Challenges with the Integration of Airports and Spaceports

Final Report

Prepared for

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Executive Summary

The Federal Aviation Administration (FAA) and our project team are beginning to research information within the topics of ground support infrastructure, personnel, flight challenges, and community infrastructure when dealing with airports and spaceports as commercial space travel is beginning to become more common. In the commercial space industry, launch vehicles are being launched at an increased rate, and they affect the safe operations of the aviation industry and the other users of the NAS, as well as the uninvolved public community. Our research identified five challenges that fall within the categories of flight challenges, personnel, ground support infrastructure, and community infrastructure. These challenges we identified affect the progress of integration of airport and spaceport activities.

Specifically, the flight challenges include delays and reroutes of flights, mainly originating from safety precautions. There is also a lack of real-time communication between air traffic controllers and space operators. The lack of real-time communication affects how long a restricted airspace is up, as well as contributing to the possibility of human error in communications. With that said, air traffic controllers are also not trained to work with space operators and their operations. This is because communication systems in place now do not allow for that collaboration, preventing real-time information to flow between pilots, air traffic controllers, and space operators. Outside of those, infrastructure is also a very important factor to support the frequency of launches. In-land spaceports like Oklahoma Air & Spaceport, and others, do not have all the infrastructure needed to support current launch operation trends, mainly with most having runways and not vertical launch pads like Cape Canaveral or Vandenberg. Community infrastructure is also another factor that could pose a challenge. The acceptable risk for launching space vehicles is not as low as the acceptable risk for the operation of airplanes, and as such, it is best to have the infrastructure and emergency plans ready to respond to possible catastrophic events.

Introduction

Project Statement

The current growth and trend of the commercial space industry indicates there is a gap between the current training methods and future commercial space transportation needs. The FAA must be able to adapt to this changing environment and their training roadmap must reflect this. The goal of the FAA for this project is to be able to create a roadmap for future training needs, and in order to do this, they will need the right information on areas that need to be addressed. This information will be provided through in-depth research on different areas of interest in commercial space operations. Team 3 will be conducting an analysis and specifically focus on the challenges associated with the commercial space operations near or at airports and dual-use airports such as Mojave Air & Spaceport, Colorado Air & Spaceport, Cecil Air and Space Port, Oklahoma Air & Spaceport, Houston Spaceport, and Midland Spaceport. The FAA is interested in knowing the unique challenges that are relevant in the following areas: ground support infrastructure, personnel, flight challenges, and community infrastructure.

Overview

This segment of the report contains the sections of Organization Background, Current Situation, and Current Operational Challenges. The Organizational Background consists of background information on the FAA and their involvement in space operations, providing a context for the project task that Team 3 is tasked with. The Current Situation Analysis provides a general view of the current situation in the space industry and how it came to the current situation. The Current Operational Challenges outlines the number of challenges the FAA could face with the current commercial space operations when the activities of spaceports and airports interact.

Organizational Background

The Federal Aviation Administration (FAA) is a transportation agency of the United States government and regulates civil aviation domestically as well as the surrounding international waters (*What we do*, 2016). The FAA strives to provide the safest and most efficient aerospace system in the world. They integrate new types of technologies into the airspace, such as unmanned aircraft systems and commercial space vehicles (*Mission*, 2021). The FAA must rationalize and rebalance existing services while modernizing the existing infrastructure to reduce costs and become more efficient in the long term.

The FAA's Air Traffic Organization oversees safety over the National Airspace System (NAS), which covers millions of airspaces in the United States (*Air Traffic Organization*, 2017). With multiple companies such as SpaceX and Blue Origin receiving licenses to launch into space, the commercial space transportation industry is an area of large growth in the coming years. The FAA also licenses all commercial space launches and reentries, which means these launches and reentries must be integrated into the National Airspace System for public safety (*About the Office*, 2021). Currently, the Commercial Space Launch Competitive Act prohibits the FAA from regulating passenger and crew safety until October of 2023 (*Space Law*, 2021). This prohibition for the FAA means they are tasked with finding innovative training methods for when the prohibition ends in 2023. Thus, the FAA needs data in order to develop a training innovation roadmap to plan for future training needs to maintain safety and efficiency.

Current Situation

Human space tourism has been the buzz recently, especially with Blue Origin and Virgin Galactic sending their founders Jeff Bezos and Sir Richard Branson into suborbital space earlier this year. On July 11, 2021, Virgin Galactic sent Sir Richard Branson, Beth Moses, Colin Bennett, Sirisha Bandla, Michael Massucci, and David Mackay into suborbital spaceflight at Spaceport America in New Mexico. The crew members of VSS Unity, a SpaceShipTwo vehicle, experienced four minutes of weightlessness at 86 km above the surface of the Earth before finally returning to Spaceport America (Gohd, 2021). Just a couple of days later, on July 20, 2021, Blue Origin conducted its first commercial suborbital human spaceflight on New Shepard at their private launch site Launch Site One, with passengers Jeff Bezos, Mark Bezos, Wally Funk, and Oliver Daemen (Smith, 2021). The crew flew past the Karman Line, an internationally recognized boundary of space, and experienced space for their first time (Mathewson, 2021).

There is amazing progress being made in the space economy, technological breakthroughs like reusable components from SpaceX has proved to be extremely useful in lowering costs for future launches. It is important to note that past launches are often sending satellites up into space or for scientific experiments, such as SpaceX's Starlink launches and Commercial Resupply Services (CRS) missions to the ISS (*Recent Launch*, 2021). Regardless of the trend, space launches are becoming more and more frequent. The launch sites around the United States must be adequately prepared to accommodate the increased frequency in the future to not inhibit the growth of the space industry.

As of 2021, there are 12 licensed space ports that are in operation throughout the United States (*Licenses*, 2021). These space ports are licensed by the FAA and are categorized as either federal ranges or are private ranges, owned by companies such as SpaceX and Blue Origin. With these 12 licensed spaceports, the spaceports that are used most often in the United States are Cape Canaveral and Kennedy Space Center in Florida, and Mid-Atlantic Regional Spaceport since 2012 shown in Figure 1; data gathered from FAA website Licensed Launches (*Licensed Launches*, 2021). These spaceports are mainly used by launch operators like SpaceX, Blue Origin, Rocket Lab, and Virgin Galactic.

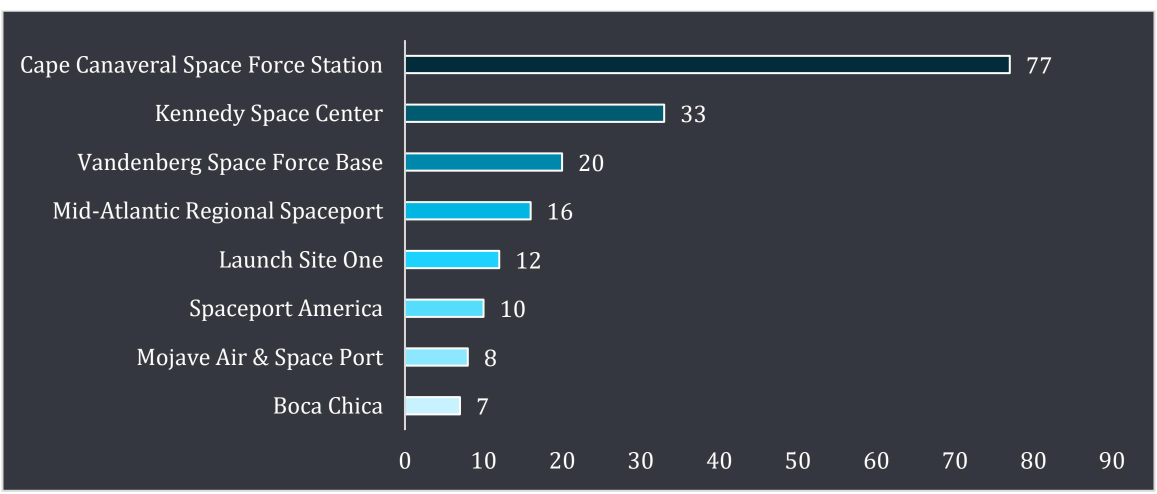

Figure 1 2012-2021 Summarized Launch Site Data

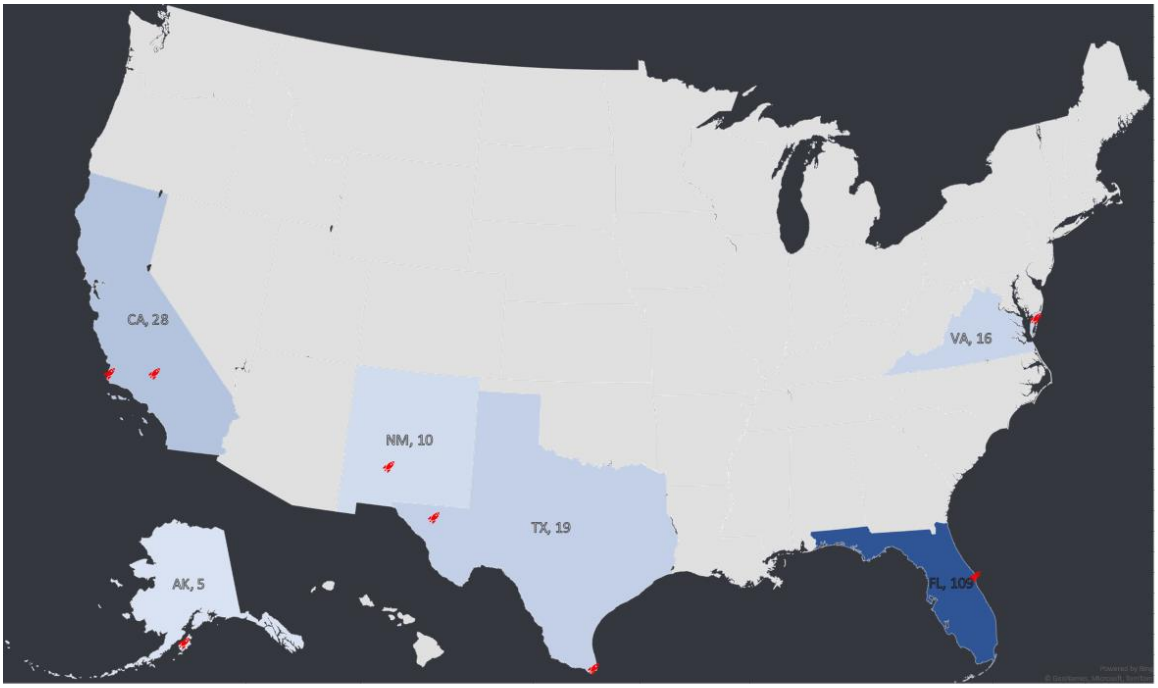

Figure 2 2012-2021 Launch Count by State

In Figure 2, all commonly used space port locations are located near the coast. With the pace of launches increasing year by year, launch sites will have to adapt to more frequent launches and/or these commercial space operators will have to utilize in-land spaceports, or dual-use airports. Some of these types of space ports are listed as the following: Mojave Air & Spaceport, Colorado Air & Spaceport, Cecil Air and Spaceport, Oklahoma Air & Spaceport, Houston Spaceport, and Midland Spaceport. Of these six in-land spaceports, only Mojave Air & Spaceport has completed licensed launches (*Licensed Launches*, 2021). There are challenges with the interactions of the space operations and nearby airports. The following sections describe the areas of concerns we have identified and recommend the FAA to investigate further to foster a safe and efficient NAS integration of space operations.

Current Operational Challenges

Flight Challenges

From the data that we have gathered from the FAA Licensed Launches (2021), we have calculated the average number of days between each launch throughout the years since 2012. Since 2012, the average days between launches throughout the year has decreased from 52 days to just 8 days in 2021, as shown in Figure 3. Considering it is only November in 2021, the more accurate days between launches this year is only 6.97 days. That is, on average, a single FAA-licensed space launch per week for the year.

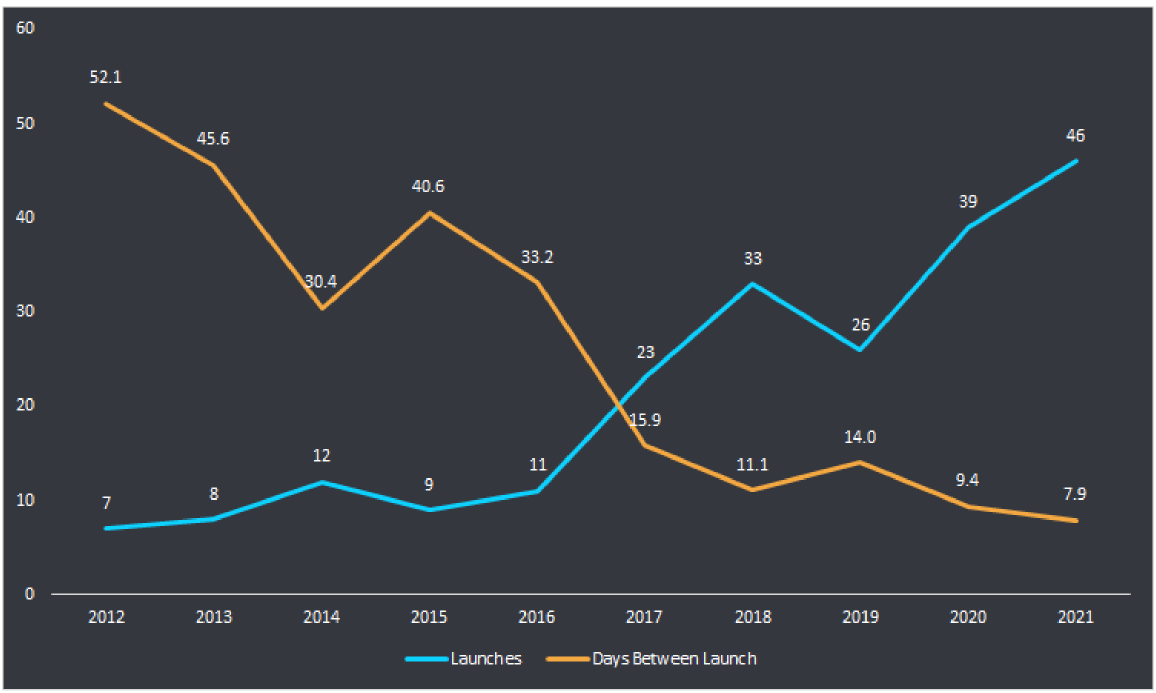

Figure 3 2012-2021 Launch Frequency and Days Between Launches by Year

The current method of protecting aircrafts from the launch operation is to separate them by restricting the airspace when space operations occur, preventing aircraft from entering that restricted airspace until the restriction is lifted (Modderno, 2020). Looking into the future, if the current airspace restriction continues, the FAA would be looking at restricting airspace near the coasts on a regular basis week by week. This impact would disrupt the NAS and likely cannot be sustained and would need to be addressed.

The restrictions used are often Altitude Reservations (ALTRVs) or Temporary Flight Restrictions (TFRs). According to Modderno (2020) ALTRVs "dictates airspace use under prescribed conditions and are normally employed for the mass movement of aircraft or other special user requirements that cannot otherwise be accomplished." The ALTRVs restrict the airspace around the launch site from the ground and to unlimited altitude. TFRs on the other hand are "temporary regulatory actions that define dimensions of airspace to prevent aircraft from operating near events including VIP movements, air shows, sporting events, hazards, disaster relief, and space flight operations (Modderno, 2020). These restrictions are sent to the aviation community as NOTAMs before the operation begins and are lifted once completed. One of the major issues when a launch operation is underway is the fact that it causes flight delays and reroutes of many flights from nearby airports. Before a launch, NOTAMs are sent out and it includes the coordinates of the affected airspace that is to be avoided by other users of the NAS (Modderno, 2020). This area of restricted airspace affects nearby airports, especially around populated areas around Kennedy Space Center in Florida or Mojave Air and Spaceport in California. The restriction does not allow aircraft like commercial airliners to fly before or during the launch window until the operation is complete, and the risks are cleared. This is for the safety of the aircraft and the public, as each space operation can be considered a "controlled explosion." According to Wayne Monteith of the FAA (Safe Skies for All, 2019), the launch vehicles are manufactured and launched under a certain amount of allowable risk; however, this allowable risk is much lower than the allowable risk for commercial aircraft. It is one of the main reasons for why current space operations needs to be separated from commercial aviation and near the coasts and ocean. If there was an off-nominal event, any explosion would occur over the ocean and not over land, making it safer for the population in-land and the flights that are delayed and rerouted away from the restricted airspace.

One of the more recent examples of an off-nominal event was the SpaceX CRS-7 launch mission in which "approximately 139 seconds into the flight, the launch vehicle experienced an anomalous event in the upper stage liquid oxygen (LOx) tank, resulting in the loss of the mission" (NASA, 2018). The craft went from flying fine to conflagration within an 800-900 millisecond timespan (NASA, 2018). This shows just how quickly things can go wrong with any type of spacecraft. Luckily, no one was injured during this anomaly and a lot of that has to do with the location of the launch site. The launch site for the craft was Cape Canaveral on the coast of Florida (NASA, 2018). Since it was on the coast this allowed the debris and capsule to fall into the ocean rather than on a populated city or any other structures. This is a prime example of understanding the dangers of spacecrafts and choosing the appropriate locations for launch sites.

If the space operations continue to remain on the coasts, the frequency of these disruptions will become a problem. This challenge brings the commercial space operators to possibly utilizing in-land space ports and dual-use airports. However, the use of in-land spaceports and dual-use spaceports are also affected by this challenge. If a flight is delayed or must reroute from nearby airports it can be very costly to everyone involved, especially the airports that had to make the appropriate adjustments for all flights during the launch window. According to data from the FAA in 2019 on "Cost of Delay Estimates" the price of delays for the year came out to be 33 billion dollars (*Cost of Delay* Estimates, 2020). According to Airlines of America "U.S. Passenger Carrier Delay Cost" the cost per minute of a flight delay is $74.24 (2020). Both numbers presumably have gone up significantly by 2021 due to Covid-19 and other factors. This is looking at four main components: Airlines, Passengers, Lost Demand and Indirect. Airlines is looking at cost associated with crew, fuel, maintenance, and other factors. Passengers is looking at cost dealing with time lost whether it's from a delay or a reroute. Lost demand is talking about the loss of demand for people that will want to fly again or more specifically fly with that specific airline. Finally Indirect is dealing with the cost of doing business with other sectors outside of aviation.

The FAA and the airline companies themselves need to look at how reroutes and delays are handled. As seen in figure 4, about 80% of flights are on time (flight departed within 15 minutes of scheduled time) but most flight delays are either caused from issues with the NAS or late arriving aircrafts. These are two issues that can be improved upon by using better data to get planes from point A to point B in timely manner and accurately adjust the NAS. As of 2019 the average flight delay was 12.4 minutes (All Things On Time, 2020). If the FAA and airlines could get this number down to 10.4 minutes per delay, they speculate that it would save about 16% or $148.4 per delay.

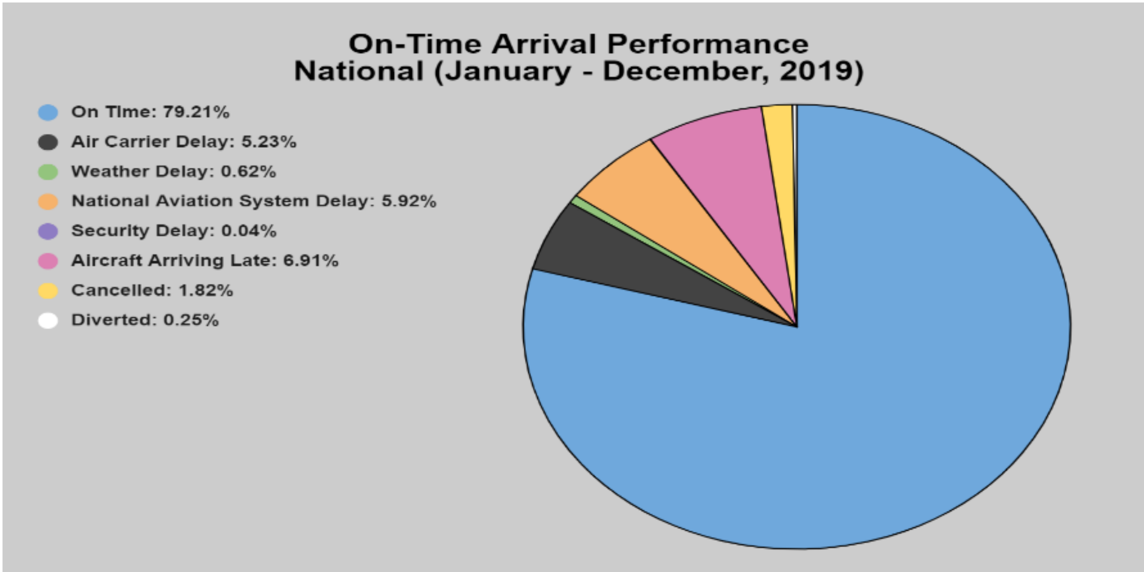

Figure 4 2019 Airline On-Time Statistics and Delay Causes

As other users, including space travel of any kind, become more prominent in the aviation sector the costs of transportation and other means will only continue to increase and the NAS will become more and more crowded. If we continue to look forward, we could see point-to-point travel become a very real reality and could be used by the public in the future. When looking at that we could only assume that it will bring more issues and increased prices as it already costs more money to fly, fuel, maintain, and be a passenger on a spacecraft of any sort. One thing the FAA could investigate is permanently restricting airspace around point-to-point spaceports. This would help the point-to-point industry grow as they would not have to worry about getting permission to use the airspace which would create less chances for day-to-day setbacks. On the other side of it, it would make it so that airports and other spaceports would need to be aware of this permanently restricted airspace. Although the airspace would be technically always restricted this doesn't mean that other users couldn't use it if they received permission. If you were to permanently restrict airspace you would need to look at locations that would be optimal for this scenario. You wouldn't want to pick high traffic locations to start with as this could cause a lot of trouble for everyone involved including the public, becoming a logistical nightmare. Looking to the future there is a lot of uncertainty around point-to-point travel so the needs and regulations are still not finalized. This leaves a lot of room for the FAA and other parties to figure what would be the best way to ingrate point-to-point travel into the already existing systems or systems of the future.

Personnel

The continued success of the NAS is not possible without proper guidance from air traffic management. FAA's Air Traffic Organization (ATO) is responsible for providing safe air navigation, and under ATO, there are more than 14,000 employed air traffic controllers that operate from the 700 FAA facilities (*Air Traffic Organization*, 2021). They are primarily responsible for guiding thousands of pilots and their planes, and more than 2.7 million passengers from taxi to takeoff to safely landing on a daily basis (*Aviation Careers*, 2021). These air traffic controllers are trained rigorously at the Mike Monroney Aeronautical Center in our very own state of Oklahoma. Their training includes operating with air traffic control simulators, and that can take anywhere from two to four years before becoming FAA certified (*Collegiate Training Initiatives*, 2021). Air traffic controller training includes in Terminal (Tower), approach and depart, and En-Route operations. The users of the NAS are part of the commercial and private aviation industry, as well as military.

To provide this safe environment, communications between air traffic controllers and pilots must be clear, fast, and efficient. This also extends to the communication with other users of the NAS to provide safety to all involved and uninvolved parties. With the nature of commercial space operations, air traffic controllers must guide other users of the NAS away from launch operation sites to maintain safety of other aircrafts. However, the current process to manage the airspace is accommodation due to safety reasons, but indirectly also because of how information is flowing between launch operators, air traffic controllers, and other users of the NAS.

Another entity who also plays a vital role in airspace management are the members of the Join Space Operations Group (JSpOG). The JSpOG is made up of people from the Air Traffic Control System Command Center Space Operations Group (ATCSCC SOG) and members from the Office of Commercial Space (AST) (Mathewson, 2020). JSpOG manages the decision-making of airspace management planning process by assessing the proposed operation plan and alternative strategies for safely and efficiently accommodating the missions by working with space operators and the appropriate ATC facilities (Mathewson, 2020). Their responsibility also includes distributing necessary information and respond to off-nominal events.

The following quote describes the role of the JSpOG in detail,

> "On the day of the launch/reentry operation, at least one JSpOG representative monitors and evaluates the status of the operations in real-time, distributes necessary notifications and information, and remains prepared to respond to off-nominal events. Post-launch or reentry, the JSpOG evaluates the effectiveness of the AMP, gathers lessons learned, maintains historical launch/reentry information, and prepares operations reports for FAA management." (Modderno, 2020).

From the process described above, we note that the air space management process has an aspect to it that is inefficient. The inefficiency occurs when the launch operator communicates to either AST safety inspectors or JSpOG representatives, and then that information is then communicated again to the appropriate ATC facility. Through this "game of telephone", accurate information and communication details could be lost through this transfer from person to person. Without a direct communication from launch operators to air traffic controllers, certain details regarding mission status and other necessary information could not be communicated across perfectly and increase the possibility of human errors. This lack of real-time situational awareness makes integration difficult to achieve. Integration of the NAS must be safe for all parties involved and uninvolved. Without clear-cut situational awareness by real-time communications, air traffic controllers will have some difficulties in maintaining an efficient and safe NAS.

Air Traffic Controllers Needs Updated Training and Tools

We have mentioned previously that space operations are launching more and more frequently. There have been plenty of launches into space, however with regards to commercial space, the focus for our project will be on FAA-licensed launches. Directly from the FAA website, there have been 419 licensed launches since 1989, with the most recent space launch occurring earlier this month on November 13, 2021, when SpaceX sent Starlink satellite to space (*Licensed Launches*, 2021). Compared to just six years ago in 2015, the FAA had only licensed 9 launches, and as of November 17, 2021, the FAA had licensed 46 launches alone in 2021 shown in Figure 5. If this trend continues to 2025, the FAA could see up to 60 or more launches in a single year (*FAA Aerospace Forecasts*, n.d).

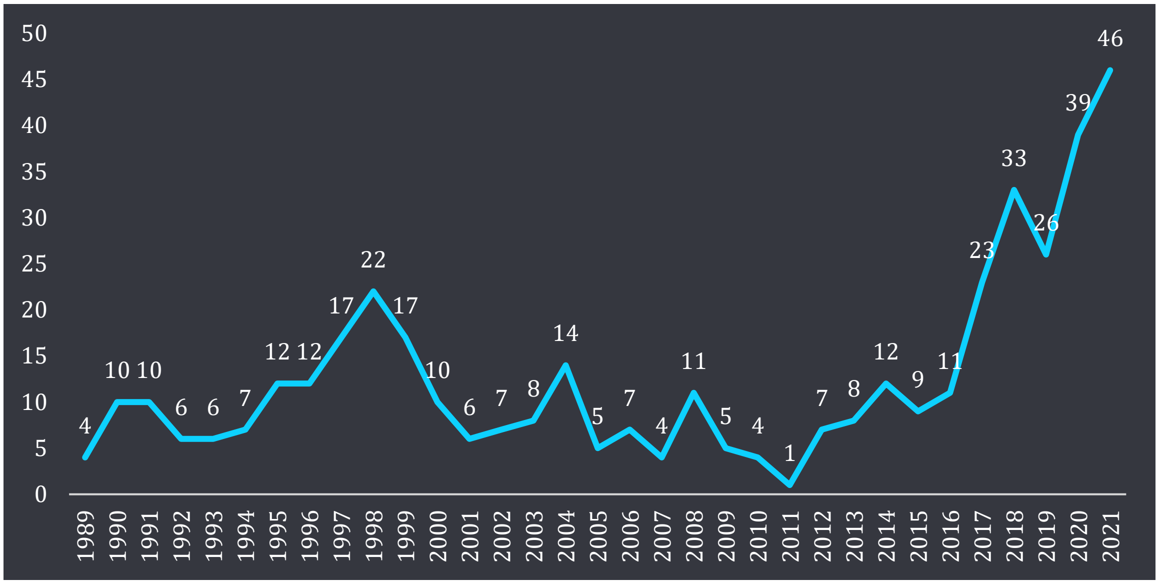

Figure 5 Summarization of Number of Launches by Year

The future is uncertain. Breakthrough technological advances could be underway as we speak and could very well increase the frequency of launches even more by next year. What we do know for sure is that air traffic controller training at the FAA Academy does not incorporate activities space operators. The training begins with classroom instruction with basics training aimed to train individuals with no prior knowledge of aviation. The next phase is to move to simulation training, which includes being trained in Air Traffic Control simulators and gain the experiences and skills needed to become successful by experienced instructors (*Air Traffic Technical Training*, 2021). The training typically takes around two to four years, and finally passing an exam to become a certified air traffic controller. This training only pertains to guide users in the aviation industry, with no training regimen to accommodate working with space operators like SpaceX or Blue Origin and others. Without training to incorporate users of commercial space, the current space operations process can prolong launch communications, and the back-and-forth flow of information between parties can result in mistakes. To prevent this from happening, it is best to develop additional training and tools to help integrate space operations into the current training program at the FAA Academy.

Air traffic controllers and must be close working partners with space operators for efficient and proper NAS management. A lack of this communication and training between the two can lead to cost and tragedies, no matter what kind of air or space travel is being conducted. A survey of the U.S. National Aeronautics and Space Administration (NASA) Aviation Safety Reporting System states that incorrect or incomplete communication between the two are a major factor in 80% of incidents or accidents. Accidents in the NAS affects all users of the NAS and the public community, it can lower trust of flying customers of airlines across the United States and across the industry if an aviation disaster were to occur. Air traffic controllers and launch operators are equally involved in the air traffic management system, therefore, as potential commercial space travel possibilities increase, the training on means of communication must be highly emphasized to achieve maximum efficiency and safety.

We do not have much information regarding the air traffic controller tools that are available to the ATC. However, we do know that the tools that are used by air traffic management rely on manual interfaces (Modderno, 2020). To our understanding, this means that tools and control systems at the FAA facilities are decades old systems that are not adequately prepared to integrate space operations into the NAS. Air traffic controllers should be able to communicate directly with space operators given the technology that we have today. However, the transition from legacy systems to new modern ones cannot be done overnight. The transition will have to be phased in, little by little, small changes in technology tools at a time. If there was a sudden change in the tools used, there could be unforeseen consequences that will affect the integrity of the NAS.

Ground Support Infrastructure

The infrastructure needs at a spaceport largely depends on the type of operations that they support. There are two types of space launch vehicles: vertically and horizontally launched. Vertical launches are the most common type of launch, and they are just like you would imagine launching a conventional rocket. The Space Shuttle is an example of a vertically launched space vehicle that everybody knows. A vertically launched rocket or vehicle would have one to three stages, with the first stage launching the vehicle or rocket off the Earth, and the second and third stage will continue the rest of its journey (Space Expert, 2021). Horizontal launches on the other hand requires an aircraft to lift off a runway and carry the rocket or launch vehicle into the air, and then release it mid-air before and continues its mission (Space Expert, 2021).

To support a vertical launch, spaceports will need certain ground support infrastructure to support these types of launches. Ground support infrastructure is defined as all things around airports and spaceports needed to make things happen. This includes taxi ways, airport runway service, ground radars, airport lighting, fuel, and propellants and much more (*FAA Should Examine*, 2020). At Cape Canaveral, some of these facilities are hangars to store the launch vehicles, a wide enough launch pad and support erected in place, hypergolic maintenance facility, landing zone, cargo processing facility, non-hazardous and hazardous material processing, etc. (Space Florida, 2017). The communication systems in place are also critical to launch operations, there will be demand for reliable communication methods. At Cape Canaveral, some of these communication systems include traditional telephone service, countdown and timing, weather, range safety, paging and operational intercommunication systems, radio-frequency communications, wideband fiber-optics, operational television, video transmission and recording, and video teleconferencing (Space Florida, 2017).

Horizontal launches on the other hand, do not need as much infrastructure in place. From Spaceport America, their facilities include infrastructure like multiple runways to support horizontal launch and landing, suborbital flight training and research, weightless flights, etc. Spaceport America also plans to build multiple hangars, passenger processing/operations facility, assembly/processing/manufacturing facilities, and propellant and fuel facilities (Spaceport America, n).

The most recent licensed launches used vertical launch vehicles like the Falcon 9 from SpaceX, New Shepard from Blue Origin, Alpha from Firefly Aerospace, and Antares from Orbital Sciences Corp. Out of the 418 FAA-licensed launches in the United States, 385 of them were launched vertically, while only 33 were horizontal. Percentage wise, 92% of all FAA-licensed launches were vertical, and only 8% horizontal. The launch vehicles making up this 8% are vehicles in the Pegasus rocket family from Northrop Grumman, the SpaceShipOne and SpaceShipTwo by Scaled Composites, and the LauncherOne from Virgin Galactic (*Licensed* Launches, 2021).

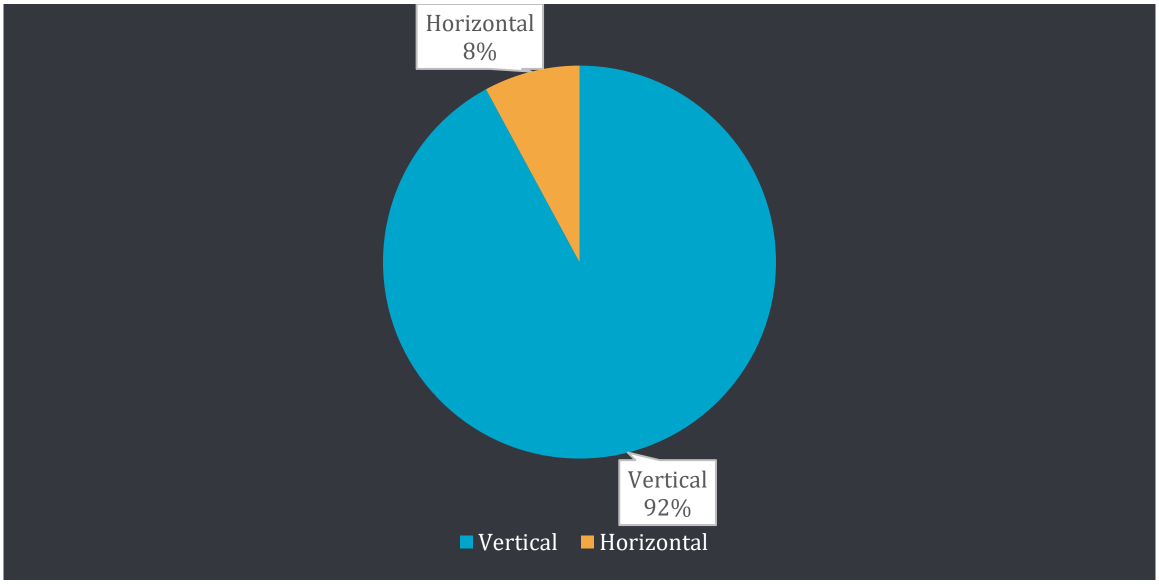

Figure 6 Summarized Vehicle Launch Type Data

The trend in the commercial space industry now is to support vertical launches, sending up astronauts, research, and satellites up into space. However, as more and more space launches occur, the topic of human space tourism and point-to-point space flight comes up. Space tourism includes orbital, suborbital, and lunar space tourism (Von ver Dunk, 2011). These types of transport will likely be both vertically and horizontally launched. Point to point space travel on the other hand is the idea of launching a rocket into space and having it land at another location, making it possible for bringing supplies or people from one side of the earth to the other in under an hour (Sheetz, 2021). However, human space travel is very expensive and not expected to be a common occurrence until the risks and the costs of such travel comes down tremendously. Until then, FAA is very likely to only work with vertically launched vehicles into space. The infrastructure at in place now at active launch sites supports the current frequency of launches, however, as more of these occur, these launches will likely have to move in-land to dual-use airports because such launch sites have not been able to support multiple launches on the same day or back-to-back ones by different launch operators (*FAA Should Examine*, 2020).

This brings us to look at the infrastructure of in-land spaceports or dual-use airports. Many of the infrastructure upgrades at the spaceports have been funded from established launch providers; they have funneled hundreds of millions to upgrade the existing launch sites to meet their needs and other requirements (*FAA Should Examine*, 2020). For example, SpaceX had funded the construction of a vehicle assembly building, payload processing facilities, and even a launch pad at Cape Canaveral. These infrastructures are critical to their commercial space launch operations, funding the construction out of pocket at the launch sites. Blue Origin, on the other hand, had gone and built their own launch facility out in West Texas to support their needs. In-land spaceports

Through our research, we have found the following information regarding five of the in-land spaceports. The information is summarized below in Table 1.

	Colorado Air and Space Port	**Cecil Spaceport**	**Oklahoma Air and Space Port**	**Houston Space Port**	**Midland Space Port**	**Mojave Air and Space Port**
Runways	Two	Four	Two	Three	Four	Three
Vertical Pad	No	Unknown	Yes	No	Unknown	unknown
Hangar Space	T and Box Hangars; 790,000 SF	18,200 SF	6 Hangars 100,000 SF; 96 Acres Aircraft Parking Space	T Hangars	Yes	T Hangars
Control Center	Unknown	Yes	Yes	Yes	Unknown	Unknown
Processing Facilities	Unknown	Unknown	50,000 SF Manufacturing Facility	Unknown	Unknown	Unknown
Fixed Base Operator	Yes	Yes	Yes	Yes	Unknown	Unknown
Fuel/Oxidizer	Fuel: Yes Oxidizer: In planning	Fuel: Yes Oxidizer: In planning	Fuel: Yes Oxidizer: Unknown	Fuel: Yes Oxidizer: No	Fuel: Yes Oxidizer: Unknown	Fuel: Yes Oxidizer: Unknown
Material Storage	Unknown	Yes	Hazmat Storage	Unknown	Unknown	Unknown
ARFF	Yes	Yes	Yes	Yes	Yes	Yes
Roadway Access	Highway, Rail	Multi-modal Transportation Networks	Rail	Highway	Highway	Highway, Rail, Seaport
RLV Storage	In Planning	Yes	Unknown	Unknown	Unknown	Unknown

Table 1 Spaceport Infrastructure Summary

The challenge here is that the infrastructure needs to be upgraded and there needs to have construction of new facilities and storage areas to support launches. Most of these in-land spaceports have some sort of infrastructure ready to support horizontal launches and they do not have the infrastructure ready to support vertical launches. Infrastructure needed for horizontal launches include things like traditional, fuel and oxidizer storage, hangar space for storing the vehicles, as well as control center for operations and a communications system. Infrastructure like runways, command control center, hangar space, and fixed base operator are in place at majority of these spaceports. Other infrastructures like processing facilities, material storage, and oxidizer storage are lacking. Processing facilities are necessary to put together the launch vehicle and make sure all the components are assembled on site. Material storage is also necessary to store payloads and other substances that the space operator needs. And most importantly, proper oxidizer storage for the launch vehicle. Oxidizers are a severe fire hazard and must be properly stored or risk explosion. Because of the lack of some necessary infrastructure, in-land spaceports cannot be compared with other licensed launch sites like Cape Canaveral, Vandenberg, Boca Chica, and many more. As a team, we suggest FAA should investigate these risks and address them for future launch and training activities.

Spaceports like Cape Canaveral have these infrastructures already in place, as they have been supporting space launches since the 1950s (Space Florida, 2017). Cape Canaveral, Vandenberg, and Kennedy Space Center has decades of experience and infrastructure to support commercial space operations, and their locations make it easier to launch into space. That is why they are so often chosen as launch sites. However, in-land spaceports do not have that same appeal. Being in-land and a dual-use airport, it is not an ideal landscape to launch. With the trend vehicles being launched vertically, only Oklahoma Air and Space Port has a launch pad for such operations, while the rest are either unknown or do not have one (*Spaceports by State*, 2021). The risk of vehicular explosion of these launch vehicles can make companies avoid using in-land launch sites and prefer coastal sites because of the safety implication. Other risks among this include the potential of hazardous fueling damaging the environment and community among the spaceports. This would have the community in concern for safety as well as possible noise abatement – distracting to ground and area ports. Despite this, many of these spaceports are making progress to upgrade their infrastructure to support space operations. Spaceports like Colorado Spaceport and Cecil Spaceport have plans or already have a Reusable Launch Vehicle storage area, where they can store these launch vehicles safely away to prevent damage from explosion to other areas (Front Range Airport, 2019). Spaceports like the ones in Oklahoma, Houston, and Midland does not explicitly state they have these infrastructures in place, and therefore are unknown. Other infrastructure like hazardous and non-hazardous material storages and processing facilities are also unknown for many of these space ports. Many of these space ports have enough land to build these structures, it comes down to being able to fund the construction and attracting potential companies to set up at the site and start launching.

Community Infrastructure

Growing rates of space launches results in growing needs of community infrastructure in cities with spaceports, specifically mainland cities that are not on a coast. This is because the safety of all personnel is reliant on an effective and efficient community infrastructure. We see this in the case of United Flight 232 disaster that took place in July of 1989. This was a routine flight from Denver, Colorado to Philadelphia via Chicago. While flying over Alta, Iowa the number 2 engine located in the rear of the airplane exploded, eventually leading to complete hydraulic failure of the aircraft (Charles, 1991). Without the hydraulics system, the pilot had no control over Flight 232's rudder, elevator, and ailerons, which control the jet's turns, pitch and roll. The pilots were also without wing flaps, used in landings and takeoffs, and brakes (Charles, 1991). With three hydraulic systems built into the aircraft, the catastrophic failure of the three redundant hydraulic systems is considered a highly remote possibility for the aircraft. In fact, the possibility is considered so minute that pilots are neither specifically trained to respond to such a catastrophe, nor are flight manuals written with instructions on how the flight crew is to proceed under such circumstances (Charles, 1991). Not 30 minutes later the plane had crashed in Sioux City, Iowa. This is when the importance of community infrastructure was really shown.

Sioux City had a disaster plan put in place; on the off chance an aircraft disaster were to occur. When it was clear that Flight 232 was going to crash, Sioux Gateway Airport, tower personnel contacted the Sioux City communications center to inform them of the situation. The communications center dispatched Sioux City firefighting personnel, police, and ambulance services to the airport (Charles, 1991). They also called nearby cities to get more ambulances and equipment to the scene, since they only had 5 ambulances in the city. "During this time both MHC and St Luke's Regional Medical Center were implementing preliminary pre-disaster procedures. At St Luke's, the Mass Casualty Plan was instituted, putting into action several predetermined and planned-for activities within the hospital. Hospital staff began preparation of the emergency room and burn unit, and phone banks were set up in the control center, while staff and physicians arrived to prepare for burn patients and other emergency needs" (Charles, 1991).

The city also blocked off an entire one-way road to the hospital so the ambulances would have a direct path with no traffic. The success of this method and the efficiency of the rescue effort were demonstrated by the fact that the first severely injured patient entered the emergency trauma center at MHC only 16 minutes after Flight 232 crashed and burst into flames. Equally telling of the efficiency of the rescue effort is the fact that all 48 seriously injured and 40 less seriously injured victims had been cleared from the crash site and transported to the MHC trauma center 39 minutes after the accident (Charles, 1991).

The analysis report written by Charles (1991) on the disaster has concluded that a good disaster plan should have:

(1) Incorporate the plan into normal routine practices on a regular basis by agencies.
(2) Multi-agency cooperation and communication must continually exist.
(3) Planning must have training, testing, and updating.
(4) The plan must be flexible and short enough to be understood by all in any type of disaster.

We know community infrastructure is a vital part of keeping people safe regarding airplanes, but now we must also look at how community infrastructure can help improve the immersion of space travel as well. There are a few main concerns to consider when attempting to implement a solid disaster plan in cities with spaceports. Looking at hard infrastructure, being able to block off certain roads and intersections for ambulances to make it to the hospital as quickly as possible might be an issue in bigger, more populated cities. However, it is extremely essential for a disaster plan to work effectively. Therefore, the FAA should consider looking into this when thinking of community infrastructure near spaceports.

Soft infrastructure has a bit more of these concerns. The first one being community involvement. Often, the individuals that work in jobs like first responders have minimal down/free time due to the nature of their work. Most EMT's and paramedics work over 40 hours a week, and because they must be available to work in emergencies, they may also work overnight and on weekends. Some first responders work in 12-hour shifts and sometimes even 24-hour shifts (U.S. Bureau of Labor Statistics, 2021). This may result in some difficulties in getting additional training for disaster events. The FAA must find a way to incorporate the new training methods into their everyday routine for this problem not to occur.

A second concern that falls under soft infrastructure is the amount of time and money it takes to train a whole community. As you know it takes anywhere from 2 to 5 months to complete training at the FAA (FAA, 2021). To become an EMT it usually takes around 120 hours of instruction (Unitek EMT, 2021). With that said, we can assume it would take around 1 to 3 months for communities to fully understand a brand-new disaster plan and be able to execute it correctly. Therefore, creating a system that is uncomplicated and that can be comprehended by every member involved could be very beneficial.

The third and final concern under soft infrastructure is the ambiguity between spacecrafts. Since most of the launches are happening from private companies, there is potential to have an extremely high number of variations from spacecraft to spacecraft. This could cause problems if the first responders are not as knowledgeable about a certain spacecraft. With every company creating innovative designs, there will be lots of differences with each launch vehicle. In 2023, when the FAA can officially create regulations for these space vehicles, they might want to develop new guidelines and policies to regulate the design of new space vehicles, just like aircrafts.

Opportunities Moving Forward for the FAA

A new capability to further enhance situational awareness is the Space Data Integrator (SDI) being developed by the FAA. The SDI is used to enhance safety of launch and reentry of vehicles into the National Airspace System by receiving and distributing data to air traffic management. It will allow the FAA to track actual versus real launch and reentry and communicate this to the command centers. Although this is a large step in the right direction of airspace communication, there is still much need for air traffic control monitoring and awareness. The end goal is to ensure safety and efficiency while integrating more space travel operations while improving situational awareness. Currently, the Air Traffic Organization's team has an SDI prototype while the FAA continues to validate and work on requirements of the SDI (*The Space Data Integrator*, 2021).

Below are visual examples of the data the SDI gathers and what it is to be used for. In Figure 7, the SDI is locating hazardous areas which could occur during a launch regarding other aircrafts also in the air at that time, represented with the red and yellow. It is also shown where the Command Center communicates this hazard area to centers and towers so that they may set proper restrictions for safety, represented by the green. In Figure 8, it is showing how the once the hazard area relaxes, it is reopened for flights to travel through again, represented by the green (*Airspace Integration*, 2021).

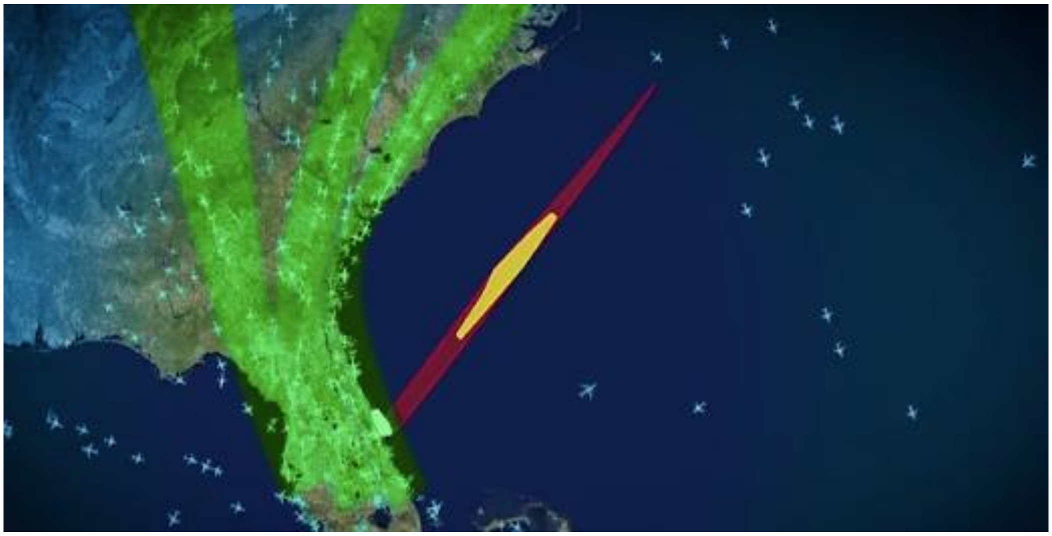

Figure 7 Locating Hazardous Areas and Communicating

Figure 8 Reopening Hazardous Areas Once Relaxed

There are and will be many new concepts and ideas that further the integration of these space operations into NAS systems. Some of these currently being researched include strengthened situational awareness and improved monitoring and alerting. These and many other future capabilities will allow better managing, routing, and scheduling during launch and reentry operations. All of this will continue to make safety certain as the FAA keeps up with the increasing commonness and complexity of these operations.

Looking at space travel, there are many different types of crafts being launched into space and of those crafts they have many different functions and purposes. The one thing they all have in common is that fact that they all take up airspace. Different types of launches such as a vertical or horizontal launch take up different amounts of airspace as well as the time around the restricted airspace. Unfortunately, there is a finite amount of airspace so looking forward there is an opportunity for the FAA to investigate different sectors. Those sectors include how to make the restricted airtime less, how to make the required restricted airspace smaller/permanently restricting airspace, improving lost cost due to delays or reroutes, location of new spaceports and the continued integration of airports and spaceports. For all these sectors using new and improved data plays a big role in figuring out how to best address these problems. Some key data that would be best to look at is how much "natural risk" there is around a location when thinking of sites to add new spaceports, scheduling data within the NAS to optimize the system and help eliminate an overload of flights within a day, and flight delay and reroute times in order to minimize the average flight delay time.

As the growth of commercial space travel continues it is vital to have strong ground support infrastructure near space ports. We have previously mentioned that most of the infrastructure upgrades are funded by private companies for their space operation needs. However, not all companies have the same resources that SpaceX or Blue Origin has. This means that the spaceports themselves would have to upgrade their infrastructure to accommodate and attract space companies to use their facilities for launches. With the growth of the industry, it is important that the spaceports have funding for these upgrades. We believe the United States has made a step in the right direction for this, as Congress has already passed the Space

Transportation Infrastructure Matching (STIM) Grants to match state, local, and private funds to upgrade spaceport facilities, funding technical and environmental studies, construction, improvement, and design and engineering of space transportation infrastructure, etc. (*FAA Commercial Space Transportation Grants Program*, 2021). We recommend the FAA continue to their support this program to fund better infrastructure and facilities for spaceports to not inhibit the growth of the commercial space transportation industry.

As well as expanding internally, the FAA can also expand externally through community infrastructure. The possibility of a spacecraft malfunctioning, and crashing is low, especially if you consider everything previously mentioned. However, that does not mean it cannot or will not happen. In the situation that a disaster does occur, the communities that harbor spaceports need to be ready to act. Implementing a disaster plan within the communities would drastically increase the chances of survival for passengers of said spacecraft. As the FAA gets more and more involved in commercial space travel, safety must be a top priority, and a great way to promote safety is by implementing disaster plans to communities throughout the United States.

Appendix A

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