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Sub-orbital Spaceflight – An addition to our multi-modal transportation system

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Abstract

The number of commercial spaceflights will be increasing by orders of magnitude over the next several decades. The current volume of space traffic can be managed on a case-by-case basis and there is little impact to the National Airspace System (NAS). This will change as more spaceports become operational, commercial sub-orbital flight companies begin serving their customers and as the cost of these flights begin to decrease. Current regulatory paths seek to allow the flexibility in the regulations for this industry to flourish while also maintaining a high standard of safety. There are, however, many nearsighted and outdated assumptions when considering these regulations.

This paper presents a vision of the future where we add another mode of transportation in our already multi-modal transportation system. Further, this paper presents a case for integrating airports and spaceports, including large hub airports. Included in this vision of integrated airport and spaceport operations will be a discussion on the shortcomings in planned regulatory paths and aspects of commercial space that need to be addressed so the old fashioned methods of regulating spaceflight can be rejected.

Introduction

The world is on the threshold of an aerospace revolution. Transportation has evolved throughout the centuries from foot travel to wagons, trains, cars and airplanes. A future mode of transportation is evolving out of the space industry in the form of suborbital space flights. To date, aircraft innovations have been driven by energy prices and environmental concerns to produce more fuel-efficient aircraft. Aircraft top speeds have changed very little. Today's technology being developed to offer passengers the chance to experience the weightlessness of space is creating a foundation that will be repurposed to develop technology and vehicles that will offer hypersonic flights around the globe.

Spaceports today are being developed for research and development and to begin quick sub-orbital flights that go up to the boundary of space and return to the same spaceport. One example of an existing spaceport is Spaceport America, a standalone facility in the remote area of southern New Mexico, not easily accessible by passengers from around the world who seek to fly aboard the SpaceShipTwo spacecraft to make one of these adventurous flights. A standalone facility is great for the current era of innovation, where the technologies are being developed and proven but eventually, operations will become common place and affordable. Having standalone facilities is an important step in the timeline of developing a commercial space market but inevitably the sustainable market will be point-to-point (P2P) sub-orbital, frequent travel and this new mode of transportation will need to be added to the national transportation system (Peeters, 2010). Therefore, the missing element is that modern airports are not built to support the operations of spacecraft and airport operations have not been designed to include the unique requirements of commercial spaceflight.

This paper presents a vision of the future where another mode of transportation is added to an already multi-modal transportation system. Further, this paper presents a case for integrating airports and spaceports, including large hub airports. According to Selvidge (2011), “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.” The Federal Aviation Administration (FAA) in the United States (U.S.) has been assigned two potentially conflicting tasks of “protecting public safety” while also “promoting the industry” (Selvidge, 2010). Part of the conflicting tasks is to determine the reliability of current and future space vehicles and to determine acceptable risk levels (Pelton, & Jakhu, 2010). Reliability is difficult to predict but it can be said with near certainty that the reliability of space vehicles will be far less reliable than current aircraft (Murray & VanSuetendael, 2006). Entrepreneurs are working tirelessly to improve reliability because they know that safety and eventual safety regulation is key for the industry to succeed (Selvidge, 2010). Finally, Crowther (2011, p. 75) provides a viewpoint that aligns with the thesis of this paper in that,

government should not apply the same stringent safety measures appropriate to more mature transportation markets... when considering space tourism. Like any other business, space tourism is expected to develop progressively, starting with a relatively small-scale and high-priced “pioneering phase.”

The paper will also discuss current regulatory and legal aspects of the commercial spaceflight industry and present a case for a staged approach to regulating the industry. Included in this staged approach are realistic expectations of reliability requirements, given the difference in industry maturity between aviation and spaceflight.

A Vision of the Future

Imagine a day when you board an aircraft at your local regional airport, fly to a major hub city, exit your aircraft and proceed to the other end of the terminal where you board a spacecraft owned by an aerospace line to launch into space or on an hour long suborbital ballistic or Ricochet trajectory at the end of which you find yourself at your destination city, continents away (Selvidge, 2010). The stated vision of the future is a representation of hypersonic P2P travel which involves ultra-high altitude transcontinental travel (Smith, 2011). Reusable and reliable sub-orbital space vehicles will provide the ability for passengers and cargo to fly very fast, at very high altitudes, long distances, several times a day (Smith, 2011). In approximately 50 years, it is possible that spaceflight could be the number one means of transcontinental travel (Selvidge, 2010). Spaceflight being the number one means of transcontinental travel does not mean that other modes of transportation would be replaced but rather space travel would complement the other modes to create a more advanced and efficient transportation system (Selvidge, 2010).

Contrary to uni-modal airports and spaceports of today, the vision presented in this paper assumes airport and spaceport are integrated together, in or near a city, and is capable of transporting thousands of passengers a day using several modes of transportation (Selvidge, 2010). These multi-modal aerospaceports would become a hub in the already existing hub-and-spoke system for international travel where the high costs of added infrastructure for space vehicle operations can be handled by the large cities that already house such hubs (Selvidge, 2010). Also, P2P travel will likely require passengers to use aircraft to continue on to their final destinations and arriving at a hub where flights are available to many other destinations will be required to make the sub-orbital industry viable (Selvidge, 2010).

Spaceports Today

The vision of multi-modal aerospaceports started to become a reality in June of 2004 as Mojave Airport became the world's first FAA certified airport-spaceport combination (Dubbs & Dahlstrom, 2011). This particular airport and spaceport has been used for research and development although it is able to provide support to commercial operations. Historically, spaceports had been owned, operated, and used by the government and the military. For the last two decades there has been a resurgence in the space industry as commercial companies have been formed with the intent of creating a commercial space travel industry. The best-known company is Virgin Galactic based out of Spaceport America near White Sands Missile Range and Kirkland Air Force Base in southern New Mexico (Dubbs & Dahlstrom, 2011). Spaceport America is the first spaceport built specifically as a commercial spaceport and the Federal Aviation Administration's (FAA) Office of Commercial Space Transportation's only role was the certification of the facility. Virgin Galactic will be offering an astronaut type experience by flying passengers in Scaled Composites SpaceShipTwo spacecraft (Selvidge, 2010). Spaceport America has also signed a partnership agreement with a European spaceport, Spaceport Sweden, for use as a potential transcontinental suborbital spaceport, in preparation for Virgin's intent to build a future global spaceport infrastructure (Dubbs & Dahlstrom, 2011) to support future P2P travel.

Today there are 10 sites that have obtained Active Launch Site Operator Licenses from the FAA which allows these sites to launch spacecraft ("Active Licenses", 2015). There are two characteristics of these spaceports: first, they are mostly located inland – compared to coastal with the heritage government sites – and, second, they were created with an interest in reusable launch vehicle (RLV), commercial passenger travel (Selvdge, 2011). These spaceports are also

different because they are all standalone facilities, designed specifically, such as Spaceport America, to launch spacecraft. Mojave Air and Space Port can technically launch space vehicles and has a runway for aircraft to takeoff and to land, but is used mainly for flight-testing and not utilized as a commercial airport. At the 10 launch sites shown in Figure 1, airspace is managed in a simplistic way: by shutting down airspace near the spaceport during launch and re-entry in the form of Special Use Airspace (SUA) and Temporary Flight Restrictions (TFR) (Murray & VanSuetendael, 2006).

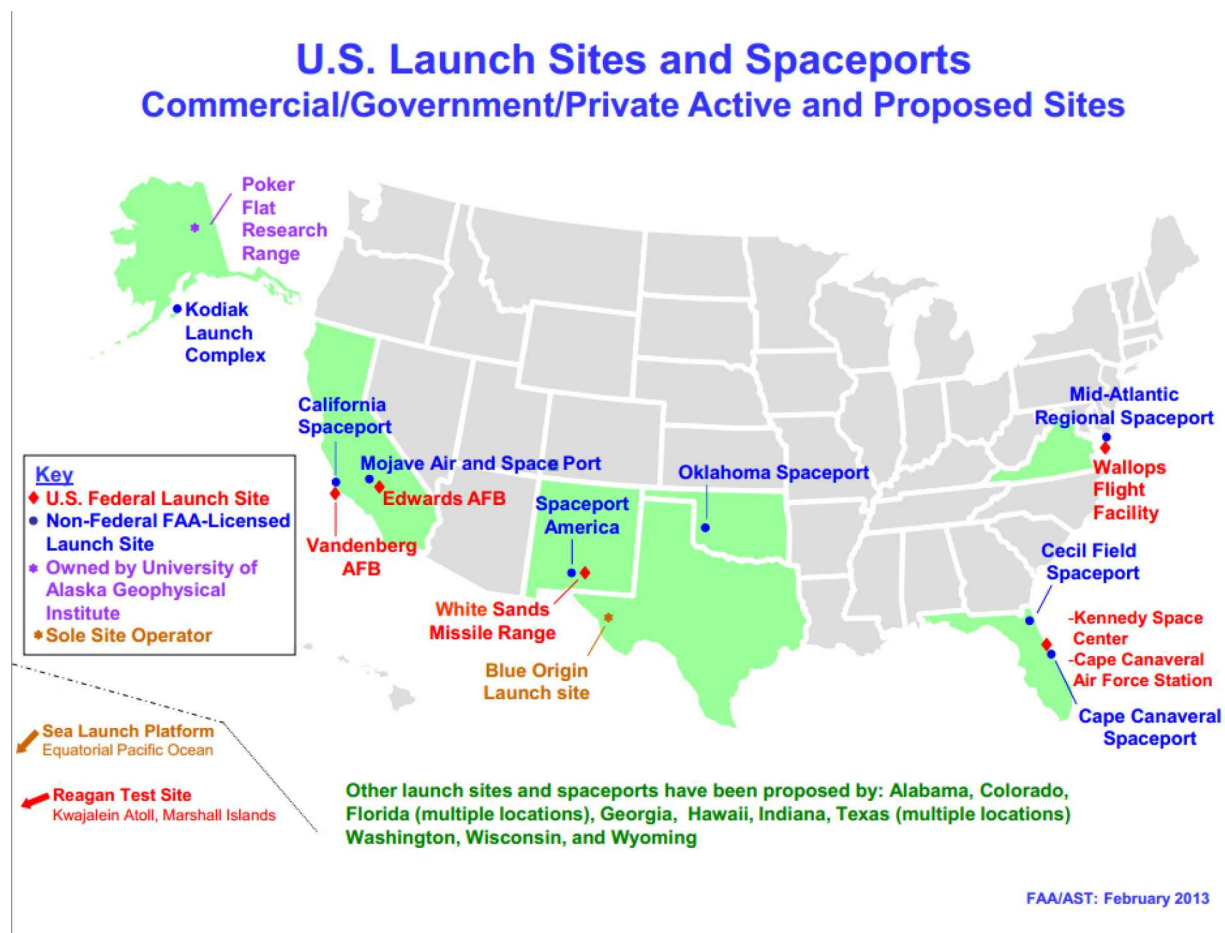


Figure 1. Spaceports in the US. Taken from:

http://www.popsci.com/sites/popsci.com/files/styles/large_1x_/public/import/2013/images/2013/09/US-Spaceports.jpg?itok=InweOgbH

The FAA has not defined standards for the minimum separation distances between spacecraft and aircraft as it has for example, for separation distances between aircraft flying through the National Airspace System (NAS).

Integrated Airport and Spaceport – Aerospaceport

Aerospaceports are envisioned to operate similarly to existing airports today.

Technological innovations are making transportation possible via high altitude, sub-orbital flights and to and from space using vehicles that are effectively the same as aircraft (Pelton, & Jakhu, 2010). Requirements for the facility would differ very little from existing airports today, requiring few additions to existing infrastructure and keeping costs low to convert an airport into an aerospaceport. Terminals, gates, multiple runways, access roadways and parking are already provided by airports, but additional facilities for spacecraft refurbishment, fueling and vertical launch facilities would need to be added (Selvidge, 2010). Additional maintenance facilities will be required for inspection crucial components including thermal systems components and engine parts (Webber, 2010). Special cargo handling areas could be required especially if a market for transplant organs is created where extraordinary cleanliness and temperature controls is needed (Webber, 2010). Oklahoma Spaceport is developing a spaceport in the vision of integrated airport and spaceport operations by supporting operations of space vehicles from many different developers as well as fixed based operations for aircraft including a flight school (Murray, 2008). Oklahoma spaceport has been a test bed for the FAA to understand how integrating air and space traffic together and Murray (2008) acknowledges that the future will likely see spaceports move to less remote locations and see higher volumes of space traffic.

The P2P Market

Aside from the savings in using existing infrastructure it makes sense to combine airport and spaceport to support a sustaining market in P2P travel. Space tourism adventure flights are fleeting with a limited market. The real sustainable market is P2P travel where the higher ticket prices will be rewarded with sizeable time savings (Peeters, 2010). The wealthy paying for the adventure trips make up the current market as they fund the development of technology that will make the P2P market possible but funding by the wealthy is just an initial step that will lead to an evolution in transportation. The evolution will provide a faster means to get around the world to the “time- poor, cash-rich” people such as top executives, sports stars, and celebrities (Peeters, 2010). As technologies are developed and the number of passengers able to travel grow, sub-orbital travel will become more affordable and efficient, opening the market to a wider base of customers (Crowther, 2011). The development route described is similar to how the aviation industry started. A century ago, travel via aircraft was expensive and a luxury that few could afford. With the help of the government and some forward thinkers, the aviation industry has flourished to its current state where flying is a common mode of transportation for most people. Peeters (2010) recounted how remarkable it was that it only took 15 years between experimental aircraft flying to companies offering commercial flights. The same timeline has not been realized in the development of space travel with more than 40 years passing between the first manned spaceflights and when the world saw the first paying passenger go into space (Peeters, 2010).

The previous section discussed combining airports and spaceports to support future P2P travel from an infrastructure point of view. Beyond infrastructure, P2P travel is reliant on operations being combined with airports due to the time-poor aspect of the P2P market. It will be necessary to have a global network of aerospaceports that are located in or near major

populations centers (Webber, 2010). If airport and spaceports are not integrated, most of the time savings will be lost due to further ground or air transportation being required to get to a standalone, remote spaceport (Webber, 2010).

For a global network, Peeters (2010) recommends routes of over 3500 km or even 7000 km be considered when developing a global network of P2P travel. An interesting consideration that will have to be evaluated several times as the market matures is the frequency of flights between network nodes. For a person who is time-poor, he or she may not be willing or able to wait several hours, a day or perhaps even week (depending on the volume of traffic) for a next scheduled flight (Webber, 2010). To support these tight time constraints, particularly in the earlier phases of the P2P industry, P2P flights will have to be managed more similarly to corporate shuttle. These flights are able to go on demand and do not follow a schedule created far in advance by an aerospace line (Webber, 2010). As the industry progresses, the volume of passengers increases and prices fall, the industry will be able to support schedules similar to airlines today. Aerospace lines will determine where demand for P2P flights exist and create the supply and timetable to support that demand.

Integrating P2P Flights

FAA

Current sub-orbital launches are infrequent and no paying passenger has yet to venture to the boundary of space in one of the many vehicles being designed. There will soon be a change due to change next year as Virgin Galactic begins commercial flights up to space and back to the ground at Spaceport America in remote New Mexico (Clark, 2015). These flights will be infrequent compared to air traffic and can therefore be managed using the existing manual means employed by the FAA. In current operations, for both sub-orbital and orbital flights, large

volumes of airspace are blocked using SUAs or TFRs, re-routing air traffic around the site where the launch and reentry is occurring (Bilimoria & Jastrzebski, 2013). Flight restrictions last for an insignificant period of time and covers a large enough area that any bits of debris from potential catastrophic failures will not pose a threat to aircraft. Using a conservative approach assures a high level of safety for surrounding aircraft, but comes at the expense of air traffic having to be re-routed, causing delays and using more fuel (Bilimoria & Jastrzebski, 2013). As previously mentioned, the use of temporary flight restrictions is a very manual process taking months of planning between the operator and the FAA to coordinate when and how much airspace to close. According to Murray (2007), it can take years of research and coordination to establish special use airspace. Both the cost penalty for disturbing air traffic and for the FAA's manual process works now while space traffic is infrequent, but will become unsustainable as traffic (both air and space) increases. The FAA is researching new approaches and developing new tools to manage the NAS as launch and reentry vehicles begin to conduct flights in a more routine fashion and transition from development to operations (Murray, 2008). Operational means that space vehicle operators have demonstrated that vehicles can carry out routine and safe trips (Murray, 2008). Failure rates and the ability for operators to predict and control to an accurate trajectory will be need to be demonstrated (Murray, 2008). Required reliability has yet to be defined by the FAA as reliability is a difficult requirement to define and varies based on characteristic of each type of vehicle (Murray, 2008).

Debris

A key concern of the FAA is how to manage the risk of debris during catastrophic failure of a space flight. An inflight explosion of a space vehicle due to aerodynamic, thermal, or inertial loads on the space vehicle has the potential to create large swaths of debris (Murray,

2007). While aircraft are capable of experiencing a disaster and creating debris, the high altitude operations of space vehicles would affect a larger area. Modern aircraft also have extremely high reliability numbers and, that paired with many aircraft operating in near the same altitude, means that failures in aircraft creating debris that hit another aircraft is extremely rare (Murray, 2008). The FAA argues that the potential for hazardous debris due to a spacecraft failure is high compared to aircraft, particularly in the current developmental phase of the industry (Murray, 2007). Therein lies the reasoning for such large volumes of airspace that have to be restricted during launches and reentry of space vehicles; a need for assured separation between aircraft and spacecraft (Murray, 2007). As time and technology progresses and space vehicles can prove their reliability, these extreme separation standards will likely and should evolve.

Other Legal Considerations

The FAA is the regulator to assure safety of the national airspace and international treaties have been agreed upon to regulate other aspects and rights of the aviation industry, but few laws exist to govern space. The lack of laws is due to the lack of need as space travel has not become part of everyday life (Trepczynski, 2006). The sub-orbital industry will quickly require the creation of laws that define everything including the basics of defining what is an aircraft and what is a spacecraft (Trepczynski, 2006). Currently, space flight participants (carefully worded in U.S. regulations to not say passenger) are required to sign an informed consent form to avoid the gaps in the legal framework. Space tourism is a hybrid activity as it involves flying through several existing regulatory regimes (Crowther, 2011). As the vision outlined earlier in this paper unfolds, governments and the international community will need to come together to create an agreed upon legal architecture for space flight. The U.S.'s current method of creating national laws will be insufficient to regulate the entire industry especially as a

global network of spaceports is created (Trepczynski, 2006). Definitions or the desire to not define the boundary of space (and therefore the boundary of airspace) have yet to be established, but will be very important when deciding which existing laws cover sub-orbital travel and if more laws and treaties are required. The U.S. government in particular needs to decide who will be the regulator covering flight outside of the NAS. Orbital satellites are certified by the National Oceanic and Atmospheric Administration and aircraft are certified by the FAA. Is there an entity in the middle who governs flights above the NAS but that do not reach orbit? Or does one government entity begin to manage all three realms. These are legal questions that still need to be answered and that will affect how P2P flights are integrated into the NAS.

Future Perspective

The future perspectives section aims to cover two topics. The FAA is being proactive and understands the challenges and complexities associated with integrating space vehicles into the NAS. While the FAA houses a lot of expertise on the issue, it is also a conservative regulator and not the most forward looking. So first the FAA's view on what the future looks like will be discussed such as how airspace will be managed and what needs to be done to get there. Second, a perspective will be given that is less conservative that will more easily allow for the industry to flourish and for the industry to follow a progressive approach towards becoming a safe and reliable mode of transportation.

The future concept of operations from the FAA for managing air and space traffic are grounded solidly in their existing method of blocking off airspace to protect aircraft from potential incursion or debris from failed flights. They have renamed these block airspace volumes to "space transition corridors" (STC) which would extend from the ground all the way up to 60,000 feet, the current agreed upon upper level of the NAS (Murray & VanSuetendael,

2006). The area on the ground of the STCs would require analysis, but would make use of a future Space and Air Traffic Management System (SATAMS) including a decision support tool (DST) that would take vehicle characteristics into account when generating the size of the STC (Murray & VanSuetendael, 2006). The first improvement here is that the analysis will be at a higher fidelity so that the volume of the STC can be minimized. In addition, the STC can be added dynamically into the system and removed quickly so as to minimize the impact to nearby air traffic (Murray & VanSuetendael, 2006). The STC would be created shortly before the planned departure time and then withdrawn once the vehicle has exited the NAS (Murray & VanSuetendael, 2006).

In addition to the use of STCs and new integrated support tools, the idea of analyzing existing traffic patterns near launch sites has been discussed by the FAA. The concept here is to find gaps in time where the airspace near launch/landing sites is less congested and allow STCs to be created during those times so as to minimize the impact on air traffic and minimize exposure to potential threats of debris hitting aircraft (Murray & VanSuetendael, 2006).

A good summary of the FAA's plan for integrating space flight into the NAS is summarized here by Murray & VanSuetendael (2006, p. 5):

The FAA is developing traffic management strategies and a decision support tool to safely and efficiently accommodate an anticipated increase in space and air traffic operations while minimizing impacts. The proposed fusion of existing technologies will create a tool capable of identifying airspace restriction requirements and mitigation options for potential impacts while providing increased situational awareness during nominal operations and accident scenarios.

Beyond that first approach of managing traffic in the near-term, the FAA does recognize that the future could allow for less restrictive treatment of space vehicles as they launch and reenter into the NAS. The FAA even recognizes that being able to have less restrictive treatment will be essential to the success of the commercial space industry (Murray, 2008). The vision presented by the FAA is that airspace would only be restricted in the event of an accident but the airspace would remain open to all users otherwise. Before airspace can remain open to all users, operators would need to innovate to make vehicles more reliable, operate predictably, and the FAA must develop technologies to improve and increase the scope of ATC capabilities (Murray, n.d.).

Bilimoria (2013) presents a simple concept that the FAA needs to keep in mind when developing its future plans, and that is a desire for both aircraft and spacecraft to receive equitable access to the shared resource of the NAS. Equitable access can be achieved while protecting air traffic from possible spacecraft malfunctions while maintaining a high level of safety for both air and space operators.

The nebulous vision presented by the FAA seems like a good path but language in most of the literature has two trends. First, it gives the impression that space vehicles are invading a territory and thus rank second in terms of hierarchy to accommodate the traffic. Second, the FAA's risk tolerance is too low for an industry that is in its infancy. Most of the papers claim to be integrating space traffic in with air traffic and making space traffic a part of the NAS but how is blocking off airspace *integrating* it. When two planes approach an airport, they are staggered and their arrival times offset by air traffic control so both arrive seamlessly. When a space vehicle and a plane approach an airport, the airspace is closed down while the space vehicle lands followed by the reopening of the airspace for aircraft to land after a delay. That is not

integration. The reason for the lack of true integration is the intolerance to the risk of debris causing damage to planes when adequate analysis of acceptable risk and probabilities of damages are not fully understood.

Going back to a comment that was made earlier regarding analyzing traffic patterns to try and time spaceflights during gaps in aircraft movements, this assume that aircraft should have the right-of-way when it comes to traffic moving through the NAS. The method of giving aircraft the right-of-way seems odd because typically the vehicle with the most constraints and least amount of maneuverability and controllability have the right-of-way. Consider the operations of a sailboat versus a motorized boat. Aircraft are easily maneuvered around to avoid any space activity but the ease of maneuverability and the ability for spacecraft to divert around aircraft is not possible. Thus spacecraft should be given the right-of-way.

Early aviation was indeed dangerous and regulations have been created to increase the safety of the industry. While it is assumed that people a century ago were aware of the dangers of aviation, airports were built in or near large populations without apparent concern for the possibility of debris or entire planes causing loss of life or damage to property on the ground. Now, however, the utmost concern in literature is the danger of debris hitting aircraft and the focus on that seems too severe and constraining to support the growth of a viable industry.

A solution to these issues lies in a streamlined approach where flexibility is given to reliability requirements and the realistic targets are created that force the industry to increase reliability over time without bogging the industry down with unattainable goals. Pelton, & Jakhu (2010) recommend setting targeted and realistic safety objectives while creating a culture and a standard of continual improvement. Targets should be created that based on performance against those standards; varying severity of regulation can be enacted to assure the industry

continues to see improvement (Pelton, & Jakhu, 2010). Implementing a performance-based set of regulations will require “better quantitative models and analytic techniques to assess space plane performance and to monitor safety enhancement processes” (Pelton, & Jakhu, 2010, p. 298).

Conclusion

Commercial ventures are innovating to bring the experience of space travel and weightlessness to the masses. While the spaceflight market will provide revenues for the short-term, eventually the participants in that market will begin to wane. Re-purposing those technologies to provide P2P sub-orbital travel is the sustaining industry. A logical step to assure that the industry is set up for success is by combining airport and spaceport to create a transportation nexus dubbed an aerospaceport. These aerospaceports will be the hubs in a hub-and-spoke system made up of aircraft and spacecraft, providing quick access to major cities and regional airports alike. The P2P spaceflight mode of transportation will first be viable for the cash-rich, time-poor users including executives, celebrities, and critical cargo. As technologies evolve and prices decrease, the P2P mode of transportation will follow the same path as air travel and become a common form of travel. P2P flights will become the primary means of transcontinental travel while aircraft will provide short-haul solutions (Selvidge, 2010). The dynamic between the two will be similar to the current dynamic between short-haul flights and high-speed rail.

For the commercial spaceflight industry to become a reality and to flourish, an appropriate staged approach needs to happen when it comes to regulations. Currently, minimal regulations exist for space travel and there is a lack of a comprehensive legal framework and space strategy with no single entity responsible for space travel (Hunter and Wright, 2010).

Methods of integrating space traffic into the NAS are manual and time consuming, but with increasing access to affordable flights, this method of regulating will soon be obsolete. Space transportation is inherently risky, but entrepreneurs in the industry know that the long-term success is dependent upon its safety record (Crowther, 2011). The FAA needs to do its part in developing advanced communication, navigation, and surveillance (CNS) systems in order to provide to tools to integrate spacecraft into the NAS, but the FAA also needs to keep in mind that a new mode of transportation will not have the reliability of the century old aviation industry (Crowther, 2011). Because of the differences in industry maturity, the government should not apply the stringent safety regulations from the aviation industry onto the commercial spaceflight industry and the FAA needs to be more risk tolerant when it comes to allowing spacecraft to fly without an over burdensome worry of debris (Crowther, 2011). In order for an industry in it's infancy to survive and flourish, expectations of reliability and strict regulations need to be slowly staged.

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