Layout Design of an Intermodal Air & Space Port for 2050 Operations

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Abstract

As the commercial space industry continues to grow, the concept of Air & Space Ports, intermodal hubs with both commercial aviation and space flight activity in a single facility, becomes more relevant. The goal of this work is to therefore determine the layout of an Air & Space Port targeting operations in 2050, identifying the design elements that would enable the functioning of the integrated facility and calculating its land requirements. Using a custom-built data-driven space traffic forecasting model, this work determined the key sizing requirements (i.e., number of aircraft parking positions, number of runways, and number of launch pads), which it integrated into a series of computer-aided design (CAD) models to visualize the layout. These models, which are freely available at this work's online Github repository, were then utilized to compute the land requirements for the layout, which came out to be 117.6 km^2. Parametrizing the design variables and considering two possible configurations (sea-side, in-land), the range of land required was 50 km^2 – 200 km^2, which is larger than most commercial airports currently operating. Although the design of Air & Space Ports is subject to change as space vehicles and safety guidelines evolve, it is critical to commit as early as possible to securing their land, not only due to the large magnitude, but also due to the existence of other competing uses.

1. Introduction

Over the past decade, the number of orbital rocket launches has increased almost two-fold, from 93 in 2014 to 263 in 2024 (Space Stats, 2025). Thus, in the dawn of an increasingly important global space industry, the planning and design of the airports of the future can't evade the undeniable imagination: the possibility of integrating airports and spaceports into a single facility, i.e., Air & Space Ports, capable of serving both Earth and planetary travel.

As a concept, Air & Space Ports are not new, and in fact, currently exist, e.g., in the states of California and Colorado in the United States (US) (FAAb, 2023). However, these facilities possess two major drawbacks: first, these sites can only accommodate horizontal launches (i.e., the space vehicle would take-off like an airplane), inherently limiting the space vehicle to sub-orbital flight (due to not being able to reach a sufficiently high speed to escape Earth's gravity); second, these Air & Space Ports were not designed to act as integrated intermodal hubs for commercial airline[1] and space flight operations.

Thus, in this context, the goal of this work is two-fold: first, **envisioning what the layout of a future intermodal Air & Space Port with vertical launch capabilities could look like**; second, **determining the land requirements of the layout for a variety of configurations**. Here, the focus on intermodality refers to the theoretical possibility for a passenger to arrive on an airliner's flight to seamlessly connect to a space flight. Meanwhile, the addition of vertical launches would allow for the accommodation of the orbital space vehicles currently being developed, such as SpaceX's Starship – Super Heavy rocket, which takes-off vertically, as opposed to horizontally on a runway.

The exercise of designing an Air & Space Port is analogous to the challenge that airport planners faced in the 1950s – 1960s at the dawn of the jet age. Spaceflight is still not widespread, so the design proposed in this work will heavily rely on assumptions on what the future could look like. While it is certainly possible that the design of Air & Space Ports will change over time as more details with regards to the space vehicles and safety are refined, this work represents the first literature attempt at providing order-of-magnitude estimates of the land requirements, which as will be evidenced in the proceeding sections, could be significant for the envisioned concept.

2. Methods

The methodology employed to dimension, design, and analyze the Air & Space Port layout with vertical rocket launch capabilities consisted of five steps. The first, shown in ***Section 2.1.***, consisted of identifying the design vehicles, which in this work were the B787-9 for the airport portion and the Starship – Super Heavy rocket for the launch site portion of the layout. The second step, in ***Section 2.2.***, focused on traffic forecasting, aiming to determine the expected number of aircraft operations and rocket launches at the site towards 2050. The third step, in ***Section 2.3.***, examined several layout design features and functional elements, with a focus on the parameters that

[1] In fact, currently none of the US' Air & Space Ports receive commercial airline flights (FAAb, 2023).

influenced the dimensioning of the overall layout. With the design requirements outlined in ***Section 2.1.*** through ***Section 2.3.***, the fourth step, in ***Section 2.4.***, integrated the requirements into a series of computer-aided design (CAD) models, allowing for a visualization of the layout. Finally, the fifth step, in ***Section 2.5.***, parametrized the design, evaluating the land requirements of the combined layout for a series of alternative configurations.

2.1. Design Vehicles

A preliminary step in the design of the Air & Space Port layout surrounded the selection of the design vehicles (i.e., the most demanding vehicles that would be used for dimensioning considerations). On the airport side, the selected design vehicle was an B787-9-like aircraft (ICAO classification 4D), envisioned to be the largest aircraft visiting the airport. Although it is possible more advanced aircraft than the B787-9 will be flying[2] by 2050, this work utilizes its dimensions as representative for the design of the airport portion of the combined facility.

On the launch site side, the selected design vehicle was the SpaceX Starship – Super Heavy rocket. Out of commercial space travel rockets (capable of transporting 50+ passengers) currently being developed, this vehicle has seen the most progress (SpaceX, 2025). In addition, designing for the Starship as the most demanding vehicle would accommodate for smaller types of rockets, including Boeing’s Starliner Capsule with the United Launch Alliance Atlas V rocket, and SpaceX’s own Crew Dragon capsule with the Falcon 9 rocket.

According to SpaceX (2025), the Starship is being built to have a turnaround time of under an hour (after landing), which is similar to that of widebody aircraft like the B787-9. This short turnaround time is in stark contrast to that of the company’s own Falcon 9 rocket, whose shortest recorded turnaround time was 21 days, or even the Space Shuttle, whose record turnaround was 55 days (Cunningham, 2023). Besides the short turnaround time, the Starship is envisioned to be utilized on both “earth-to-earth” flights (i.e., to destinations within Earth), or for “earth-to-space” flights (i.e., to destinations outside of Earth). According to SpaceX (2025b), most long-haul flights today would take under an hour if replaced by a Starship flight.

2.2. Traffic Forecasting

Having identified the design vehicles, the next step in the design of the Air & Space Port layout consisted of building a forecasting model to determine three major design variables: the number of aircraft parking positions, the number of runways, and the number of launch pads. The overall model can be visualized in **Figure 1** below, while in-depth descriptions of the calculations can be found in Sections ***2.2.1.*** through ***2.2.4.***

[2] In general, widebody aircraft in the US are flown for 20 – 30 years, which means that it is possible that B787s manufactured in 2025 will still be flying by 2050.

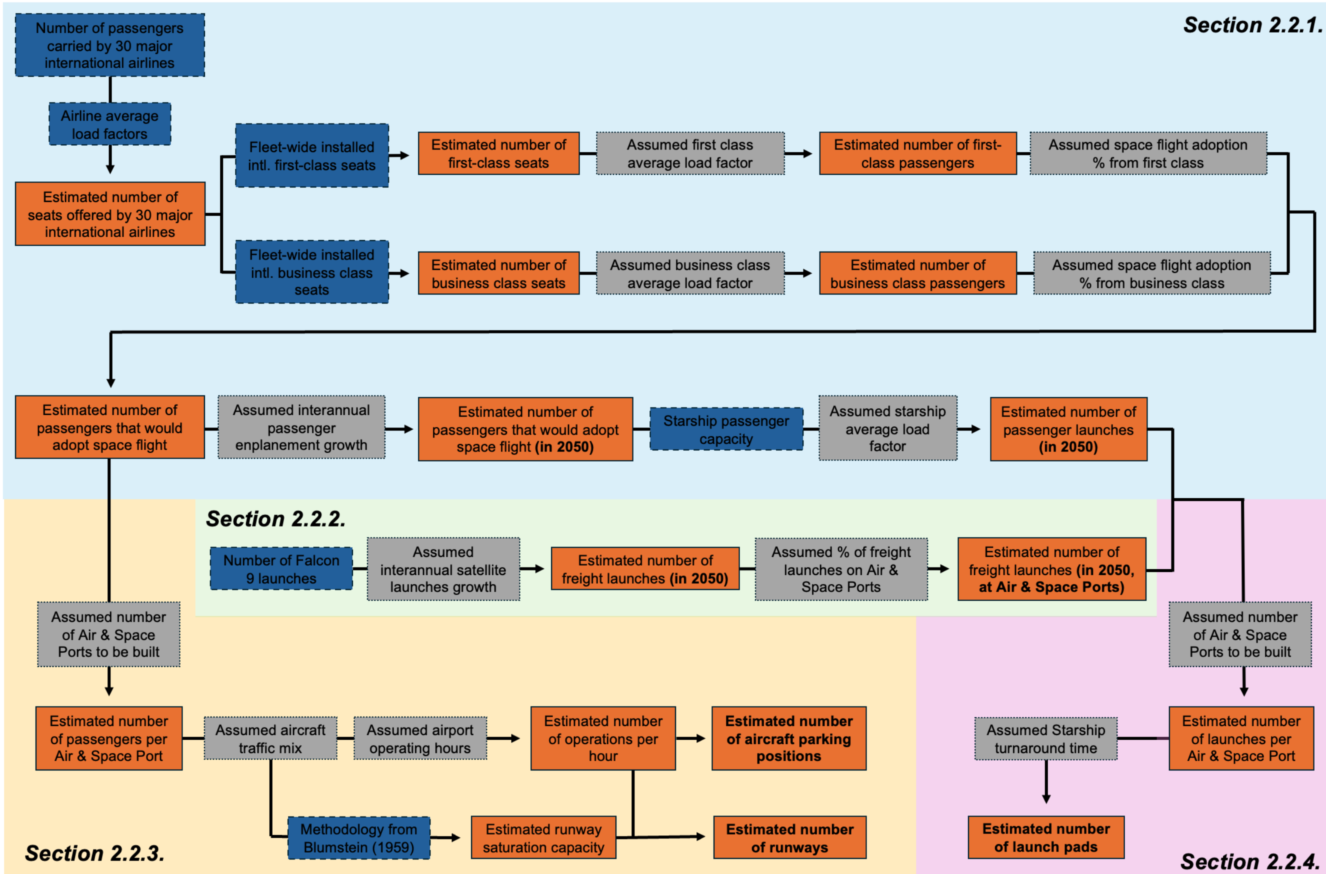

Figure 1: Traffic forecasting model flow diagram. Here, blue boxes denote data inputs, orange boxes computed values, and grey boxes assumption inputs. In the associated excel table, the values on the grey boxes can be modified to model alternative user assumptions and obtain a different set of estimated design parameters.

In summary, this work determined that the Air & Space port would require 35 parking positions, a single runway, and four launch pads. Although data-driven, these numbers were determined under a set of assumptions (shown in italics through the subsections, and on grey boxes in **Figure 1**) that can be easily modified using the excel table associated with this work, titled “Technical Specifications”.

2.2.1. Estimating Space Flight Passenger Demand Launches

The approach undertaken in this work to determine the number of launches in 2050 due to passenger travel assumed that a certain percentage of first and business class passengers flying today would adopt space flight. To this end, using publicly available corporate reports, this work started by estimating the number of first and business class seats currently on offer by 30 international airlines (the list of which can be found on the associated excel table). These airlines, which were selected due to offering international first or business class on long-haul flights, cumulatively carried ~40% of the global airline industry passengers.

In 2024, these airlines offered 2,373 million seats. Using statistics from the Centre for Aviation (CAPA, 2023) for fleet-wide installation of first class and business seats, this work estimated that 1.87 million and 152.9 million passengers flew on first and business class in 2024, *assuming load factors of 50% and 70%*, respectively. Now, under the *assumption that 10% of first-class passengers and 5% of business class passengers* would be willing to someday adopt space flight (either “earth-to-earth” or “earth-to-space”), the market for 2024 could potentially consist of 7.83 million passengers.

According to the US Federal Aviation Administration (FAA, 2025c), international passenger enplanements are *expected to increase by 3.1%/year in the 2025 – 2045 period*. As a result, assuming this rate persists until 2050, 7.83 million passengers would become 17.32 million in 2050. Hence, for a 100-passenger starship with *an average 70% load factor*, 2050 could see as many as 24,739 passenger Starship launches.

2.2.2. Estimating Space Flight Freight Demand Launches

The approach to estimate the number of launches due to freight[3] demand in 2050 followed a similar approach to ***2.2.1.*** and was conservatively based solely on the number of Falcon 9 launches in 2024. In 2024, Falcon 9 represented the rocket with the greatest number of launches, at 132 during the span of the year (Kuhr, 2025). If an annual growth of 29% (corresponding to the 2023 – 2024 period) was *maintained until 2050*, then the number of launches could rise to 94,913. Now, assuming that Air and Space Ports would *support 50%* of this freight launch demand, then 47,456 freight launches could be expected at the facilities.

2.2.3. Estimating Airport Capacity

This work envisions *creating 15* dedicated Air & Space Ports globally, with a geographic distribution of two to four per continent to serve different markets. As a result, on average, each location could see 1.15 million passengers per year by 2050 (17.32 million passengers divided by 15). In scale, this passenger traffic would be comparable to that of a regional airport in the US, such as Rochester (ROC) in New York, whose enplanement numbers for 2023 (FAA, 2024) were in the order of one million.

In terms of operations, 1.15 million passengers per year would equate to ~3200 passengers per day, or roughly 33 flights per day (~3 flights/hour on a 12-hour day) on a typical 76-seat regional jet at an 80% load factor. In this work, *assuming a traffic mix consisting of ~5% heavies (e.g., B787-9), ~15% medium (e.g., A321neo), ~70% small (e.g., E170) and ~10% light (e.g., Learjet 55)*, the airport could have a theoretical capacity to accommodate up to 31 landings or 40 take-offs per hour (~35 movements/hour average), all with a single runway, as determined using the method from Blumstein (1959) (see excel table for more details).

The key idea envisioned for the airport portion of the Air & Space Port is that it would likely act as a connection point for further space travel. As such, under this work's concept, it would not constitute a major airline hub, but rather a spoke of a larger network. In particular, this work envisions that first, the Air & Space Port would not be in proximity to major population centers, and second, most travelers would be arriving by air.

2.2.4. Estimating Launch Pads Capacity

Adding the number of launches from passenger and freight space flight would result in an estimated 72,195 launches[4] per year by 2050, or approximately 13 launches per day at each one of the 15 Air & Space Ports. Now, because the Starship is being designed to have a turnaround time of 2 hours, then only 2 launch pads would be necessary at each site, *assuming this turnaround rate is achieved*.

2.2.5. Overall Estimated Design Requirements

A summary of the estimated design requirements from the forecasting model presented in Sections ***2.2.1.*** through ***2.2.4.*** can be seen on **Table 1** below. Next to each estimate is the selected design quantity for this work, which in all cases but the number of runways saw a larger quantity being selected than the estimated requirement. For the runway, the argument was that it would see an average hourly utilization of 8% (~3 estimated movements/35 capacity movements), leaving sufficient room to expand the airport operations should demand rise, all with a single runway. For the number of positions and launch pads, the logic was that having more space would act as spare capacity and thus could help accommodate greater demand as the market grows. Furthermore, more aircraft stands and launch pads could allow for more flexibility in case of contingencies, allowing for more Starships to land[5] should any issue arise.

[3] In this work, freight primarily referred to satellite payloads.

[4] As was seen in ***2.2.1.*** and ***2.2.2.***, passenger and freight space flights were treated separately, although it could be possible that a single flight could serve both purposes, as is the case today in the airline industry.

[5] Starships are designed to take-off and land at the launchpad, where they are secured in place and caught by a pair of "chopsticks". Unlike airports, the launchpads in spaceports could act simultaneously as the parking position as well as the runway.

Table 1: Design requirements for the Air & Space Port.

Design Variable	Estimated Requirement	Selected Quantity
Number of airport parking positions	At least 35.	42 (20 jetway stands, 22 remote stands).
Number of runways	At least one.	One (more than sufficient, due to the expected 33 flights/day to be accommodated).
Number of launch pads	At least two.	Four (for redundancy and safety, allowing for more rocket landings should contingencies arise).

2.3. Layout Design Considerations

The three subsections that follow elaborate on the layout design and dimensioning considerations of the airport portion and launch site portion of the Air & Space Port.

2.3.1. Airport Layout Design

The layout design of the airport portion followed standard recommended practices for airport design as dictated by the International Civil Aviation Organization (ICAO), in particular Documents 9157, Part 1 (ICAO, 2006) and Part 2 (ICAO, 2005), as well as Annex 14 (ICAO, 2018), for the dimensioning of the tarmac, taxiways, and runway.

The envisioned layout shown in **Figure 3b** and **Figure 3d,** as well as **Figure 4b**, is 8.6 km^2 (2.05 km by 4.2 km), which is similar in size to regional airports in the US like Knoxville (TYS) in Tennessee, at 9.1 km^2 (McGhee Tyson Airport, 2025). The larger 4.2 km dimension was driven by the runway length, which in this work was chosen to be 4.12 km long. The reason for possessing such a long runway (which would be longer than that of most commercial airports) was so that it could fall in the range of runway lengths of existing Air & Space Ports that allow for horizontal space vehicle take-offs. For instance, the longest runway at the Mojave Air & Space Port (12-30) is 3.8 km long (Mojave Airport, 2025), while that at the Kennedy Space Center (KSC) at the Shuttle Landing Facility is 4.6 km long (NASA, 2025).

Besides the runway, some of the (non-exhaustive) features included in the design shown in **Figure 3b** were the main terminal, 42 parking positions (for 20 jetway positions and 22 remote stands), cargo terminal, hangars, fuel tanks, car parking buildings, as well as the intermodal hub building. Indeed, as mentioned above, the underlying concept surrounding the proposed Air & Space Port layout is intermodality, i.e., being able to arrive to the site by air (or ground transportation) and smoothly transfer to the space port terminal to catch an “earth-to-earth” or “earth-to-space” flight. To this end, as shown in the illustrations in **Figure 3d**, the airport and space port terminals would be connected via the intermodal hub building. Another key feature of the space port terminal building is the inclusion of a series of helipads. Because a large distance (>5 km) would separate the passenger space port terminal from the launch pads themselves (see ***Section 2.3.2.***), this work envisions utilizing vertical take-off and landing vehicles (VTOLs) to transport the passengers to and from the facilities.

More details with regards to the layout dimensioning can be seen in **Figure 4**, as well as in the excel table associated with this work, titled “Technical Specifications”, under the “Airport Sizing” table.

2.3.2. Launch Site Layout Design

The layout design of the launch site portion largely resembled that of launch site 39 at the KSC. The reason for this is because, currently, SpaceX is working to refurbish the historic launch pad 39A (the same pad where Shuttle and Apollo flights took place) to enable the launch of the Starship – Super Heavy rocket (FAA, 2025), the design vehicle in this work. As a result, the design of the launch pads shown in **Figure 3c** and **Figure 3e** followed the guidelines published by NASA (2006), whose (non-exhaustive) features are listed in **Table 2** below.

Table 2: Key features of the launch pads featured in this work.

Design Element	Description
Two Fixed Service Structures	One fixed service structure would be utilized for rocket support, equipped with what SpaceX denotes as “chopsticks”. These are arms that extend from the fixed structure and would be utilized to not only help with the assembly of the Starship – Super Heavy booster (by stacking the former on top of the latter), but also with catching the rockets upon return to earth. As mentioned in ***Section 2.1.***, the

	Starship - Super Heavy represent reusable vehicles, and to that end, the "chopsticks" could help facilitate a quick operational turnaround. The other fixed service structure would be used for servicing the rocket and includes a crew access arm (analogous to an airport jetway).
Two fuel storage tanks	These fuel storage tanks would contain liquid oxygen (LOx) and liquid methane (LCH_4), the two propellants utilized on the Starship - Super Heavy rocket.
Flame Trenches	These structures, built with heat-resistant bricks, help deflect the heat and pressure of the exhaust plume during lift-off. In this work, the flame trenches point northwardly towards the sea-side, away from the rocket.
Sound Suppression System	This structure is used to inject water during ignition to reduce the high acoustic energy from the over-pressure waves. In confined areas, these waves can compress, expand, and reflect back to the vehicle itself, which could cause damage (Brehm et al., 2013).

Besides the launch pads, another noticeable design feature of the launch site layout in **Figure 3a** is the crawler way, which connects all four launch pads to the rocket maintenance facility. The purpose of the crawler way, inspired by the design at the KSC, is to act as a pathway for the crawler-transporter vehicle to carry the Starship – Super Heavy rocket to/from the maintenance facilities and launch pads. Currently, SpaceX uses an Orbiter Transporter System (OTS) to transport Falcon 9 rockets at the Cape Canaveral Space Launch Complex 40 (NASAb, 2006), and a crawler-like vehicle to transport the Super Heavy at their Starbase, in Boca Chica, Texas.

The overall launch site portion of the Air & Space Port, as shown in **Figure 4d**, would occupy a land area of 109.0 km^2 (5.8 km by 18.8 km). These land requirements would be evidently larger than that of the airport layout itself, primarily because of large separation standards meant to ensure safety. The FAA (FAA, 2011) has produced a guide with a list of equations that can be used to calculate these separation standards (otherwise known as a public safety zone radius), based on the net explosive weight (NEW) of a rocket. Featured on the code of federal regulations 49 CFR Part 420 (License to Operate a Launch Site), Appendix E, the minimum distance from a launch pad to a public area (for NEW > 250,000 lb, under a Division 1.1 categorization[6]) would be given by:

$$\mathrm{D(in\ km)} = \frac{50 \cdot \mathrm{NEW}^{1/3}}{3280.8} \tag{1}$$

The Super Heavy is designed to hold up to 7,500,000 lb of propellant (i.e., 6,000,000 lb of LOx and 1,500,000 lb of LCH_4), while the Starship itself can carry 3,300,000 lb (SpaceX, 2025). In total, the two rockets amount for 10,800,000 lb of fuel. Hence, applying **Eq. (1)**, the minimum distance to the public area would be 3.37 km. This result is in the order of magnitude of the values shown in a NASA schematic for the Kennedy Space Center, which established a radius of 3 km as the public safety zone for Launch Pads 39A and 39B. In this work, due to the combined operations with the airport, a value of $\mathrm{D} = 5.2$ km was selected, which corresponds to approximately a safety factor of 1.5 (with respect to the calculated D). This distance is more in line with the location of the Vehicle Assembly Building at the KSC, which is situated 3.5 miles (5.6 km) from the nearest launch pad, 39A (Waldek, 2022). The same NASA schematic also listed a radius of 1.4 km as the blast danger zone for a particular launch pad. In this work, twice this radius was set as the minimum separation between adjacent launch pads to enable parallel operations at each pad. While NASA never launched simultaneously from pads 39A and 39B, 2008 was the first time two Space Shuttles (Atlantis and Endeavor) were mounted at the same time at these launch pads, with Atlantis launching first and Endeavor acting as a back-up in case a rescue mission was necessary (NASA, 2008).

Overall, 5.2 km as the distance to the public area and 2.8 km as the distance between adjacent launch pads drove the overall dimensioning of the launch site.

[6] LOx and LCH_4 propellants would be categorized under Division 1.1., according to 49 CFR Part 173, subpart C.

2.3.3. Airspace Restrictions

One final design consideration surrounding the design of the integrated Air & Space Port with vertical rocket launches is that of airspace restrictions. Indeed, rocket launches induce airspace closures, not only to prevent collisions between aircraft and rockets, but also in the unlikely[7] worst-case-scenarios, to mitigate the risk of rocket debris (due to an explosion) impacting any aircraft.

In this context, the design of the airspace around Air & Space Ports, with their associated Aircraft Hazard Areas (AHAs, polygon that would be subject for closure whenever rocket launches take place) becomes a non-trivial challenge. AHAs most often consist of temporary flight restrictions (TFRs), as well as other combination of airspaces, such as restricted areas, warning areas, and altitude reservations (FAAb, 2023). In general, according to FAAb (2025), TFRs could last from hours to minutes, depending on the complexity of the space launch operation.

At the KSC, TFRs take the shape of the half clamshell polygon seen in **Figure 2**. The area that projects outwardly towards the sea corresponds to the direction of the rocket launches, which is consistent with this work. Previously, the polygon followed a full clamshell, although deeming it safe, the FAA recently halved its size, so to avoid disrupting flight operations (FAA, 2023).

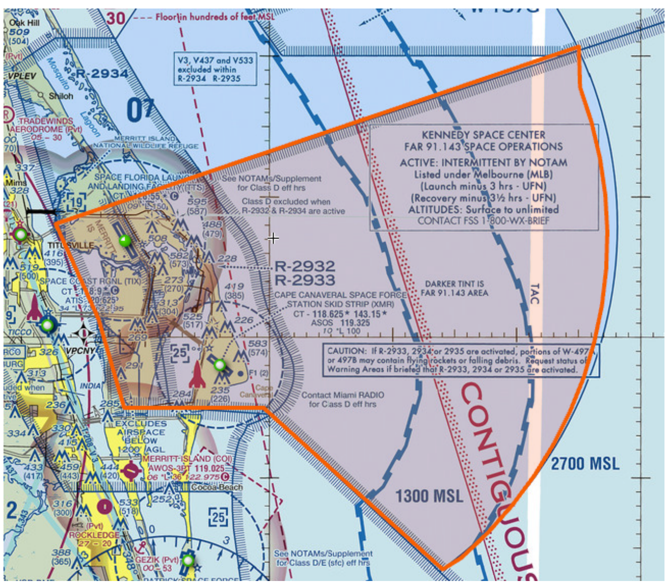

Figure 2: Polygon (in orange) of the airspace temporary flight restrictions at the Kennedy Space Center during launches at pads 39A and 39B.

The code of federal regulations CFR Section 91.143 outlines the requirements for the temporary flight restrictions that ensure the safety of aircraft flying in proximity to space launch areas. Some key considerations include: no airport may lie within the Aircraft Hazard Area (AHA); the probability of impact with debris should be lower than 10^{-6} (14 CFR Section 450.101); specialized letters of agreements could be developed to ensure that aircraft following clearly articulated Instrument Flight Rule flight paths could land and take-off from such airports. As can be seen, the polygon design of AHAs is not trivial, and even though a distance of ~7 km would separate the runway from the launch pads in this work, it could still be possible that the entire airport would fall within the bounds of the TFR. However, since the number of expected rocket launches per day (as determined in the forecasting ***Section 2.2***) would be quite reduced compared to the number of aircraft operations, long-term strategic scheduling could be conducted to ensure the least operational disruptions when TFRs are in place.

2.4. Computer-Aided Design (CAD) of the Air & Space Port Layout

Using the design requirements outlined in ***Section 2.1.*** through ***Section 2.3.***, this work generated a series of Computer-Aided Design (CAD) models to visualize the proposed layout of the combined Air & Space Port with vertical rocket launch capabilities. These designs were utilized to generate the illustrations found in **Figure 3** and **Figure 4**, and are freely available at this work's online Github repository. The CAD models constitute medium-fidelity, in the sense that the layout is relatively detailed (namely with the inclusion of the runway, tarmac markings, Crawler way, and launch pads) and allows for an understanding of the overarching concept, but the buildings themselves lack interiors.

Below, **Figure 3** depicts a few select views of the 3D CAD representation of the layout, while **Figure 4** contains four engineering drawings of the site with representative dimensions.

[7] As of 2024, Falcon 9 launches have seen a mission success rate >99% since 2010, while United Launch Alliance's rockets have seen a 100% success rate since 2006 (Space Insider, 2024).

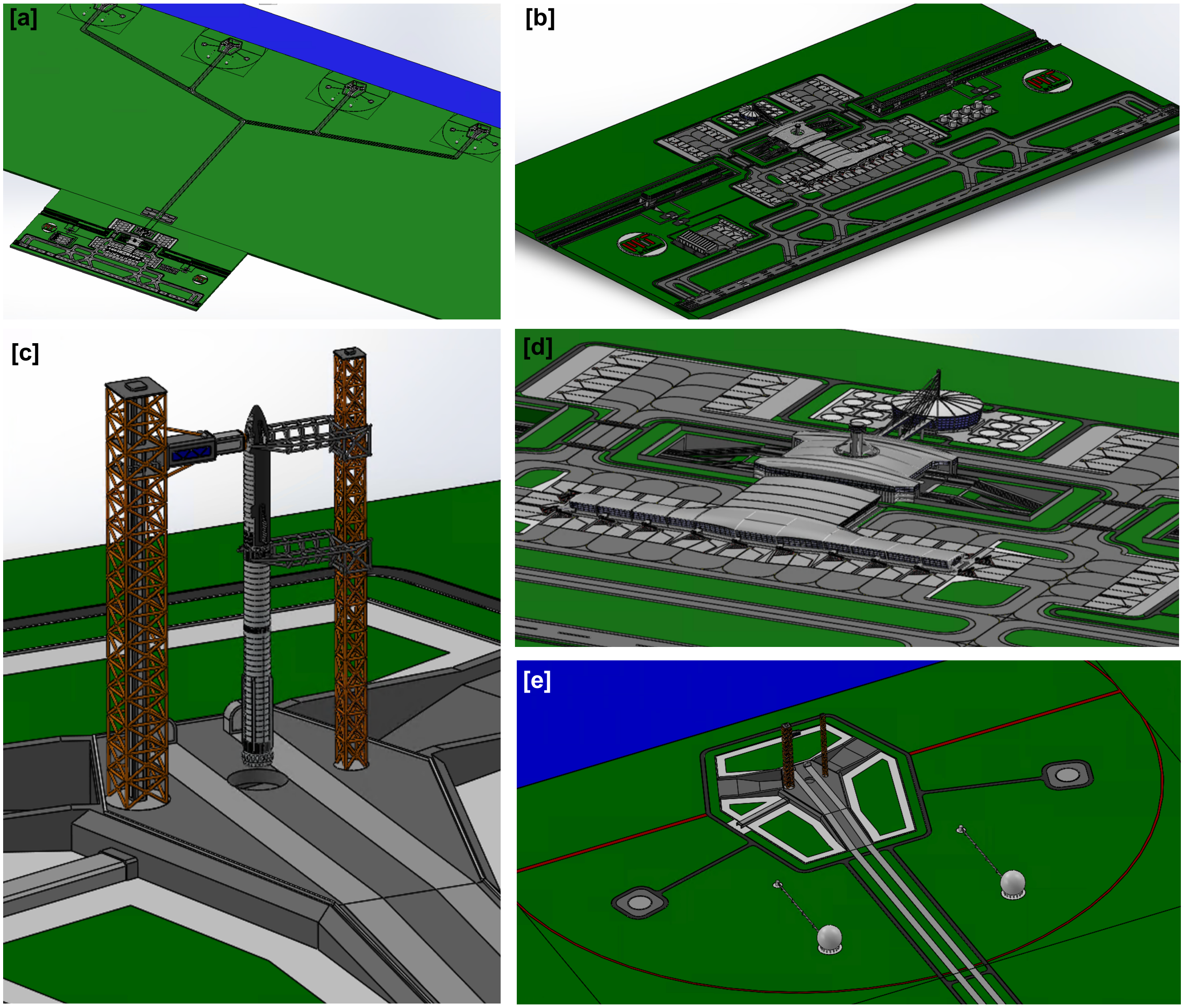

Figure 3: [a] Isometric view of the combined Air & Space Port Layout, with the airport portion in the bottom left and the launch pads on the top right. Notice the crawler way connecting all four launch pads to the maintenance facility towards the bottom left corner; **[b]** Airport layout, which includes the main runway and terminal (center), as well as a hangar and freight area (bottom left) and fuel tanks (top right); **[c]** Zoomed-in view of the launch pad tower area, with the Starship in position, being help by two "chopsticks" structures, and with attached to a crew access arm; **[d]** Zoomed-in view of the airport terminal, as well as the main transportation hub (center) and the space port terminal at the back, connected with a suspension bridge. Notice the helipads to the side of the space port terminal; **[e]** Launch pad area, with a view of the side fuel tanks, as well as helipads (for passenger access to/from the terminal area). The blue areas represent water, while green the land. Additional 3D views of the layout can be found at this work's online Github repository.

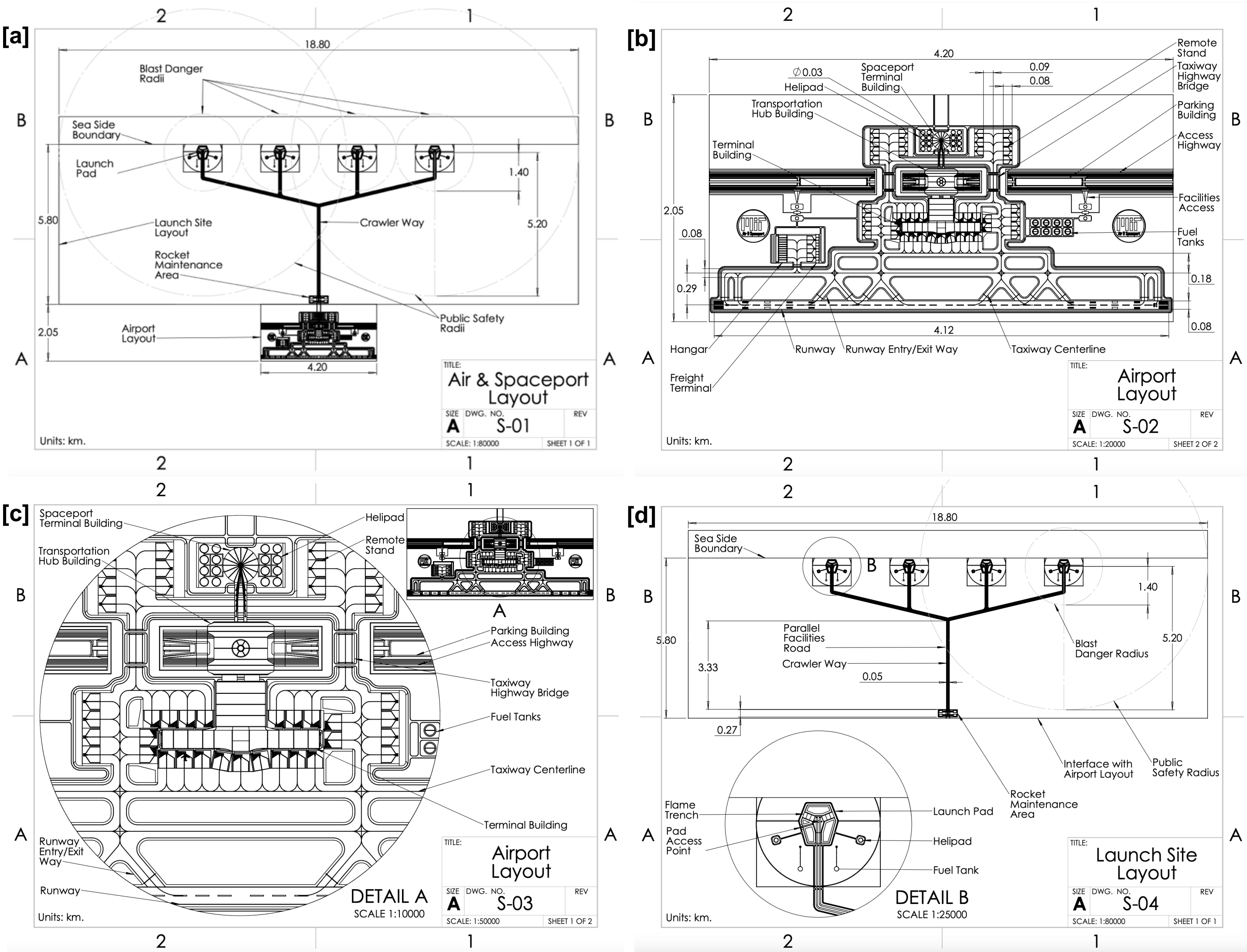

Figure 2: Engineering drawings for the integrated Air & Space Port. **[a]** depicts the full combined layout; **[b]** only the airport layout portion; **[c]** a zoomed-in view of the airport; and **[d]** only the launch site layout. Here, the blast danger radius and the public safety radius follow the guidelines identified in ***Section 2.3.2.***, of 1.4 and 5.2 km.

2.5. Layout Parametrization

Although non-exhaustive in scope and subject to change with time, the visualizations and schematics on **Figure 3** and **Figure 4** allow for first-order estimates of the land requirements to build an integrated Air & Space Port. As can be seen visually, most of the layout's land would be allocated to the launch site area, due to both the large safety separation requirements between the launch pads and the public area and also between the launch pads themselves, as determined in ***Section 2.3.2.***

The current Air & Space Port design, with a single runway, four launch pads, and a sea-side configuration (i.e., the launch pads are located adjacent to the water, so to enable launches towards the sea) has a total area of 117.6 km^2 (8.6 km^2 for the airport, 109.0 km^2 for the launch site). Under the baseline design configuration, the launch site area would be 12.7 times bigger than the airport itself (109.0/8.6). However, the area of the launch site itself could be parametrized according to the number of launch pads, n, as shown in **Eq. (2)**:

$$\mathrm{Area}_{\mathrm{Launch\ Site}} = 5.80 \cdot (2 \cdot 5.20\ + 2 \cdot (\mathrm{n}-1) \cdot 1.40) = 11.6 \cdot (5.20\ + (\mathrm{n}-1) \cdot 1.40) \tag{2}$$

When $n = 4$, $\text{Area}_{\text{Launch Site}} = 109.0\ \text{km}^2$, as reported above. As can be seen, if the number of launch pads was different, or the configuration changed from sea-side to in-land, the land requirements could change abruptly. To this end, **Table 3** below denotes the results for several launch site configurations, considering the number of launch pads and the specific location (i.e., sea-side, in-land) of the Air & Space Port. Ranging from one launch pad to five, and sea-side to in-land configuration, the launch site to airport area ratio could be as small as 7 (60.3/8.6) or as large as 26.1 (224.6/8.6).

Table 3: Launch Site Layout area (in km^2), for a variety of configurations. The number in parenthesis denotes the ratio between the Launch Site area and that of the airport Layout. If the configuration changed from sea-side (as shown in the schematics) to in-land, the $5.80\ \text{km}$ vertical distance factor shown in **Eq. (2)** would increase to a minimum of $2 \cdot 5.20 = 10.40\ \text{km}$ (i.e., twice the public safety radius).

Number of Launch Pads	1	2	3	4	5
Sea-side Configuration	60.3 km^2 (7x airport)	76.6 km^2 (8.9x airport)	92.8 km^2 (10.8x airport)	109.0 km^2 (12.7x airport)	125.3 km^2 (14.6x airport)
In-land Configuration	108.2 km^2 (7x airport)	137.3 km^2 (15.9x airport)	166.4 km^2 (19.3x airport)	195.5 km^2 (22.7x airport)	224.6 km^2 (26.1x airport)

While there could be more efficient layout considerations that would minimize the land requirements (i.e., a non-rectangular layout, or having the launch pads be placed radially from the airport), the linear layout featured in this work maximizes the distance between the launch pads and the runway, so to minimize disruptions on aircraft traffic.

3. Conclusion

The present study constitutes the first literature attempt at visualizing and understanding the land requirements of an integrated commercial Air & Space Port concept with vertical rocket launches. For the demand forecasts for both passenger and freight space traffic at the facility, this work estimated that 117.6 km^2 of land would be needed. However, this result is dependent on the specific layout configuration chosen (i.e., rectangular or radial, sea-side or in-land), as well as the employed assumptions on the forecasting model, which influence the key design variables of number of launch pads, number of runways, and number of aircraft parking positions. Parametrizing these design options, the combined facility could therefore require as little as 68.9 km^2 or as much as 233.2 km^2 of land, the latter being comparable to the size of some small island countries.

Albeit first order estimates, this work represents a starting point from which further work can build upon to further refine the conceptualization and design requirements for an integrated Air & Space Port. While the specific land requirement numbers will change over time as both aircraft and space technologies advance (and perhaps enable a reduction in separation distance), the magnitude will likely fall in the 50 km^2 to 200 km^2 range. This is a non-trivial amount of land to secure, especially close to the equators (to favor rocket launch trajectories). Airports, which are often considered the largest built area polygons at the city they are located at, tend to be smaller than 50 km^2 in area. In fact, only four airports in the world are currently larger than 50 km^2 in size, i.e., Dammam (DMM), Denver (DEN), Dallas (DFW) and Orlando (MCO) (World Population Review, 2025). As a result, it is critical to not only conduct further research into Air & Space Port designs, but also commit as early as possible to securing the land, especially in the context of other competing land uses.

This work focused purely on layout design, and as such excluded several aspects pertaining to Air & Space Ports that are important to examine, but not relevant to this work's scope. Future work could merit including a hazards assessment to determine appropriate airspace restriction areas; an overview of the operations and logistics of the integrated facility; as well as an analysis of the commercial viability and environmental impact of Air & Space Ports.

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