baggage for departing flights.
**Point-to-Point System (PTP):** System of transportation, where the traffic moves directly between destinations, rather than through a central hub.

**Reusable Launch Vehicle (RLV):** a vehicle that is capable of launching into space more than once, in contrast to expendable launch vehicles which is discarded after one launch, like most rocket.

**Service/Fire Lanes:** identified rights-of-way on the apron designated for aircraft ground service vehicles and tire equipment.

**Security Inspection Station:** a control point for passenger and baggage inspection and controlling public access to parked aircraft.

**Satellite:** airside building separate from terminal building surrounded by airline gates

**Single-Stage-To-Orbit (SSTO):** a reusable space vehicle that can reach orbit from the surface without jettisoning any hardware.

**Sterile Area:** area within terminal building accessible only by security-cleared passengers and airport staff.

**Suborbital Spacecraft or Spaceplane:** a rocket power space vehicle that reaches space, but due to its trajectory having too low an altitude at perigee or too slow a speed, cannot complete an orbit. The vehicle operates at the edge of space to take advantage of the less dense air. It combines the features of an aircraft with those of a spacecraft.

**Taxilanes:** reserved to provide taxiing aircraft with access to and from parking positions.

**Taxiway:** pathway for aircraft to move around the airfield.

**Travellator:** horizontal moving walkway (+1.4m width & +/-60m long, 1:15 incline).
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