ASCI 691 Graduate Capstone

Inherent Barriers for the Growth of the Space Transportation Industry

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Abstract

Space transportation has come a long way in the past fifty years, fostering tangible technological achievements for the benefit of mankind, and gradually changing our way of life. Commercial space transportation on the other hand, which formally started in 2004 (NASA, 2012), has much ground to gain in terms of development and sustainability. Investment in spacecraft designs, certification of spaceports and vehicles, regulatory and legal hurdles, and funding from private sources are just some of those factors which will be examined by using primary data in the form of interviews conducted with industry experts, and through analysis of secondary data such as key NASA and FAA publication, and employees of aerospace consulting companies. The project will also analyze socio-political and human factors involved in the application of new technology, and the sub-problems the industry will encounter, which will be detailed under the *barriers* section of this project.

The researcher will utilize a quantitative methodology by investigating the relationship between the results obtained using inferential statistics, such as correlations effect, as well as descriptive analysis of both primary and secondary aerospace industry sources. The specialization is addressed in this individual project with meeting Program Outcome 11.

Keywords: barriers for sustained growth, space transportation industry, spacecraft designs, certification of spaceports, private investment, regulatory and legal hurdles

Proposal

Inherent Barriers for the Growth of the Space Transportation Industry

Barriers for Growth

The project may identify current socio-political and financial conditions that might prevent a sustained growth for the commercial space transportation industry in the next thirty years. New technological concepts such as composite materials and hybrid rocket motors will also be identified in order to ascertain if the logical barriers might be offset by the availability of these technological breakthroughs. The reader should gain a better understanding of all the different financial, technological and regulatory factors that might affect a sustained growth for this industry, and other sub industries, such as space tourism.

First, a brief definition of the commercial space industry will be rendered, as well as basic activities which depend from it. Next the nature of the problems to be considered as samples will be discussed, via interviews of industry experts, results which will influence the researcher's conclusions. Finally recommendations about the future of the industry for the next thirty years will be given based on the aforementioned primary and secondary industry data.

Through the analysis of the following sub-problems, the researcher will first identify the logical barriers via accepted evidence; and through the project outcome, make an effort to demonstrate how these barriers might be overcome:

1. The first subproblem is safety. This has always been the predominant factor when sending humans into space. If civilians were to be considered, a more comprehensive and detailed approach would need to be presented to the public due to

legal issues and third party risks to innocent bystanders. As well as risks linked to direct participation in the space program, such as those related to launch, re-entry and other elemental risks, such as radiation. More so if the number of civilians to go into space gradually increases over time.

2. The second subproblem is security. This has been a variable since the start of the space program, considering that initial missions were developed during the Cold War, and security played a central role, providing a strategic military advantage over other nations. Today, the motivation is different and is a legitimate concern for countries like the United States, due to malicious acts that might be planned by terrorists on a growing space transportation industry (ITAR, 2012).[1]

3. The third subproblem is financial. The cost of every space mission has traditionally been extremely high. From the manufacturing of the crafts, cost of fuel and training, to the ground personnel required to support the missions. According to NASA (2012), the average cost to launch a space shuttle was about $450 million dollars per mission, and according to Sellars (2008), the launch can sometimes account for nearly 30% of a mission’s cost. Therefore, if we take the above estimate given by NASA of $450 million, then 30% of the general cost would render a launch cost of $135 million dollars per mission. This is just for the launch part of the mission; without considering manufacturing and testing, or communications and mission operations.

4. The fourth subproblem is physical & mental fitness. Due to the characteristics of the space environment, from the effects of zero gravity to the mental aptitude for

[1] *current configuration of the International Traffic in Arms Regulations ("ITAR") creates a significant impediment to private industry's ability to reach international markets, as there can be major delays in getting approval for exports. This policy is "disconnected from program requirements and the reality of international space activity”.The obstacle effectively bars smaller entrepreneurial companies from participating in this market at all, which adversely affects the amount of diversity in innovation.*

launch and re-entry procedures, rigorous training has always been enforced by the space agencies to guarantee the success of the missions (Clement, 2008). The same approach should also be considered for ordinary civilians as the industry grows, since the latter might represent basic physiological and psychological problems for the selection of would-be civilian tourists. Therefore, an assessment to each candidate must be made by the respective space transportation companies to avoid liabilities and other legal consequences that might arise.

5. The fifth subproblem is the available technology and the willingness to share the knowledge. Technology has taken giant leaps since the start of the space program and this variable is turning in our favor with each passing generation. The true setback has been the limitation of governments and nations to share breakthrough technologies with the private sector. The process is stagnant and is only available years later (Handberg, 1995).

6. The sixth subproblem is legal. All operational activities of this industry is subject, and will continue to be subject, to legal, regulatory, liability, insurance and environmental factors.[2]

[2] *A committee from the American Bar Association is currently drafting the legal framework for their members on the space transportation industry, to be presented in August 2012 at the ABA Conference in Chicago (ABA, 2012).*

Program Outcomes

Program Outcome No. 1:

Students will be able to apply the fundamentals of air transportation as part of a global, multimodal transportation system, including the technological, social, environmental, and political aspects of the system to examine, compare, analyze and recommend conclusion.

How the above Outcomes will be addressed:

The researcher proposes to implement the Political, Environmental, Social, Technological (PEST) analysis, to be addressed as follows:

- Political. Rendering a summary of political achievements and laws passed over the last decade which favors the commercial space industry. Including Laws such as the “National Space Policy” (FAA, 2010), and the “Private Space Companies Act” (NASA, 2011). The latter, according to The Space Settlement Institute (2012), was passed to promote space exploration and settlement by private space companies by promoting incentives for entrepreneurial investment in space and by assuring appropriate property rights for those who seek to develop space resources and infrastructure.
- Social. Analyzing the perception of the public, of this and past generations, and their overall evolution in thinking in space related activities. As well as their desire and willingness in acquiring deeper knowledge of space, and its overall benefits. For this, a series of interviews will be conducted under the “Proportional Stratified Sampling” method (Leedy & Ormrod, 2010), whereby sampling will be taken from: 1. Ordinary civilians, 2. Industry professionals, and 3. Political

figures to different age range and educational background. The location of the first set of interviews would tentatively be at an office building, and the second at a local mall.

One age target will be a younger population within the ages of 21-33, represented by Y^1; and the older target population within the 50-65 age range, represented by O^1. For a more objective result of the sampling, a rather equal level of education will be contemplated for the above age targets. Further details are available under Program Outcome 2 of this project.

- <u>Environmental.</u> Describing how a gradual transition into a "horizontal" launch method, the implementation of new propulsion systems and transportation concepts will affect the usage of fossil fuels emissions, and how they will minimize the impact on the environment.
- <u>Technological.</u> Focusing on the development component, critical in terms of the long range development of space, and how the NASA's diminishing budget will affect space related companies through purchases of their goods and services.

Program Outcome No. 2:

The student will be able to identify and apply appropriate statistical analysis, to include techniques in data collection, review, critique, interpretation and inference in the aviation and aerospace industry

<u>How the above Outcomes will be addressed:</u>

This program outcome will be addressed by conducting a series of interviews, targeted to two independent audiences, as follows:

1. Interviews will be conducted to ordinary civilians to analyze the perception of the public, of this and future generations, and their overall evolution in thinking in space related activities, using the "Proportional Stratified Sampling" method (Leedy & Ormrod, 2010), whereby sampling will be taken from US nationals belonging to two different age range. The location of the first set of interviews would tentatively be at an office building, and the second at a local mall.

One age target will be a younger population within the ages of 21-33, represented by Y^1; and the older target population within the 50-65 age range, represented by O^1. For a more objective result of the sampling, a rather equal level of education will be contemplated for the above age targets.

2. Interview will be conducted to: 1. Ordinary civilians, 2. Industry professionals, and 3. Government/Public Officials, in order to ascertain elements such as new design concepts being considered or manufactured by the private sector, and analyze the tangible benefits scaled composite materials signify for future development of spacecrafts. Additional questions will also be asked, such as what atmosphere re-entry benefits are obtained from new operational approaches such as the "feathering" technique (Virgin Galactic, 2012).

Data tables for accuracy and reaction time will be imported from an Excel spreadsheet for review and input into the statistical analysis, accompanied by descriptive stats to visually represent the results obtained. A factorial Analysis of Variance (ANOVA) will also be conducted to evaluate if main or interaction effects exist from the interviews conducted to both groups.

For this purpose, a target of 20% of the selected location's population should be sampled for accurate results, respective of each group (ordinary civilians and spacecraft designers) represented by $P\pm$., subsequently the samplings which obtain an end result of 60% or greater of the population will be represented by $N\times$. Furthermore, results which render unknown variables or neutral opinions will be represented by U^{o} (Formula i.e.: Y^{1}: $P\pm - U^{o} \geq N\times$). The results will then be tabulated and duly represented by a line graph, under the Ordinal data concept (Leedy & Ormrod, 2010).

Program Outcome No. 3:

The student will be able across all subjects to use the fundamentals of human factors in all aspects of the aviation and aerospace industry, including unsafe acts, attitudes, errors, human behavior, and human limitations as they relate to the aviators adaptation to the aviation environment to reach conclusions.

How above Outcomes will be addressed:

- Human Factor. Supported by previous expert research on human factor topics in aerospace, such as the publication "Human Factor in Aviation/Aerospace" (Salas & Maurino, 2008), the researcher will address the effects of a zero gravity environment and fatigue on the performance of work related operations, as well as other health related variables to the human body, such as Space Motion Sickness (SMS), cardio-vascular, musculo-skeletal, and psychological effects, respectively (Clement, 2008).
- Human Limitations & Errors. The researcher will analyze the "Correspondence Error" theory, as they relate to the cockpit environment for would be pilots and operators. A comparison will then be rendered as to how the change from a

naturalistic environment to a deterministic (internal, electronic) has influenced, and will continue to influence cockpit displays.

- <u>Aviators' Adaptation</u>. Determine that if the widely accepted "horizontal launch", from designs such as Burt Rutan, and other equally effective concepts, are to be considered by the private companies for space launches, how this new method will represent an intrinsic and unknown human factor element that must be addressed, as it might relate to spatial disorientation or other yet unknown variables.

Program Outcome No. 4:

The student will be able to develop and/or apply current aviation and industry related research methods, including problem identification, hypothesis formulation, and interpretation of findings to present as solutions in the investigation of an aviation / aerospace related topic.

<u>How above Outcomes will be addressed</u>:

- <u>Problem Identification & Investigation of an Aviation Topic</u>

Through a quantitative method, the researcher will identify weather as a major problem for the sustainable growth of the commercial space transportation industry. This will apply for weather within the earth's atmosphere, as well as space weather, pertaining to elements such as plasma, magnetic fields, radiation and other matters. The former is applicable since this project will contemplate horizontal launch as the main method of launch for reaching space for the next thirty years, as it represents a much safer and financially feasible alternative (FAA, 2011).

Since the ignition of rocket boosters to reach space, in horizontal launches, might be performed during regular cruising altitude; then it is safe to assume that before reaching this step the spacecraft would follow a basic flight pattern like any other flight. Therefore, it is the researchers' opinion that relevant flight accident statistics from the National Transportation Safety Board and the FAA, respectively, will also add significant tangible data on weather related accidents that have occurred during: 1. taxing, 2. takeoff, 3. initial climb, 4. cruise, 5. descent, 6. approach, and 7. landing phases of flight. On the other hand, secondary data in the form of descriptive statistics from NASA will also be obtained, those relating to space weather incidents reported on manned STS missions which negatively affected astronauts or their instruments on board, such as plasma and solar radiation, which will also add valuable data to support the desired outcome.

The representation and interpretation of this data is especially important in this program outcome since most of the spacecraft designs possess liquid fuel propellant for their rockets, which is undoubtedly a very important variable that must be fully assessed due to the inherent danger it poses when combined with oxidizers; more so if we consider the presence of unstable weather while having a highly ignitable propellant during a flight. If civilians are considered for future space flights, then space weather and its negative effects are also legitimate concerns and another crucial barrier for the sustained growth of this industry.

Relevant publications in aviation human factors, such as "Human Factor in Aviation/Aerospace" (Salas & Maurino, 2008) will be referenced to try to obtain sufficiently specific or accurate information to allow pilots to distinguish hazardous-looking but benign weather from truly hazardous weather (Salas & Maurino, 2010), as well as publications relating to the effects of space on the human body, from a physiological and psychological standpoint (Clement, 2008).

Lastly, the researcher will concentrate on the interpretation of findings, which shall be a correlation rendering data tables for accuracy and reaction time imported from an Excel spreadsheet for review and input into the descriptive and inferential statistical analysis, following the “Proportional Stratified Sampling” method (Leedy & Ormrod, 2010). These samplings will be taken from the two aforementioned agencies, accompanied by descriptive stats to visually represent the results obtained.

- **Program Outcome – MAS Specialization #11**

The student will investigate, compare, contrast, analyze and form conclusions to current aviation, aerospace, and industry related topics in space studies, including earth observation and remote sensing, mission and launch operations, habitation and life support systems, and applications in space commerce, defense, and exploration.

<u>How above Outcomes will be addressed:</u>

Attending the future use of new spacecraft design for commercial space activities, the researcher proposes to investigate:

- <u>Regulatory Aspects of Spaceports for Spacecraft Operations.</u> By researching previous dissertations and publications, such as the “U.S. Commercial Space Transportation Developments and Concepts: Vehicles, Technologies, and Spaceports” (FAA, 2011), and the “Commercial Spaceport Licensing Review and Recommendations” (FAA, 2012), as well as private research from consulting companies, such as InterFlightGlobal, involved in Spaceport licensing; the researcher will put forth data as to the hurdles that potential airport operators must overcome to allow sustained spacecraft operations. Analyze the current regulatory framework in place by the FAA and other country's aviation authorities, to determine its practicality and/or required modifications for commercial Spacecraft in the event of: 1. potential collision with other objects during taxing, 2. contingency plans in the event it's fuel propellant ignites, or 3. any other incidents which might arise during the course of regular operations within the airport environment.

- Launch Operations. By investigating official NASA descriptive statistics and scholarly articles, available through the Embry-Riddle Library, the researcher proposes to identify the intrinsic dangers that come with vertical launch operations and the negative effects this method poses on the atmosphere. Elements, such as heavy structural loads required to sustain the fuel for this type of launch, as well as financial and logistical implications. Hence, highlighting the opportunities a horizontal launch represents for the future growth of the industry.

Intertwined with Program Outcome 2, new horizontal spacecraft concepts will be analyzed, such as those utilized by Virgin Galactic, as well as other equally effective design concepts and combinations. Taking the latter concepts into consideration, the outcomes will be addressed as follows:

1. Spacecraft Development. Description of how those particular models are being manufactured by the private sector, and analyze the tangible benefits scaled composite materials signify for future development of spacecrafts. As well as what atmosphere re-entry benefits are obtained from new operational approaches such as the "feathering" technique (Virgin Galactic, 2012).

2. Research and Development. Intertwined with political factors of Program Outcome 1, a descriptive analysis will be rendered as to the effects of the US governments' decision to extend the space activities to the private sector, and how this decision will expand the funding opportunities from non-governmental sources for research in years to come. This will be assessed by various interviews to management figures of private aerospace and consulting companies, as well as government defense contractors, to have their particular points of view on the matter.

3. Production. The researcher will take into account the demand of space activities to LEO and Sub-Orbit for the next 30 years, from satellite usage for remote sensing and telecommunications, to research and development for military applications. Attending the latter results, a brief summary will be rendered to account for the physical necessity of production and manufacturing plants to attend this niche, as well as the technical labor required.

Abstract

Technological advances in today's aerospace industry have placed us in a very unique and interesting time in human history, for we have the opportunity to expand our overall involvement in space. Nonetheless, we are also facing tangible challenges which must be seriously contemplated if we are to move forward to a sustainable growth of the commercial space transportation industry. Investment in spacecraft designs, certification of spaceports and vehicles, regulatory and legal hurdles, and funding from private sources are just some of those factors that have been examined by using primary data in the form of interviews conducted with industry experts, and through analysis of secondary data such as key NASA and FAA publications, and employees of aerospace consulting companies. The project also analyzed socio-political and human factors involved in the application of new technology.

Keywords: barriers for sustained growth, space transportation industry, spacecraft designs, certification of spaceports, private investment, regulatory and legal hurdles, Challenges

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Project Introduction

Statement of the Problem

Since Konstantin Tsiolkovsky, father of Russian cosmonautics, first calculated in 1880 the escape velocity required for journey beyond earth's atmosphere, and suggested that burning a combination of liquid hydrogen and liquid oxygen could improve rocket efficiency, humans have long desired to achieve the goal of spaceflight. In the 1960's humans started to venture into space through various missions, and since then the process has been conducted through the use of rockets as the principle mean of transport.

Today, placing a spacecraft into orbit requires a great amount of logistics, facilities, and of course, personnel. Through this report, the author will put forth new technological breakthroughs, such as composite materials and hybrid rocket motors and how they represent important steps in the right direction to achieve a long term sustainable growth for the commercial space transportation industry. Nonetheless, as the researcher will prove in this report, the commercial side of this industry is still in its infancy; thus, multiple barriers will become evident to the reader, barriers which must be fully assessed and overcome in order for this industry to become sustainable.

First and foremost, the researcher will render the following definitions of key terms being utilized by the industry.

<u>Space Transportation Industry:</u> According to the FAA's Office of Commercial Space Transportation (2011), the latter is defined as a competitive industrial base that consists of space products and services with the objective of sustaining key partnerships,

enabling commercial spaceflight capabilities for the transportation of crew and cargo to and from space.

Spaceport: Is defined as a site dedicated to launching orbital or suborbital vehicles into space. These sites often provide the capability to integrate launch vehicle components, to integrate vehicle with payloads, and to fuel and maintain vehicles (FAA, 2011).

RLV's: Acronym meaning Retrievable Launch Vehicle, pertaining to orbital or suborbital vehicles that can be re-used for launch and spaceflight (AIAA, 2011).

ELV's: Acronym meaning Expendable Launch Vehicle, pertaining to orbital or suborbital vehicles that are used only once after the launch and performance of its mission (AIAA, 2011).

Concept "X": Are launch vehicles in an all-in-one RLV. These take off similar to an airplane from a runway using jet power and flies to a safe location before igniting its rocket engines horizontally to complete its launch phase. After its flight it lands horizontally as a regular airplane (AIAA, 2011).

Concept "Y": Are launch vehicles which ignite its rocket engines while on the ground and takes off horizontally from a runway. It then returns gliding unpowered for a horizontal landing (AIAA, 2011).

Concept "Z": Are launch vehicles with a two part launch, consisting of a reusable carrier aircraft and a reusable/expendable launch vehicle. The carrier aircraft is powered by jet engines and designed/modified to carry the launch vehicle to a high altitude where the two components detach and the rocket engine of the launch vehicle is ignited (AIAA, 2011).

Orbital Flight: Is defined as a spaceflight in which a vehicle is placed on a trajectory where it could remain in space for at least one orbit. To do this around the Earth, it must be on a free trajectory which has an altitude at perigee (altitude at closest approach) above 100 kilometers. These can be Low Earth Orbit (LEO), Medium Earth Orbit (MEO), or Geostationary Orbit (GEO) (Anderson, 2008).

Sub-Orbital Flight: Is defined as a spaceflight in which the vehicle reaches space, but its trajectory intersects the atmosphere or surface of the gravitating body from which it was launched, so that it does not complete one orbital revolution (Anderson, 2008).

Composite Materials: Is defined as a structural material being utilized by the aerospace industry for spacecraft designs, and characterized by being relatively light, high strength, low thermal coefficient, and high conductivity (Peters, 2004).

Hybrid Motor: Is a rocket with a motor which uses propellants in two different states of matter, one solid and the other either gas or liquid (Figure 1). Hybrid rockets exhibit advantages over both liquid rockets and solid rockets especially in terms of simplicity, safety, and cost (Space Propulsion Group, 2012).

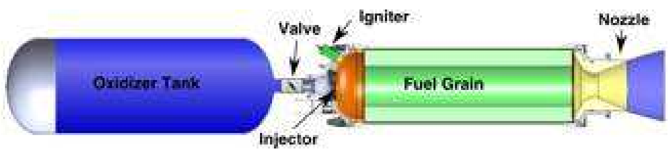

Figure 1. Hybrid Rocket Motor. Retrieved from Space Propulsion Group (2012).

The following sub-problems are to be considered the most basic barriers the commercial space industry currently faces, and which will be discussed throughout the course of this project:

1. The first subproblem is safety. This has always been the predominant factor when sending humans into space. If civilians were to be considered, a more comprehensive and detailed approach would need to be presented to the public due to legal issues and third party risks to innocent bystanders. As well as risks linked to direct participation in the space program, such as those related to launch, re-entry and other elemental risks, such as radiation. More so if the number of civilians to go into space gradually increases over time.

2. The second subproblem is security. This has been a variable since the start of the space program, considering that initial missions were developed during the Cold War, and security played a central role, providing a strategic military advantage over other nations. Today, the motivation is different and is a legitimate concern for countries like the United States, due to malicious acts that might be planned by terrorists on a growing space transportation industry (ITAR, 2012).[3]

3. The third subproblem is financial. The cost of every space mission has traditionally been extremely high. From the manufacturing of the crafts, cost of fuel and training, to the ground personnel required to support the missions. According to NASA (2012), the average cost to launch a space shuttle was about $450 million dollars per mission, and according to Sellars (2008), the launch can sometimes account for nearly 30% of a mission's cost. Therefore, if we take the above estimate given by NASA of $450 million, then 30% of the general cost would render a launch cost of $135 million

[3] Current configuration of the International Traffic in Arms Regulations ("ITAR") creates a significant impediment to private industry's ability to reach international markets, as there can be major delays in getting approval for exports. This policy is "disconnected from program requirements and the reality of international space activity".The obstacle effectively bars smaller entrepreneurial companies from participating in this market at all, which adversely affects the amount of diversity in innovation.

dollars per mission. This is just for the launch part of the mission; without considering manufacturing and testing, or communications and mission operations.

4. The fourth subproblem is physical & mental fitness. Due to the characteristics of the space environment, from the effects of zero gravity to the mental aptitude for launch and re-entry procedures, rigorous training has always been enforced by the space agencies to guarantee the success of the missions (Clement, 2008). The same approach should also be considered for ordinary civilians as the industry grows, since the latter might represent basic physiological and psychological problems for the selection of would-be civilian tourists. Therefore, an assessment to each candidate must be made by the respective space transportation companies to avoid liabilities and other legal consequences that might arise.

5. The fifth subproblem is the available technology and the willingness to share the knowledge. Technology has taken giant leaps since the start of the space program and this variable is turning in our favor with each passing generation. The true setback has been the limitation of governments and nations to share breakthrough technologies with the private sector. The process is stagnant and is only available years later (Handberg, 1995).

6. The sixth subproblem is legal. All operational activities of this industry is subject, and will continue to be subject, to legal, regulatory, liability, insurance and environmental factors.

Review of Relevant Literature

After briefly reviewing the basic aforementioned barriers, as follows, the researcher will proceed to discuss industry specific barriers, intertwined with the review of relevant literature; and the use of the PEST analysis described in the *Program Outcome 1 and 3* section of this project.

1. Political:

In the early 90's the space industry faced a new challenge with the termination of the Cold War, pertaining to the process of separating military and civilian space activities. Military space activities were the original focus justifying public sector involvement in space. The military simply saw space as a high ground and a tool by which to prevent strategic surprises (Handberg, 1995). There was no economy of scale because of the compartmentalization imposed by security, and up until recently, the involvement of private enterprises in space activities was simply limited to that of vendor and contractor, whereby private companies would only sell equipment and materials employed by the military and NASA for its purposes.

Today however, the industry has shifted considerably and the challenges are a bit different, since we are now faced with the responsibility of gradually separating not the military, but the government, from the activities which will be performed by new private aerospace companies. This gradual transition in the industry has been undoubtedly fueled by various factors, such as the global financial recession faced by almost all space-faring country's within the past 4-6 years, reducing government budget and spending, mainly the United States; and of course the advent of new technology and concepts which has allowed the private industry to consider venturing out into this arena, more so with sub-orbital flights.

In terms of government support, and directly intertwined with the aforementioned financial recession, it is worthwhile pointing out that the United States has passed key legislation that addresses the need for increased investment from private sources for the benefit of the industry. A survey conducted to County and State political figures will be assessed on the *results* section of this report, which provides an insight into their respective perception on the topic. As follows, a brief rendition of key Laws passed by the United States with the objective of incentivizing and promoting private venture into the industry:

- The Private Space Companies Act: Passed in 2010 and resolved by the Senate and House of Representatives of the United States of America in Congress to:

promote space exploration and settlement by private space companies, by promoting incentives for entrepreneurial investment in space and by assuring appropriate property rights for those who seek to develop space resources and infrastructure (Space Settlement Institute, 2012).

- National Space Policy Act: Passed in 2010 to: i. Energize competitive domestic industries to participate in global markets and advance the development of satellite manufacturing; satellite-based services; space launch; terrestrial applications; and increased entrepreneurship, ii. Expand international cooperation on mutually beneficial space activities to broaden and extend the benefits of space; further the peaceful use of space; and enhance collection and partnership in sharing of space-derived information, iii. Strengthen stability in space through domestic and international measures to promote safe and responsible operations in space; improved information collection and sharing for space object collision avoidance; protection of critical space systems and supporting infrastructures, with special attention to the critical interdependence of space and information systems; and strengthening measures to mitigate orbital debris, iv. Increase assurance and resilience of mission essential functions enabled by commercial, civil, scientific, and national security spacecraft and supporting infrastructure against disruption, degradation, and destruction, whether from environmental, mechanical, electronic, or hostile causes, v. Pursue human and robotic initiatives to develop innovative technologies, foster new industries, strengthen international partnerships, inspire our Nation and the world, increase humanity's understanding of the Earth, enhance scientific discovery, and explore our solar system and the universe beyond, and vi. Improve space-based Earth and solar observation capabilities needed to conduct science, forecast terrestrial and near-Earth space weather, monitor climate and global change, manage natural resources, and support disaster response and recovery (FAA, 2010).

Today, just two years since the abovementioned Laws were passed, we have seen a sustainable increase in the participation and creation of private aerospace companies. As follows, a brief rendition of significant events carried out by private companies, or government agencies in favor of private companies, in the past two years:

- FAA/AST issued its first safety approval for a commercial Spaceflight Training System (STS)
- FAA/AST issued a Spaceport license for New Mexico's Spaceport America
- FAA/AST issued a Spaceport license for Florida's Cecil Field Spaceport
- NASA selected the first round of winners for the Commercial Crew Development initiative.
- Scaled Composites started test flights of its SpaceShipTwo suborbital crewed vehicle

- Space X inaugural Falcon 9 Launch was a success, and consequently now considered as a top provider by the US Government to send crew and cargo into space.
- NASA announced its intentions to procure commercial manned launches to carry its astronauts to the ISS beginning in 2017.[4]

2. Environmental:

Of all the factors in this PEST analysis, the Environmental variable is perhaps one of the most important that might impede the accelerated growth of the industry, especially from the spaceport development and certification perspective. This factor will always be one in which the government will have a more direct intervention and non-flexible role if Federal or State environmental Laws are not met.

According to Anderson (2008), the existing rocket propulsion system consumes a great amount of fuel “propellant” in the form of liquid oxygen and liquid nitrogen. Clark (1972), also found that a three stage solid rocket booster has a launch mass of 23,130 kg, low earth orbit payload is 443 kg, for a payload fraction of 1.9%., compared to a Delta IV Medium, 249,500 kg, payload 8600 kg, payload fraction 3.4%. At liftoff an orbiter and external tank carries 835,958 gallons of the principle liquid propellants: hydrogen, oxygen, hydrazine, monomethylhydrazine, and nitrogen tetroxide. The total weight is 1,607,185 pounds (Anderson, 2008).

Despite the above chemicals currently in use, perchlorate was an ingredient heavily used in rocket fuel and some fireworks and fertilizers; and still has been regularly detected in public drinking water supplies. According to the EPA (2000), exposure to perchlorate has been shown to inhibit thyroid functions, subsequently causing

[4] According to the Government Accountability Office (2012), since NASA retired its Space Shuttle program in July 2011, it lacks a domestic capability to send crew and cargo to the ISS. Thus, to maintain the ISS through 2020, as required by the NASA Authorization Act of 2010, NASA is relying on international partners and commercial vehicles to transport cargo.

developmental problems. It would therefore also be a legitimate question to ask the long term effects of the chemicals currently replacing perchlorate, and the side effects that might surface in coming years.

For a more succinct material, this topic has been divided into two: 1. Environmental impacts on a global scale, and 2. Environmental impacts on a local/regional level.

According to McDonald & Bennett (1995), three independent studies were conducted for assessing the impact of rocket launches on the earth's environment. These studies addressed issues of acid rain in the troposphere, ozone depletion in the stratosphere, toxicity of chemical rocket exhaust products, and the potential impact on global warming from carbon dioxide emissions from rocket launches. Local, regional, and global impact assessments were examined and compared with both natural sources and anthropogenic sources of known atmospheric pollutants with the following conclusions:

- Neither solid nor liquid rocket launches have a significant impact on the earth's global environment, and there is no real significant difference between the two.
- Regional and local atmospheric impacts are more significant than global impacts, but quickly return to normal background conditions within a few hours after launch.
- Vastly increased space launch activities equivalent to 50 U.S. Space Shuttles or 50 Russian Energia launches per year would not significantly impact these conclusions.

Table 1

Major Exhaust Products During and After Rocket Launch

Propellant System	Major Exhaust Products
Ammonium Perchlorate Aluminum	HCI, AI_2O_3, CO_2, CO*, N_2, H_2*, H_2O
Ammonium Perchlorate Sodium Nitrate Aluminum	NaCI, AI_2O_3, CO_2, CO*, N_2, H_2*, H_2O
Ammonium Perchlorate Magnesium	MgO, $MgCI_2$, CO_2, CO*, N_2, H_2*, H_2O
Ammonium Nitrate Magnesium or aluminum	AI_2O_3, ORMgO, N_2, CO_2, CO*, H_2, H_2O
Liquid Oxygen Liquid hydrogen	H_2O, H_2*
Liquid oxygen Hydrocarbon	CO*, CO_2, HYDROCARBONS, H_2O
N^2 O4 Dimethylhydrazine	N_2, NOx, CO*, CO_2, H_2O

Note: Mostly consumed during afterburning. Adapted from “*Environmental impacts of rocket launches” by* McDonald & Bennett, 1995, pp 2-4.

Nonetheless, according to Toohey (2011), just a handful of NASA space shuttle launches release more ozone depleting substances in the stratosphere than the entire annual use of CFC based medical inhalers used to treat asthma and other diseases in the United States.

Highly reactive trace gas molecules known as radicals dominate stratospheric ozone destruction, and a single radical in the stratosphere can destroy up to 10,000 ozone molecules before being deactivated and removed from the stratosphere. Microscopic particles, including soot and aluminum oxide particles emitted by rocket engines, provide chemically active surface areas that increase the rate such radicals "leak" from their reservoirs and contribute to ozone destruction (Toohey, 2011).

In addition, Toohey (2011) also found that every type of rocket engine causes some ozone loss, and rocket combustion products are the only human sources of ozone destroying compounds injected directly into the middle and upper stratosphere where the ozone layer resides.

In the study conducted by McDonald & Bennett (1995), the results obtained indicate no global environmental impact on the use of propellants during and after launch. Current global rocket launches deplete the ozone layer by no more than a few hundredths of 1 percent annually (Toohey, 2011). Since 1987 CFCs have been banned from use in aerosol cans, freezer refrigerants and air conditioners, and many scientists expect the stratospheric ozone layer, which absorbs more than 90 percent of harmful ultraviolet radiation that can harm humans and ecosystems, will return to levels that existed prior to the use of ozone-depleting chemicals by the year 2040 (Toohey, 2011).

On the local and regional level, however, the impacts are more tangible. Acid rain is one of such variables, and according to McDonald & Bennett (1995), since SRB's produce hydrochloric acid in the exhaust plume, there has been considerable concern over the impact that this acid rain may have on the global environment, but more specifically on local launch sites. All rockets produce some acid rain as a result of the formation of NOx in the near field of the plume from afterburning that forms nitric acid in the presence of water.

As follows, Figure 2 depicts the annual U.S. contribution to the global acid rain problem from various anthropogenic sources, including solid rockets. As can be seen from the figure, other energy conversion processes such as heating and power production (33,000 kilotons), transportation (9,100 kilotons), and industrial processes (6,100 kilotons) clearly overshadow the acid production (3 kilotons) from solid rocket launches.

Most of the acid produced from these industrial activities is in the form of sulfuric acid, with significant quantities of nitric and hydrochloric acid also produced. Without considering other countries in the world, rockets are responsible for less than 0.006 percent of acid rain produced by U.S. industries alone.

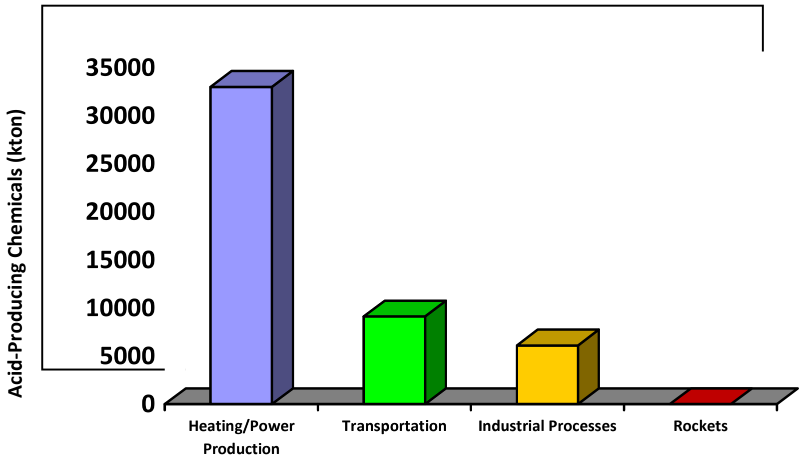

Figure 2. Acid-Producing Chemicals. Adapted from *"Environmental impacts of rockets" by* McDonald & Bennett, 1995, pp-8-9.

On a local scale, acid rain from SRB's is more significant and does have near field acidification effects in the vicinity of the launch site. These effects are limited to a very localized area within less than one-half mile from the launch pad directly in line with the SRB flame trenches, as shown in Figure 3. Some plant and small fish (minnows) mortalities occur in the lagoon area just north of the launch pad, less than 0.1 square mile of area (which is much smaller than the launch pad itself). Catch basin for the sound suppression water is neutralized after each launch and the pre- and post-launch environmental conditions are documented on each Space Shuttle launch (McDonald & Bennett, 1995).

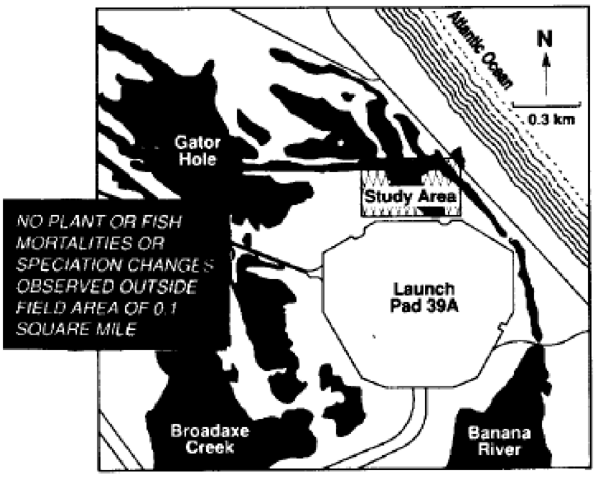

Figure 3. Flora & Fauna Study around Launch Site. Retrieved from "*Environmental impacts of rockets" by* McDonald & Bennett, 1995, pp.8-9.

Considerable concern has been raised relative to the toxicity and corrosiveness of the SRB ground cloud as it drifts away from the launch site. Bionetics Corporation has periodically monitored HCI concentrations for NASA and routinely conducts model calculations on HC1 concentration in the far field of the Space Shuttle plume (McDonald & Bennett, 1995).

It should also be noted that according to McDonald & Bennett (2011), the maximum HC1 concentration in the ground cloud of 0.9 parts per million is well below the American Conference of Governmental Industrial Hygienists' recommended threshold limit value (TLV) of 5 parts per million for long-term continuous exposure (8 hours per day 40 hours per week). HC1 concentrations measured in the path of the Titan III SRB ground cloud as it drifted several kilometers from the launch site at Vandenberg

AFB have also been well below the 5 ppm threshold limit values, i.e., 0.005 ppm to 0.5 ppm.

Hydrochloric acid is the most toxic substance associated with cured solid propellants and it is only produced by combustion. Storable liquid bipropellants consisting of nitrogen tetroxide (NO_4) and hydrazine compounds are far more toxic, but have been safely and routinely handled at various launch sites for decades. Even in very minute concentrations, these liquid bipropellants can be a significant health hazard while HCI in minute quantities is only considered a corrosive or irritant (McDonald & Bennett, 2011).

On the other side of the spectrum, according to Toohey (2011), on a global scale and as the rocket launch market grows, so will ozone-destroying rocket emissions, and if left unregulated, rocket launches by the year 2050 could result in more ozone destruction than was ever realized by CFC's.

Nonetheless, it is the researcher's opinion that for the short-term to mid-term growth of the commercial space industry a more tangible barrier will be on the local scale, as more and more communities will become more adamant in overseeing the overall impacts of rocket launches within their communities. The latter will undoubtedly require multiple studies on the subject to guarantee their overall health and impacts to the surrounding flora and fauna. This will become more evident as the commercial space industry grows and the need for spaceport certification grows alongside it.

In some instances, it will be safe to assume that some communities will not even consider the positive local economic effects that a spaceport might have in their area, perhaps not even with the scientific support of multiple environmental impact studies which might indicate minimal negative effects. A survey conducted to ordinary civilians and political figures will be assessed on the *results* section of this report which will provide an insight into their respective perception on the topic.

Another important part of the environmental barriers is the noise element, directly attributable to vertical launches. According to Caimi, Margasahayam & Nayfeh (2001), at lift off the thrust of the rocket motors and resulting acceleration of the launch vehicle impose a large steady state load. Significant transients due to engine ignition produce vibration over a wide range of frequencies. However, a particularly serious source of vibration is very high amplitude acoustic noise generated by the propulsion system of the first stage main engines at lift off. The noise reflects upward from the ground and envelopes the spacecraft and launch pad equipment and structures. This lasts about 10 seconds until the rocket clears the pad.

Caimi, Margasahayam & Nayfeh (2001) also found that the airborne sound acting on the structural elements above the ground excites a typical building or structure in the vicinity of the launch pad. A part of this sound energy is transmitted into the building interior via any opening in the walls and re-radiation from the vibrating walls. Unless the building structure is acoustically isolated, a significant portion of acoustic energy may propagate into the building interior.

Furthermore, ground vibrations generated by the exhaust stream of the rocket engine that impinges off the deflector can also be transmitted structurally from the launch pad to the parts of the building below ground, thereby exciting the rest of the building into vibrations. Airborne and structure borne noise and vibration will affect equipment and machinery located inside the structure (Caimi, Margasahayam & Nayfeh, 2001).

Reviewing the findings from the study above, it is safe to conclude that the recurring exposure to vibration and an ignition overpressure environment may cause serious structural and equipment failures resulting in a direct impact to would be communities which might have a spaceport in its proximity, and specifically conducting launches vertically. Therefore, knowledge of the fundamental factors governing the vibratory source characteristics and their subsequent responses is imperative to the designer of launch pad facilities, equipment, and structures.

For a better edification to the reader, Figure 4 shows the characteristics of ignition overpressure peaks as a result of using solid rockets rather than liquid rockets. It represents a shock loading to the structures and equipment located on the launch pad. Solid fuels are superior to liquid fuels in terms of their high-thrust capability during the early phase of launch. However, their main drawback is the inability to throttle the engine once ignited.

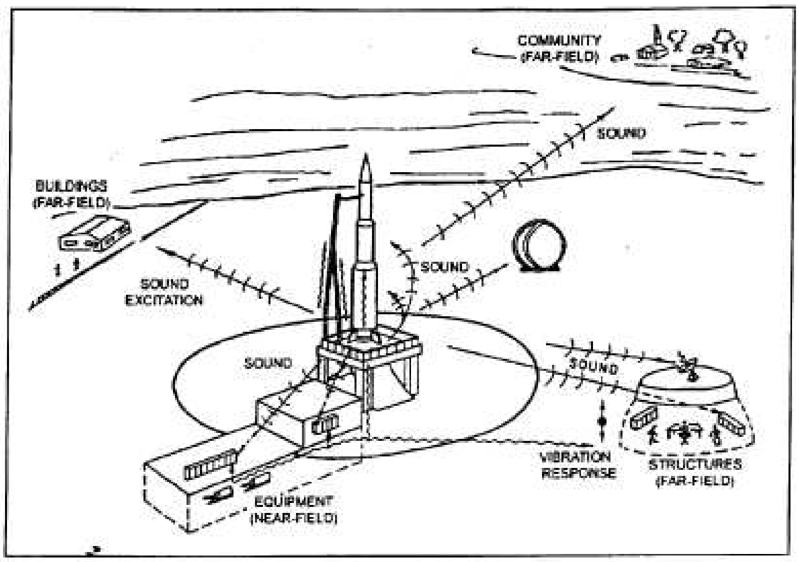

Figure 4. Rocket noise and vibration affected areas. Retrieved from "*Rocket launch-induced vibration and ignition overpressure response*" by Caimi, Margasahayam, & Nayfeh, 2001, pp. 1-8.

To further substantiate the impacts of vertical launches on a local fauna, the researcher will put forth the study conducted by Brent Stewart (1998) on the impacts of launch on fauna, conducted from the Kodiak Launch Complex. The study in question utilized sound measuring and recording instruments placed at three sites within several miles of the launch pad[5].

Most of the sound energy that impacted the Azimuth site occurred within 20 seconds after launch, though some noise was audible above background levels for a total of about 59 seconds. The frequency content of that noise was mostly below 4 kHz with a substantial amount of energy at frequencies of 100 to 500 Hz. The sound exposure level for the noise event was 110 dBA and the maximum sound pressure level was approximately 104 dBA, both slightly higher than predicted for the aft rocket motor at that distance from the launch pad (Stewart, 1998).

The study concluded that data for hearing thresholds in eared pinnipeds (family Otariidae) and birds indicate that the launch noise would have been detected by local bird and pinniped fauna and that those species likely would have responded behaviorally to the launch noise event impacting the three monitoring sites (Stewart, 1998).

According to Stewart (1998), in the case of sea lions, data available indicate that their in-air hearing thresholds are about 18 to 30 dB between 1 and 4 kHz, respectively. Data for one California sea lion suggest an in-air hearing threshold of around 77 dB (re: 20 mPa) at 100 Hz. If we consider the latter data, than most of the launch noise that was recorded would have been audible to sea lions that may seasonally reside at Ugak Island around Kodiak, Alaska.

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[5] Study conducted by Brent S. Stewart, PhD., Senior Research Biologist of Hubbs-Sea World Research Institute, titled: "Evaluation of the Potential Impacts of Launches of the USAF atmospheric interceptor technology from the Kodiak Launch Complex". Performed on 05th November 1998.

Thus, hearing impairment of sea lions exposed to this short duration noise event would not be likely; nonetheless, sea lions would likely be alert to and perhaps be stimulated to move towards or into the surf by these unique noises. The same conclusions would apply to bald eagles in the near vicinity (Stewart, 1998).

3. Social:

The social element of this project's PEST analysis was focused on the overall perception of the public, specifically through the use of surveys conducted to three respective audiences, divided into three parts. Part A was targeted to ordinary civilians to show their perception and overall evolution in thinking of space related activities; Part B was targeted to industry professionals to show their personal and professional opinions in spacecraft design, industry trends, and spaceport certification, and Part C was targeted to government/public officials and representatives of County, State and Federal agencies to ascertain their perception in the future of the commercial space transportation industry and of spaceport certification in their respective communities.

Data tables for accuracy and reaction time were imported from an Excel spreadsheet for review and input into the statistical analysis, accompanied by descriptive stats which visually represented the results obtained. A factorial Analysis of Variance (ANOVA) was also conducted to evaluate if main or interaction effects existed from the interviews conducted to the three respective groups.

The data obtained will be thoroughly discussed in the respective *methodology* and *results* section of this report. Nevertheless, it's worthwhile pointing out that said results did in fact indicate important statistical trends as to the perception of all the audiences involved, which undoubtedly served the main purpose of the survey as to successfully meet the *program outcomes 3* described for this project.

4. Technological:

For the commercial space industry, the more critical public activity has been the development component; more critical that is in terms of the long range development of space. Although in the short term, the comparatively large budget of NASA has kept alive some space related companies through purchases of their goods and services. All this, however, is now gradually changing as reduced government spending and financial constraints are decreasing NASA's budget and evolving towards funding from private sources, as has been discussed in the *political* section of this project.

Handberg (1995) found that the tendency in space related technological development which was once explicit to the government will still be fostered by them but proactively incentivizing private companies in technological innovation, such as supporting new physical processes like crystal growth in microgravity, developing alternative launch technologies, or new technologies to solve space-related problems that have usefulness in the private sector.

Commercial Development of Space

Orbital and Sub-Orbital Trends

Following the definition of orbital flights in the *project introduction* section of this report, the researcher will now present an industry snapshot pertaining to commercial activities on orbital spaceflights.

As we have gradually seen throughout this report, opportunities for the economic exploitation of space do exist and are expanding. Significant players are considering the field, including individuals and institutions not usually interested in space. According to Handberg (2008), the expressed interest comes only because of possible profits. The trend for orbital activities will be dramatically facilitated by sustained investment in new, more cost efficient launch technologies. Such advances and economic development of space will likely lag behind expectations and growth potential. Commercially, the technology will become a means to an end, that end will be achieving a profit.

With the end of the Space Shuttle missions in 2011, and with the goal of streamlining their operation with a reduced budget, NASA has actively searched for new launch alternatives for their future orbital missions. For manned missions, NASA is temporarily utilizing Russia's SOYUZ capsules to reach space; nonetheless, it has also signed a Space Act Agreement with the company SpaceX for the development of human spaceflight hardware. This agreement is a flexible partnership that allows NASA to work cooperatively with industry to develop and transfer technology in support of national priorities and NASA's missions (NASA, 2012).

Interesting news is that at the moment of writing this project NASA has announced the arrival to Kennedy Space Center of the Orion Capsule, designed to fly up to four astronauts to near-Earth asteroids, the moon, Mars and other destinations beyond the space station's orbit (NASA, 2012). The Orion capsule is scheduled to launch in 2014, and is made up of an aluminum alloy hull, and its arrival is just the beginning of what eventually will be put on top of a Delta 4 Heavy rocket and shot some 3,450 miles into space.

Also worthwhile discussing herein is the private investment in innovative space-related ventures for non-traditional orbital purposes; referring of course to deep space missions for mining asteroids. Here we see a perfect example of how the attainment of technology from investment in space is a clear means to an end, being profit the ultimate goal. In April of 2012 a new private venture was announced, the creation of the company "Planetary Resources", which plans to survey and mine precious metals and minerals from asteroids (DiscoveryNews, 2012).

The venture has drawn a list of high-profile investors, including Google executives Larry Page and Eric Schmidt, filmmaker James Cameron and former Microsoft software chief Charles Simonyi, who flew twice to the International Space Station as a private space traveler.

According to DiscoveryNews (2012), the first step for the company will be to design fleets of small low-cost probes that can travel beyond low-Earth orbit. There are thousands of asteroids that come close enough to Earth and that are easier to get to than the moon. Planetary Resources also expects to extract water and other raw materials from some of the thousands of asteroids that pass relatively close to Earth.

Water, for example, could be processed into fuel by breaking apart the oxygen and hydrogen molecules. It then could be sold commercially from fuel depots in orbit to

NASA and other entities conducting robotic and human space missions. An asteroid about one-third as long as a football field could have as much as $25 billion to $50 billion worth of platinum at today's prices (DiscoveryNews, 2012).

As we move forward in the development of commercial Space, we still hold true to the fact of six major national players in the Space arena: United States, Russia, Japan, France, Germany, and China, latter which should be considered as an important competitor to the United States. Nevertheless, according to Handberg (2008), the United States remains overall the dominant single Space commerce player, although that position remains fragile.

Of these major players, it’s safe to assume that in the development and growth of private space companies for commercial purposes, the United States also has the lead. This has been fueled in part by the prizes and competitions, such as: 1. the NASA Centennial Challenge, 2. Google Lunar X Prize, and 3. The Ansari X Prize; as well as the strategic Laws passed by the U.S. government in the past 2-3 years to incentivize the private industry (*see political section*). This has undoubtedly contributed for space-related private ventures to take off, literally and figuratively.

Now if we look in the global arena, in the case of France and Germany, their activities range from independent to cooperative within the framework of the ESA. Europe at some level is an entity, but in other context, each country also does it alone (France much more than Germany). As follows, a brief snapshot of each of the major players besides the Unites States:

- Russia: Represents an enigma when one evaluates its long-term space commerce potential. The Russian space program represents a strong competitor across the spectrum of space activities. They possess exceptional launch capability, commercial application and remote sensing.

- Japan: Great potential, but modest accomplishments, due to deliberate choice and historic circumstances. Their space program was not fueled by large military motives as the U.S. or Russia, for obvious reasons related to their defeat in World War II. It is an explicitly commercially oriented space program. Strong areas are in robotics and remote sensing.

- France: Is a striving commercial player. They are a dominant player within ESA through Arianespace and remote sensing through SPOT images. They are more committed to space programs than any other European country. They are currently seeking partnerships with Russia and China, nonetheless, their physical location limits certain activities.

- Germany: Should be considered as a major player due to its economic growth and demonstrated technological capability. They have been scientific and commercial in their aspirations; however, space efforts are often subject to extreme pressure because of other domestic political priorities. Their space program is characterized by international projects to which they are vital contributors but not dominant players. Their potential like the Japanese is tremendous, but still lies in the future.

- China: Has made a determined bid for prominence in the world launcher market. Its rocket family covers the spectrum from small to heavy payloads. According to Handberg (2008), fears concerning their ability to under price and totally capture the launch market has led to agreements restricting their access to the marketplace. Their next major area of concentration is remote sensing, where applications have immediate social utility (e.g., soil studies, floods).

On the sub-orbital side of the industry, there has also been significant development from the private sector in recent years. In particular, six companies made significant progress in the development of sub-orbital reusable launch vehicles (RLV). According to the FAA (2012), a number of these companies are conducting or planning operational flights in the next few years.

For the purpose of discussing this sub-topic we must take note of the definitions given in the *project introduction* of this report, pertaining to spacecraft design. According to the FAA (2012), vehicles that access outer space, operate within the space environment, return safely to Earth, and can be used again are referred to as RLV's. Those that do not attain enough velocity to enter into a sustainable orbit around the Earth and re-enter are SRLV's.

Of the six sub-orbital space companies, there are those which are concentrating in operating under a horizontal launch method, and others will maintain a vertical launch.

- Virgin Galactic's SpaceShipTwo vehicle and XCOR's Lynx vehicle are Horizontal takeoff and Horizontal Launch (HTHL).
- Armadillo, Blue Origin, and Masten design are Vertical takeoff and vertical landing vehicles (VTVL).

As of now there are no crew capable sub-orbital or orbital RLV's in operation. However, several companies have completed significant milestones in crewed SRLV development. According to the FAA (2012), six U.S. sub-orbital launch service providers have made the most progress in the design, development, and testing of their respective vehicles: Armadillo Aerospace, Blue Origin, Masten Space Systems, UP Aerospace, Virgin Galactic, and XCOR Aerospace.

Some are flight testing hardware and conducting experimental launches, while others will enter the flight test phases in the near future. Five companies plan to conduct scheduled commercial suborbital launches by the end of 2012 to 2014 timeframe (FAA, 2012). Finally, the researcher would like to render a pyramid of what the aerospace industry will look like in the next 20-30 years, as per current industry trends.

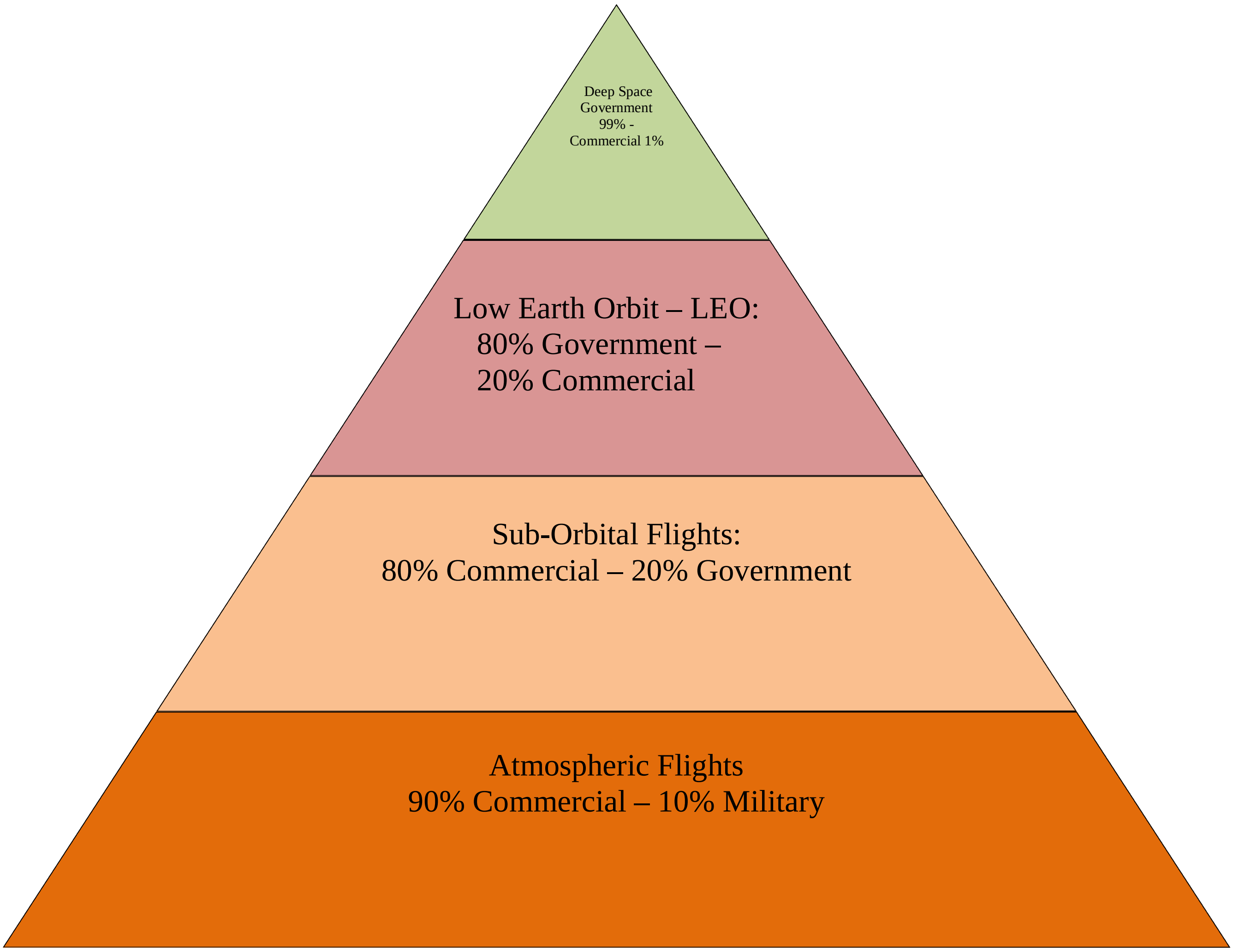

Figure 5. Pyramid with expected traffic of Aviation/Aerospace flights for the next 30 years. Courtesy of InterFlightGlobal, 2012.

Spacecraft Designs

Current Spacecraft designs for manned Orbital or deep space flights are limited to capsules, which basically require rockets to complement their functions of reaching space. A manned space capsule must have everything necessary for everyday life, including air, water, food, as well as the capability of protecting the astronauts from the radiation of space and the cold. Other elements must also be present in the design of the capsules, such as the requirement of being well insulated, and the presence of a system that controls the inside temperature and environment (NASA, 2012).

Over the years, various capsules have been designed by different countries, such as the Soyuz by the Russians, the Gemini and Apollo by the U.S., and the Shenzhou by the Chinese. A new capsule developed for orbital purposes and deep space exploration is the U.S. Orion capsule.

Figure 6. Orion Capsule for Orbital and Deep Space missions. Retrieved from NASA "Researcher News", 2012.

According to NASA (2012), the capsule is based on the design requirements for traveling beyond low Earth orbit (LEO), and will serve as the exploration vehicle that will carry the crew to space, for future Mars missions, provide emergency abort capability, sustain the crew during the space travel, and provide safe re-entry from deep space return velocities, and it is scheduled for use by 2014.

On the other hand, the design and development of sub-orbital vehicles is also experiencing positive growth, which is largely due to the $10 million Ansari Prize in 2004, won by Mojave Aerospace Ventures using a vehicle operated by Scaled Composites called SpaceShipOne. This prize motivated 26 teams to invest over $100 million to win the prize, consequently showing to investors and consumers the possibility of sub-orbital flights (FAA, 2012).

Current spacecraft design concepts for sub-orbital vehicles either launch vertically like a traditional launch vehicle, at a high altitude from a carrier craft, or horizontally take off under rocket power from a runway. The vehicles then either use rockets or parachutes to assist landing vertically, or they use wings to land like a glider or conventional aircraft (FAA, 2012).

It’s worthwhile pointing out that various private companies, such as RocketPlane, are also considering not the construction from the ground up of a newly designed spacecraft, but looking into the possibility of taking an already FAA-certified aircraft, such as a Citation X, and simply modifying some aspects of its fuselage to accommodate an ignition tank for sub-orbital spaceflights, under a “X” concept vehicle (InterFlightGlobal, 2012).

One of the main advantages which will become immediately evident with sub-orbital flights will be the duration of the flights from a determined point A to point B, which will be initially offered to businessman that require short flight times, as well as to tourist which will want to be part of the experience. As shown in Figure 7 below, we can appreciate a proposed sub-orbital flight, elaborated for RocketPlane by Embry-Riddle engineering student, and InterFlightGlobal intern, Jose David Edid:

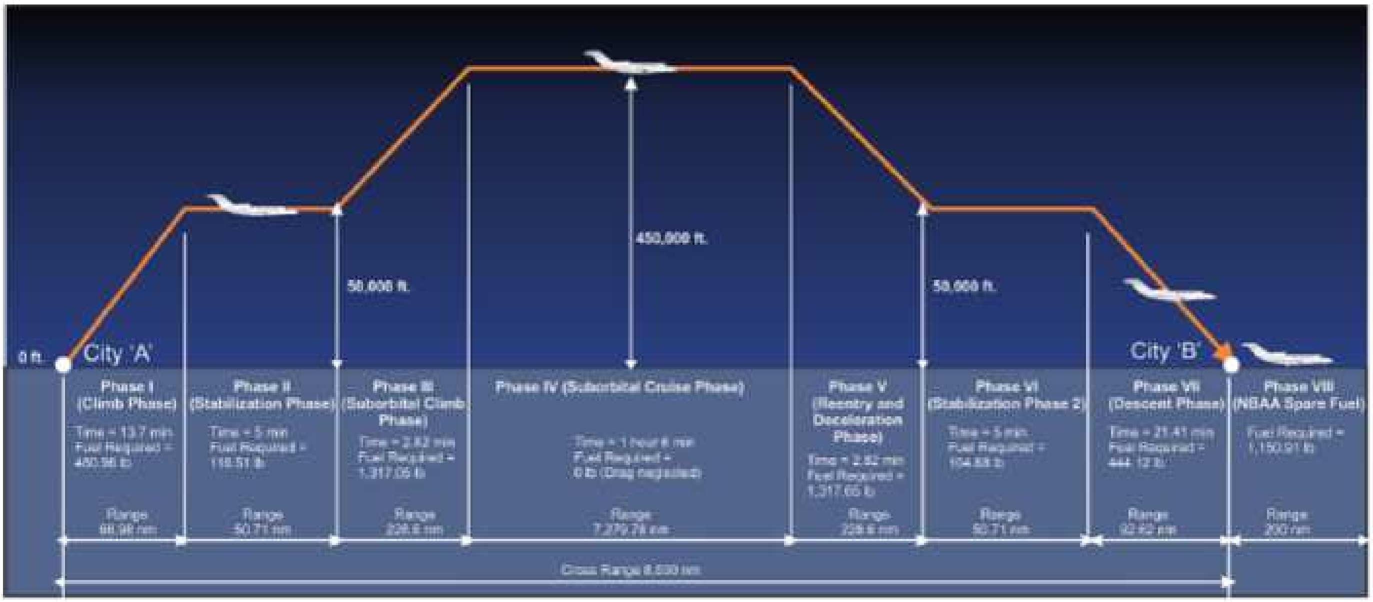

Figure 7. Preliminary trajectory of a sub-orbital flight. Retrieved from "*IFG Sub-Orbital Flight Trajectory*", by Jose David Edid on behalf of InterFlightGlobal, 2012, p. 3.

According to InterFlightGlobal (2012), an already FAA-certified aircraft would only require a Part 23 certification to approve the particular area which has been modified or added to the aircraft. The latter scenario presents greater financially-feasible alternatives for sub-orbital flights, since companies will not be inclined, at least during the first years of industry growth, to invest large amounts of capital in the design from the ground up of new spacecrafts.

The downside to this, of course, is that no new enabling technological or design breakthroughs will be attained as a byproduct. However, it just might be the gradual, yet flexible, transition small private sub-orbital companies might need to get off the ground, at least until the industry grows and develops substantially; bringing forth public demand in its services to significantly produce a steady flow of investments.

As follows, we can appreciate some illustrations of spacecraft designs from various of the new private sub-orbital companies:

Figure 8. Lynx Concept "X" Vehicle for Horizontal takeoff Horizontal Land (HTHL). Retrieved from "XCOR Aerospace", 2012.

Figure 9. SpaceShipTwo Concept "X" for Horizontal takeoff Horizontal Landing (HTHL). Retrieved from "VirginGalactic", 2012.

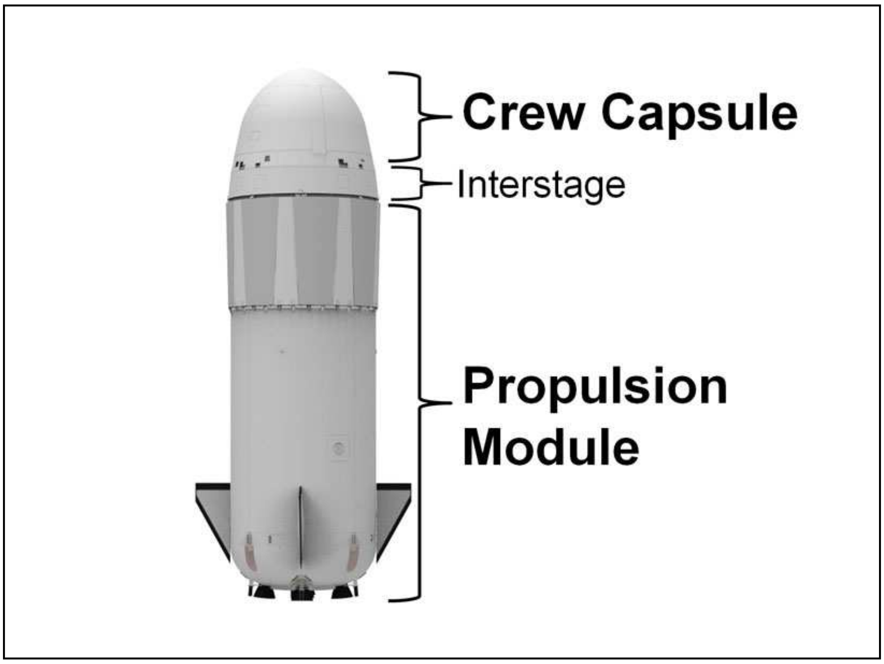

Figure 10. New Sheppard Vehicle Concept "Z" for Vertical takeoff Vertical Landing (VTVL). Retrieved from "BlueOrigin", 2012.

Enabling Technologies

Enabling technologies should be considered as those that directly enable launch vehicles, solve system challenges, support government projects, and provide a competitive edge. Successful new technologies for the commercial space industry are often designed for a specific system, but they can expand in use for a range of future systems (FAA, 2012).

For the benefit of the reader, the researcher has divided this sub-topic into the following three basic areas:

1. Guidance, Navigation, and Control:

The use of hardware pertaining to navigation controls and avionics are an essential requirement for all activities of controlled flight, and this is no exemption for the orbital and sub-orbital flights. Both RLV and ELV require such use and the development of new systems will undoubtedly represent a great technological leap for future spacecraft. As follows are some of the technologies which have been developed for these purposes:

- Emergency Detection System (EDS) was designed to supports converting the Atlas V and Delta IV launch vehicles into crew transportation systems. This system is a sensor and software package designed to detect launch vehicle failure (FAA, 2011).

- Autonomous Flight Safety System (AFSS) was designed to reduce costs associated with range safety by incorporating flight termination decisions within the vehicle's onboard processors (FAA, 2011).

- The Commercial Orbital Transportation Services (COTS) was designed to provide a data link between the International Space Station (ISS), SpaceX's Dragon capsule, and ground control. The system also enables astronauts on the ISS to monitor and control Dragon during unscrewed cargo mission (FAA, 2011).

2. Life Support:

For habitat within the capsules, new life-support systems are required. Fortunately, various companies are developing environmental controls and life support systems (ECLSS). It's important to first distinguish to two different systems, 1. Air revitalization systems are designed to support short duration missions, such as orbital transport vehicles, and 2. The ECLSS designed to support space stations and other long-duration habitats (FAA, 2011). As follows some of the life-support technologies being developed:

- Environmental Control and Life Support System: Under development by Bigelow Aerospace for its next generation expandable space habitats. The first system will support the needs of Bigelow's Sundance module, which will provide about 180 cubic meters of usable volume and can sustain a crew of three. Eight hour long tests were conducted with volunteers at Madison, Wisconsin by ORBITEC on behalf of Bigelow (FAA, 2011).

- Commercial Crew Transport – Air Revitalization System: Under development by Paragon Development Corporation for a modular air revitalization system for commercial crew transport. It will provide atmospheric control during short flight to LEO. It is being designed as a drop-in system for any commercial crew vehicle.

It is also being designed to eliminate contaminants, carbon dioxide, and it also cools the air and provides humidity control (FAA, 2011).

3. Propulsion:

These include: 1. Liquid rocket engines, 2. Solid rocket motors, 3. Propellants, and 4. Associated subsystems.

- Propulsion – Engines and Components: multiple investments are being made by rocket and spacecraft developers to meet the expected demand of orbital and sub-orbital flights. According to FAA (2011), under current development are cryogenic liquid engines, hydrocarbon liquid engines, solid rocket motors, and non-toxic liquid/solid hybrids.

- The Draco Thrusters: Developed by SpaceX for orbital maneuvering and attitude control for their Dragon spacecraft. The Draco thrusters can generate up to 400 newtons (90 pounds) of force, and they can fire in bursts as short as a few milliseconds for precision maneuvering, or up to several minutes for orbital maneuvering. Depending on their mission, each spacecraft can use up to 18 Draco thrusters that receive propellants from eight spherical titanium propellant tanks.

- Cryogenic Piston Pumps: Developed by XCOR to pump liquid hydrogen pneumatically. Unlike traditional turbopumps, which rely on traditional rotating machinery, these pumps use one or more pistons to accelerate propellants into the combustion chamber and failure of a piston pump is less destructive to adjacent hardware.

- Liquid/Solid Hybrid Rocket Motor: Developed for Dream Chaser spacecraft by the Sierra Nevada Corporation, it provides a simple solid motor with restart and throttle ability. It uses non-toxic materials, nitrous oxide (NOx) as an oxidizer and synthetic rubber as a solid fuel.

- Liquid Oxygen/Liquid Hydrogen Cryogenic Engines: Developed by Pratt & Whitney, it can support commercial spaceflight. This is an upgrade from the RS-68 engine and will provide 178 kilonewtons (40,000 pounds) of thrust more than its predecessor and will increase fuel efficiency for the Delta IV.
- Vertical Take-off and Landing Engines: This concept has been developed by Masten Space Systems, it was the first vertical take-off and landing vehicle to demonstrate in-flight re-light capability, demonstrating the capability for controlled flight and stability.

4. Space Suits:

A space suit is defined as a full-pressure protective garment with a, n integrated environmental support system designed for extravehicular activity, which can also be used in the event of loss of cabin integrity (FAA, 2011). As follows, a list of new spacesuits under development for commercial use:

- Contingency Hypobaric Astronaut Protective Suit (CHAPS): Designed by The David Clark Company for Intravehicular Activity (IVA) only. It weighs less than 20 pounds and fits in a volume of about 0.2 cubic meters, and protects the user from loss of cabin pressure and hypothermia. Consists of coverall with a pressure-sealing rear entry and soft, flexible joints, as well as helmet and gloves.
- I-C2 Commercial Launch Suit: Designed by ILC Dover, original designer of suits

for the Apollo missions, it consists of a pressure garment with waist entry and a moisture vapor permeable bladder. It also has a cooling garment under the suit for temperature control. According to FAA (2011), the outer cotton layer is fire resistant, and it features safety reflectors and hand holds for emergency rescue.

- Industrial Sub-Orbital Spacesuit: Designed by Orbital Outfitters for the emerging sub-orbital tourism market. Its primary purpose is to protect the user from loss of vehicle cabin pressure.

Also appropriate to point out under this section is the Technology Readiness Level (TRL) methodology utilized by NASA for the assessment, evaluation and application of new and upcoming technologies. According to NASA (2012), this methodology is divided into the following nine levels:

- TRL 1 Basic principles observed and reported: Transition from scientific research to applied research. Essential characteristics and behaviors of systems and architectures. Descriptive tools are mathematical formulations or algorithms.
- TRL 2 Technology concept and/or application formulated: Applied research. Theory and scientific principles are focused on specific application area to define the concept. Characteristics of the application are described. Analytical tools are developed for simulation or analysis of the application.
- TRL 3 Analytical and experimental critical function and/or characteristic proof-of concept: Proof of concept validation. Active Research and Development (R&D) is initiated with analytical and laboratory studies. Demonstration of technical feasibility using breadboard or brassboard implementations that are exercised with representative data.

- TRL 4 Component/subsystem validation in laboratory environment: Standalone prototyping implementation and test. Integration of technology elements. Experiments with full-scale problems or data sets.
- TRL 5 System/subsystem/component validation in relevant environment: Thorough testing of prototyping in representative environment. Basic technology elements integrated with reasonably realistic supporting elements. Prototyping implementations conform to target environment and interfaces.
- TRL 6 System/subsystem model or prototyping demonstration in a relevant end-to-end environment (ground or space): Prototyping implementations on full-scale realistic problems. Partially integrated with existing systems. Limited documentation available. Engineering feasibility fully demonstrated in actual system application.
- TRL 7 System prototyping demonstration in an operational environment (ground or space): System prototyping demonstration in operational environment. System is at or near scale of the operational system, with most functions available for demonstration and test. Well integrated with collateral and ancillary systems. Limited documentation available.
- TRL 8 Actual system completed and "mission qualified" through test and demonstration in an operational environment (ground or space): End of system development. Fully integrated with operational hardware and software systems. Most user documentation, training documentation, and maintenance documentation completed. All functionality tested in simulated and operational scenarios. Verification and Validation (V&V) completed.
- TRL 9 Actual system "mission proven" through successful mission operations

(ground or space): Fully integrated with operational hardware/software systems. Actual system has been thoroughly demonstrated and tested in its operational environment. All documentation completed. Successful operational experience. Sustaining engineering support in place.

Spaceports

As defined in the *project introduction* section of this report, Spaceports are sites dedicated to launching orbital or sub-orbital vehicles into space. These sites also provide the capability to integrate launch vehicles with payloads and to fuel them. The FAA licenses the operations of commercial spaceports in the United States, and by 2010 the FAA issued eight licenses, as shown in Figure 11.

Figure 11. Licensed Spaceports in the United States. Retrieved from *"U.S. Commercial Space Transportation Development and Concepts"* by FAA, 2011, p. 47.

According to the FAA (2012), these licenses can be reviewed every five years. NASA operated Kennedy Space Center and the Air Force's Cape Canaveral Station are examples of launch facilities that do not require an FAA license, because they are operated by the federal government.

The two aforementioned federal facilities in Florida are available to commercial launch providers using FAA-licensed vehicles, and Kennedy Space Center is planning to host commercial reusable launch vehicles (RLV's) in the near future.

One interesting concept, which in the reader's opinion will represent a tangible progress in the commercial space transportation arena, in the short to mid-term, will be the use spaceports combined with "X" and "Y" concept vehicles into sub-orbit. In this sense, four FAA-licensed Spaceports: 1. Cecil Field Spaceport, 2. Mojave Air and Space Port, 3. Oklahoman Spaceport, and 4. Spaceport America also feature runways for launch vehicles that take off or land horizontally, similar to airplanes, following the "X" and "Y" concepts mentioned above. The following Table will render a list of current available Spaceports in the United States:

Table 2

Licensed Spaceports in the United States

Spaceport	Operator	State	License First Issued	Expires
California Spaceport	Spaceport Systems International	CA	1996	09/2011
Cape Canaveral Spaceport	Space Florida	FL	1999	06/2015
Cecil Field Spaceport	Jacksonville Aviation Authority	FL	2010	01/2015
Kodiak Launch Complex	Alaska Aerospace Development Corporation	AK	1998	09/2013
Mid-Atlantic Regional Spaceport	Virginia Commercial Space Flight Authority	VA	1997	12/2012
Mojave Air and Spaceport	East Kern Airport District	CA	2004	06/2014
Oklahoma Spaceport	Oklahoma Space Industry Development Authority	Ok	2006	06/2011
Spaceport America	New Mexico Spaceport Authority	NM	2008	12/2013

Note: Adapted from “U.S. Commercial Space Transportation Development and Concepts,” by FAA, 2011, p. 48.

Space Tourism

Space Tourism can be considered as a sub-industry of the commercial space transportation industry, and in terms of sustainability, is perhaps the most difficult as we move forward, simply because it will not be immediately available to the masses due to inherent financial limitations.

Nevertheless, a wide array of activities can be considered as space tourism. For instance, the orbital flights which few civilians have undertaken in the past with the Russian Soyuz capsules can be considered as tourism. Today, however, the industry is gradually expanding and the definition is as well applicable towards sub-orbital flights; which according to InterFlightGlobal (2012), is to be considered the cash cow of space tourism for the next thirty years.

A tourist in space sounds far-fetched, but that has actually happened in non-astronauts which have flown to space for purposes of personal leisure. According to Handberg (2008), we are not that far from the prospect of space tourism as one might expect. Obviously, flying to orbit or sub-orbit will begin as an activity of the wealthy, but will soon catch up to the masses as the prices go down.

At the time of writing this project, Virgin Galactic’s Sir Richard Branson has announced that the company will make its maiden tourist flight into space by next year 2013. He also unveiled plans to use WhiteKnightTwo to carry a vehicle called “LauncherOne” that will deliver commercial satellites into orbit (Virgin Galactic, 2012).

The vehicle is already in development and is expected to be ready for operation by 2016. According to Virgin Galactic (2012), it will offer “frequent and dedicated launches at the world's lowest prices”, and four private companies have already put down deposits for several dozen launches. Furthermore, the company has received deposits for suborbital tourist flights from 529 people, which is just above the total of 528 people who have flown in space to date. “LauncherOne” will be a two-stage vehicle able to carry up to 500 pounds to orbit for prices below $10 million (Virgin Galactic, 2012).

On the other hand, one interesting concept that has been considered, both by the researcher and independent investors, is that of a hotel-like spacecraft in space. As farfetched as this idea might seem, the company Bigelow Aerospace is designing such scenario.

They developed Genesis I, an expandable spacecraft placed in low earth orbit in 2006, followed by Genesis II in 2007. The two spacecraft remain in orbit and are operational today, continuing to produce invaluable images, videos and data for the company (Bigelow Aerospace, 2012). Thus, the expandable spacecraft are demonstrating the long-term viability of expandable habitat technology in an actual orbital environment.

Bigelow Aerospace is currently developing the BA 330, which can function as an independent space station, or several BA 330 habitats can be connected together in a modular fashion to create an even larger and more capable orbital space complex (Bigelow Aerospace, 2012). The BA 330 will be functional in the 2014-2015 timeframe and represents an important project for the future of space tourism, since it is designed to hold up to six humans on a long-term basis. Each BA330 will contain its own independent habitation system, including lavatory and hygiene facilities, as well as four large windows coated with a film for Ultra Violet (UV) protection, providing an unparalleled opportunity for both celestial and terrestrial viewing (Bigelow Aerospace, 2012).

This particular project from Bigelow Aerospace represents the closest hotel-like spacecraft currently being developed by the industry. When completed, it will not only provide accommodation for astronauts from different countries which require it, but will also be a space destination for regular tourists in the next thirty years as the industry grows.

Similar projects are being incentivized by NASA from a school to a college level, fostering the creativeness and willingness of future generations to open their minds to this possibility. For instance, NASA sponsors a yearly “Space Settlement Contest” for all students up to 12th grade (18 years old) from anywhere in the world, with adult advisors. Individuals, small teams of two to six, and large teams of seven or more are judged separately to select the winning project. Past winners include students from schools in India, Romania, and the United States (NASA, 2012).

Another valuable program, sponsored by NASA, is the “2012 X-Hab Academic Innovation Challenge” for students on the college level, which includes past winners from Oklahoma State University and University of Wisconsin (NASA, 2012).

In the author’s opinion, all of these activities represent invaluable steps in the right direction, by planting the seeds of technology so that future generations become involved and interested in these types of projects, thus bringing us closer and closer to seriously considering space as a tangible tourism destination.

Other Challenges Facing the Commercial Industry

Legal

From beginning to end, there are many variables that can occur throughout the process of a spaceflight which will represent inherent legal actions and measures, from awareness to prevention to subsequent corrective measures.

A wide array of foreseeable and unforeseeable variables might and most likely will occur as the commercial space transportation industry grows. Variables such as debris that might fall upon a person, house or other objects, or contamination which might occur from any given chemicals directly or indirectly derived from spacecraft launches are just some of these scenarios.

From a legal standpoint, it is therefore safe to assume that government agencies, such as the FAA and other service providers like insurance companies, will have to be prepared to face these issues as they arise, and the would-be users will most likely have to be aware that the signing of waivers for the direct participation of these activities will become normal. Nonetheless, since we are discussing a topic regarding an industry that is very much in its infancy, not all the legal framework, procedures and precedence are in place; therefore, it will be something that both the space transportation companies and the legal teams will have to work on as the industry gets closer and closer to a reality for ordinary people.

As was discussed in the *Project Introduction* section of this report, the American Bar Association is conducting a conference in Chicago on august of this year, in order to create a legal framework on how lawyers will need to attend the aforementioned issues as they arise (ABA, 2012).

Regulatory

In 2006 the Government Accountability Office (GAO) reported that the commercial space launch industry had evolved and moved further toward space tourism than ever before, meaning that human space travel for ordinary civilians is now closer than ever (GAO, 2006).

In this regard, the Federal Aviation Administration (FAA) oversees the safety of commercial space launches, licensing and monitoring the safety of such launches and of spaceports; and according to InterFlightGlobal (2012) the FAA is leaps ahead of any other world agency, so much so that others are following their lead. The FAA is also responsible for overseeing the safety of space tourism, but it may not regulate crew and passenger safety before 2015, except in response to high-risk incidents, serious injuries, or fatalities (InterFlightGlobal, 2012).

This consists of overseeing: 1. Recent trends in the commercial space launch industry, 2. Challenges that FAA faces in overseeing the industry, and 3. Emerging issues that will affect the federal role (GAO, 2006). The latter statement is based on GAO's October 2006 report on commercial space launches, updated with information GAO gathered from FAA, the Department of Commerce, and industry experts in November 2009 on industry trends and recent FAA actions.

Furthermore, GAO also recommended that the FAA take several actions to improve its oversight of commercial space launches, including assessing its future resource needs (GAO, 2012).

Safety

Hereunder, the researcher divided the safety variables that can occur to humans during spaceflight into two: 1. Those which might occur indirectly while on the ground as innocent bystanders, and 2. Those which might occur as a direct result of being a spaceflight user.

As was presented in the *Legal* section, the reader was presented with foreseeable negative variables, such as debris that might fall upon a person, house or other objects, or contamination which might occur from any given chemicals directly or indirectly derived from spacecraft launches. These are just some of the scenarios which might occur and that most likely will occur as the industry grows.

Therefore, it’s safe to assume that government agencies, such as the FAA and other service providers like insurance companies, will have to be prepared to face these issues as they arise, and the would-be users will most likely have to be aware that the signing of waivers for the direct participation of these activities will become normal. As was discussed in the *Legal* section of this report, the American Bar Association is also conducting a conference in Chicago on august of this year, in order to create a legal framework on how lawyers will need to attend the aforementioned issues as they arise (ABA, 2012).

For the second aspect of this sub-topic, the researcher considered adequate to also divide it into two crucial variables, which have a direct link to the overall safety of commercial space transportation; especially attending the new tendency of horizontal launches, applicable towards sub-orbital flights. This will successfully meet the *Program Outcome 4* of this project. These are:

1. Human Factor. The researcher has investigated the effects of a zero gravity environment and fatigue on the performance of work related operations, as well as other health related variables to the human body, such as Space Motion Sickness (SMS), cardio-vascular, musculo-skeletal, and psychological effects, respectively (Clement, 2008).

The researcher found that for manned sub-orbital flights, the latter variables do not reflect a direct impact on the pilot's ability to successfully perform his designated tasks. This is due, in part, to the short duration time of the trajectory of a sub-orbital flight, since it does not complete an entire orbit around earth, thus the effects are less than astronauts which are accustomed to multiple orbits around the earth. And the second factor is due to the minimized G forces which will be encountered on sub-orbital flights.

According to InterFlightGlobal (2012), one of the most important factors to commercially offer sub-orbital flights is that commercial space transportation companies will need to design Spacecraft to focus on the minimization of the G forces of the flights, both at ignition as well as re-entry. This will attract a greater number of potential civilian customers, either for business or tourism flights, as forces greater than 4 G's will not be suitable for civilians (InterFlightGlobal, 2012).

2. Aviators' Adaptation. The researcher also determined that if the widely accepted "horizontal launch" for sub-orbital flights will be the commercially accepted tendency for years to come, then it is also pertinent to point out the would be human factor challenges that pilots might encounter during the performance of the basic rocket ignition procedure at cruising altitude, applicable towards concept "X" and "Y" sub-orbital vehicles, as shown in Figure 12.

In the case of sub-orbital flights, and specifically the operational mode utilized by "X" and "Y" concept vehicles to reach space, the ignition of rocket boosters in horizontal launches are performed from a cruising altitude of about 50,000 feet. If we take the latter into account then it is safe to assume that before reaching this step the spacecraft would follow a basic flight pattern like any other flight. Thus, it is the researchers' opinion that data pertaining to the accidents and fatalities which have occurred during each one of the phases involved signify crucial information, adding significant tangible data on weather related accidents that have occurred during: 1. taxing, 2. takeoff, 3. initial climb, 4. cruise, 5. descent, 6. approach, and 7. landing phases of flight, as shown in Figure 5 below.

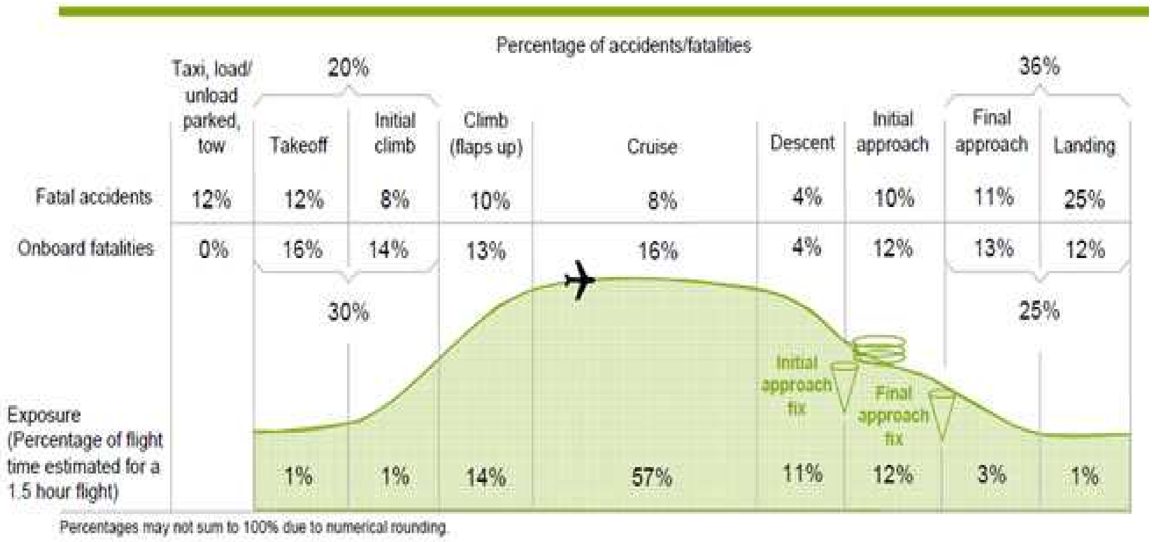

Figure 12. Percentage of accidents/fatalities during phases of flight. Retrieved from "Statistical summary of commercial jet airplane accidents - 1959-2008" by Boeing, 2009.

Licensing

This section will discuss the licensing requirements in the space transportation industry of: 1. Licensing of new Spacecraft by the FAA, and 2. Licensing of Spaceports.

1. Licensing of Spacecraft:

In the United States, the FAA has divided the licensing of Spacecraft into expandable, and reusable. An FAA-licensed reusable or expendable Spacecraft license authorizes the holder to conduct launches or reentries from one launch or reentry site within a range of operational parameters of launch or reentry vehicles from the same family of vehicles transporting specified classes of payloads or performing specified activities. An operator license remains in effect for two to five years from the date it's issued (FAA, 2012).

Beforehand, the FAA requires the solicitor to meet with FAA/AST prior to submitting the license application. Pre-application consultation consists of any and all meetings, communications, and draft application submittals that a potential applicant may undertake with FAA prior to submitting a formal application. Application Procedures are described in 14 CFR Part 413 (FAA, 2012). The following basic steps outline the FAA licensing process:

- Pre-Application Consultation
- Policy Review and Approval
- Safety Review and Approval
- Payload Review and Determination
- Financial Responsibility Determination
- Environmental Review
- Compliance Monitoring (post-issuance of license)

2. Licensing of Spaceports: On November 15, 1995 the Secretary of Transportation delegated commercial space licensing authority to the Federal Aviation Administration; the largest effort being the completion of 14 CFR Part 420 in October, 2000 (COMSTAC, 2012). New commercial launch sites are being developed in both coastal and inland areas and are capable of supporting a wide range of potential launch vehicles, both expendable and reusable. Most importantly, some of the new launch vehicle systems are being developed to require only aviation type facilities, as they utilize existing airport infrastructure, such as runways and hangars, and standard aviation departure and arrival procedures (COMSTAC, 2012).

According to AIAA (2012), the possibility exists for many airports around the United States and the world to become Spaceports and provide the necessary infrastructure and capabilities to support suborbital launch activities. For an airport or aviation authority that are considering the option of becoming a spaceport the best place to begin is with the creation of a Spaceport Development Plan.

For a spaceport to be granted a license it will basically need to support Suborbital RLVs that takeoff from the runway in a horizontal configuration. While the capability may eventually be added to some Spaceports to support vertically launched rockets.

Licensing may be granted so that flights and missions are operated to start and end at the same spaceport or point-to-point missions that start at one Spaceport and end at another. Spaceports will need to seek to operate like airports, accommodating a wide variety of existing and planned flight vehicles and operators, and providing quick turnaround times between flights (AIAA, 2012). As discussed in the *sub-orbital* section of this report, presently there are three broad generic launch vehicle concepts that are compatible with use at an Spaceport, these are referenced as Concept X, Concept Y, and Concept Z launch vehicles.

According to AIAA (2012), the licensing requirements for Spaceports currently follow the same regulatory requirements as typical launch sites and are described in the United States Code of Federal Regulations (CFR) Title 14 Part 420, also known as 14 CFR Part 420. The latter includes four subparts and multiple appendices. Some of the licensing requirements identified in Part 420, pertaining to Spaceports, include the following:

- General information about the Spaceport
- Environmental Assessment
- Identification of proposed launch vehicle type and class considered for use at Spaceport
- Launch site location information and review
- Explosive site plan
- Launch site operations
- Risk Analysis & Safety Requirements – must satisfy the public risk criteria by not exceeding the expected casualty value of 30x10-6 for a sample mission.

Methodology

Participants

To meet the Program Outcome 2 of this project, the researcher conducted three separate surveys. The sample size of survey participants was based on a moderate number of the selected location's population. Thirty adults were selected belonging to two different age range, as well as different educational backgrounds.

One age target was a younger population within the ages of 21-33, represented by Y^1; and the older target population within the 33-50 age range, represented by O^1. For a more objective result of the sampling, a rather equal level of education was contemplated for the above age targets.

The interview was conducted to: 1. Ordinary civilians, 2. Industry professionals, and 3. Government Officials. Data tables for accuracy and reaction time were imported from an Excel spreadsheet for review and input into the statistical analysis, accompanied by descriptive stats which visually represented the results obtained. A factorial Analysis of Variance (ANOVA) was also conducted to evaluate if main or interaction effects existed from the interviews conducted to the three groups.

Subsequently the samplings which obtained an end result of 60% or greater of the population was represented by $N^\times$. Results which rendered unknown variables or neutral opinions were represented by U^o (Formula i.e.: Y^1: $P\pm$ - $U^o \geq N^\times$). The results were then tabulated and duly represented by a line graph, under the Ordinal data concept (Leedy & Ormrod, 2010).

Assessment Instruments

The first questions of the surveys were used to establish basic age eligibility requirements and participant educational background (See Appendix A and B, respectively). All participants were required to be at least 21 years old. Additional strategic questions were also included to see if the participant had inclinations towards space exploration and science.

Test Reliability and Validity

Instrument reliability was assessed by conducting a t-test for independent means to evaluate the mean reaction times and error rates for the three respective surveys. Since every member of the population cannot be sampled, the standard deviation σ was estimated by examining a random sample taken from the population following the formula shown below.

$$s_N = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \overline{x})^2}.$$

The mean reaction time for survey "A" was: 3.240 (SD = 1.914), *t test / P probability* = 0.34. There were no significant differences between mean reaction time for the survey conducted. The hypothesis one was accepted since the above result of 0.34 is greater the 0.05, as shown in Figure 13.

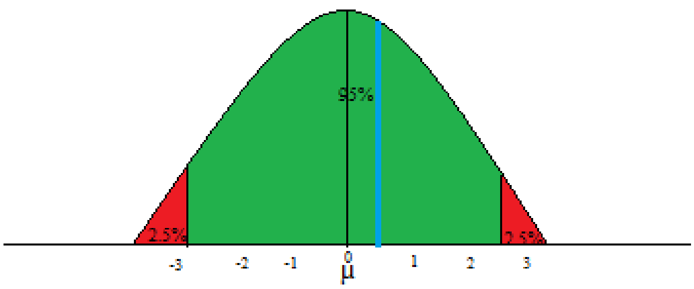

Figure 13. Mean One Tail/Two Tail Hypothesis Test for Conducted Survey. Adapted from "Practical Research" by Leedy & Ormrod, 2010.

Procedure

For the survey conducted to ordinary civilians, the researcher travelled to a local mall, which was determined to be an adequate location to obtain the required samplings. The survey link was also provided to civilians fitting the selected profile. For the other two surveys, it should be pointed out that the researcher performed a graduate internship at the aerospace consulting company InterFlightGlobal, based in Miami, Florida; and to this end conducted the surveys to industry professionals and government officials with the assistance and collaboration of the aforementioned company.

The latter was performed by means of reaching out to the company's professional contacts database through emails and personal phone calls, followed by the remittance of the survey links. Subsequently, the researcher utilized the website surveymonkey.com and fluidsurveys.com to tabulate and export the graphs with the results obtained.

Results

Survey Analysis and Discussion

Survey A targeted to Ordinary Civilians: In practical terms, the results obtained from the survey conducted to ordinary civilians rendered the following results:

Age:

- 40% of the responses were in the 21-33 age range (Y^1)
- 60% of the responses were in the 33-50 age range (O^1)

Level of Education:

- 30% of the responses had at least 2 years of college
- 50% of the responses had 4 years of college
- 20% of the responses had graduate studies

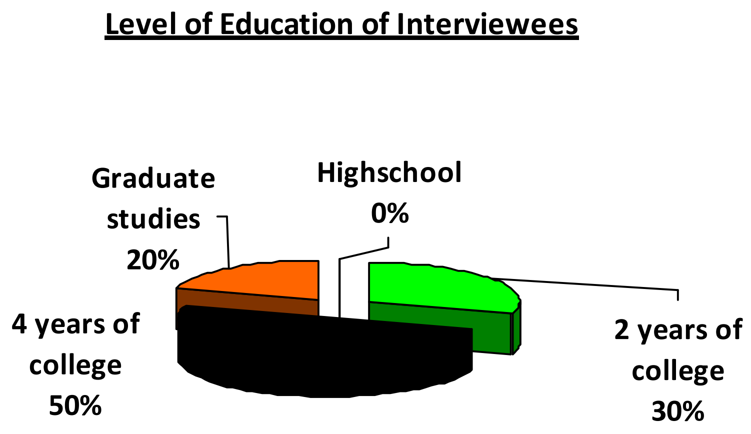

Figure 14. Results from survey conducted, by author, 2010.

Predispositions:

- 50% of the responses selected science fiction genre, when asked what type of movies the interviewees preferred in order to ascertain their inclination
- 50% distributed between romance, horror, and action, respectively

Perception of public on humans going into space:

- 40% of the responses selected “Adventurous”
- 60% of the responses selected “Beneficial”
- 0% selected “Unnecessary” or “Dangerous”

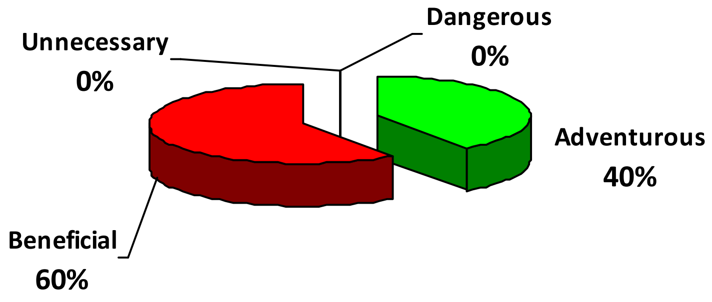

Figure 15. Results from survey conducted, by author, 2010.

- 100% of the responses concluded that humans will in fact one day go into space for commercial or tourism purposes.

<u>Perception of public when asked in how many years ordinary civilians will go into space:</u>

- 30% of the responses selected "Less than 10 years"
- 40% of the responses "10-25 years"
- 20% of the responses "30-40 years"
- 10% of the responses "40+ years"

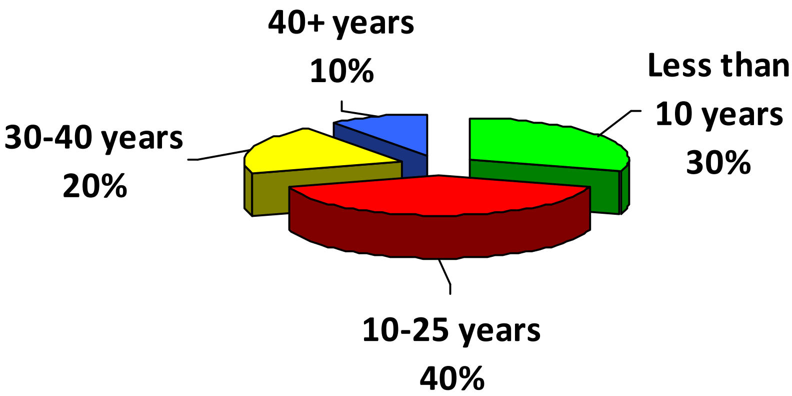

Figure 16. Results from survey conducted, by author, 2010.

From the above results, we can clearly evidence that the general public is very much aware of where the space transportation industry is, and the trends pertaining to the timeframe of humans going into space. The majority (70%) believe we are less than 25 years from obtaining this goal.

<u>When asked if ordinary civilians do not go into space in the next thirty years:</u>

- 80% of the responses selected due to "Financial Resources"
- 10% of the responses selected due to "Lack of Technology"
- 10% of the responses selected due to "Regulatory Issues"
- 0% of the responses selected due to "Disinterest"
- 0% of the responses selected due to "Safety Concerns"

When asked on going to space, if space tourism becomes affordable in the next thirty years:

- 80% of the responses selected “Yes”
- 0% of the responses selected “No”
- 20% of the responses selected “Maybe”

When asked if they would consider going into space for a second time:

- 70% of the responses selected “If the Price is Right”
- 20% of the responses selected “No. One time is enough”
- 10% of the responses selected “If accompanied by family/friends”

When asked if space becomes affordable, and they choose not to go:

- 90% of the responses selected due to “Financial Resources”
- 10% of the responses selected “Safety Concerns”

<u>Survey B targeted to Industry Professionals</u>: Professionals from companies such as Virgin Galactic, Generation Orbit, InterFlightGlobal Corporation and Boeing were surveyed, and in practical terms, the following results were rendered:

<u>The Role of the interviewee within their company/industry:</u>

- 33% of the responses were "Engineering"
- 33% of the responses were "Managerial"
- 17% of the responses were "Consulting"
- 17% of the responses were "Other"

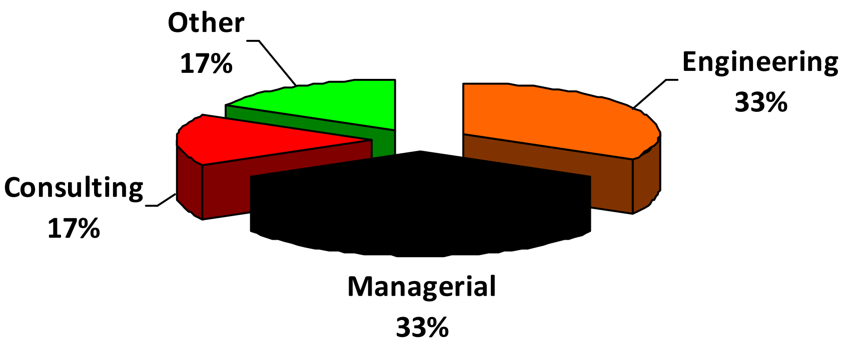

Figure 17. Results from survey conducted, by author, 2010.

<u>When asked type of spaceflight company/spaceport is considering:</u>

- 34% of the responses were "Sub-Orbit"
- 33%of the responses were "None at the Time"
- 33% of the responses were "Both"

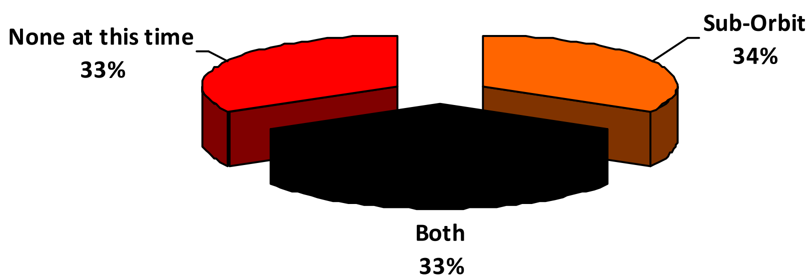

Figure 18. Results from survey conducted, by author, 2010.

Thus, we can see a clear preference for sub-orbital flights for the industry professionals interviewed, resulting in 0 responses in favor of orbital spaceflights.

When asked the type of launches being considered:

- 80% of the responses selected Concept “X”
- 20% of the responses selected Concept “Z”

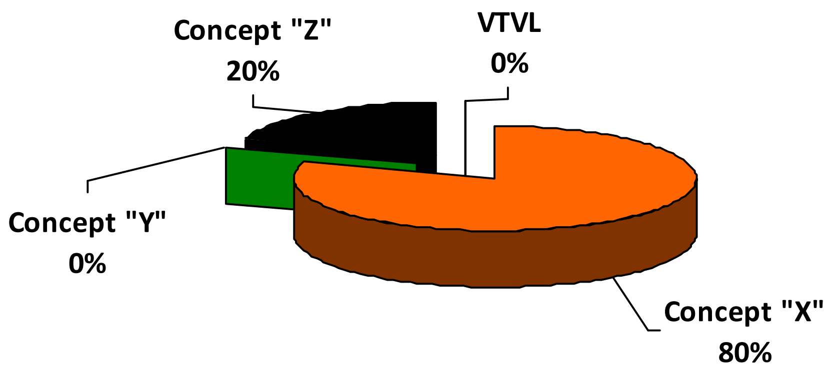

_*Figure 19*. Results from survey conducted, by author, 2010.

When asked on expendable/reusable vehicles:

- 70% if the responses selected “Reusable Vehicles”
- 20% of the responses selected “Both”
- 10% of the responses selected “Expendable Vehicles”

Designs Being Considered:

On the open comment field of the surveys, interesting topic brought up by some of the interviewees were concentrating on the “Go Launcher 1” and “Go Launcher 2”, as well as other elements like Composite Materials and Hybrid Motors. Other, such as airport authority, were open to any concept chosen by the transporter.

On the topic of the future is spacecraft launches:

- 50% of the responses selected “Horizontal”
- 40% of the responses selected “Both”
- 10% of the responses selected “Vertical”

When asked if privately owned/new spaceport would be considered:

- 100% of the responses were “Yes”

Reason for launching from private spaceport:

- 20% of the responses selected “Cost”
- 10% of the responses selected “Location”
- 70% of the responses selected “Other”

<u>Survey C targeted to Government/Public Officials</u>: Government and Public Officials were surveyed from agencies such as the U.S. Air Force, New York-New Jersey Port Authority, and airport authorities from New Hampshire, Louisiana, Texas, and Miami-Dade, respectively; and rendered the following result:

Role within their Agency:

- 67% of the responses were "Managerial"
- 22% of the responses were "Legal"
- 11% of the responses were "Technical"

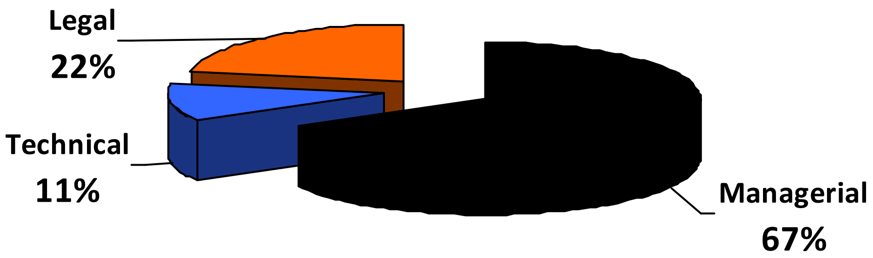

Figure 20. Results from survey conducted, by author, 2010.

Perception of Space Transportation:

- 100% of the responses considered space transportation to be "Beneficial"

Humans into Space:

- 100% of the responses considered that ordinary civilians will go into space for commercial or tourism purposes in the next thirty years"

Reasons ordinary civilians might not go into space in next thirty years:

- 62% of the responses selected "Financial"
- 25% of the responses selected "Regulatory"
- 13% of the responses selected "Disinterest"

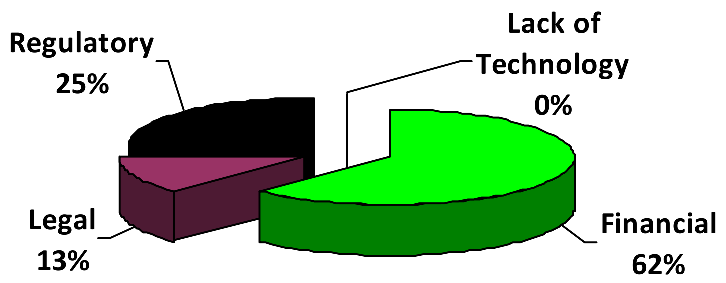

Figure 21. Results from survey conducted, by author, 2010.

Consider Space Transportation to be:

- 100% of the responses selected "Beneficial"

Timeframe Space Transportation will be accessible for ordinary civilians in:

- 67% of the responses selected "10-25 years"
- 33% of the responses selected "Less than 10 years"
- 0% of the responses selected "Beyond 25 years"

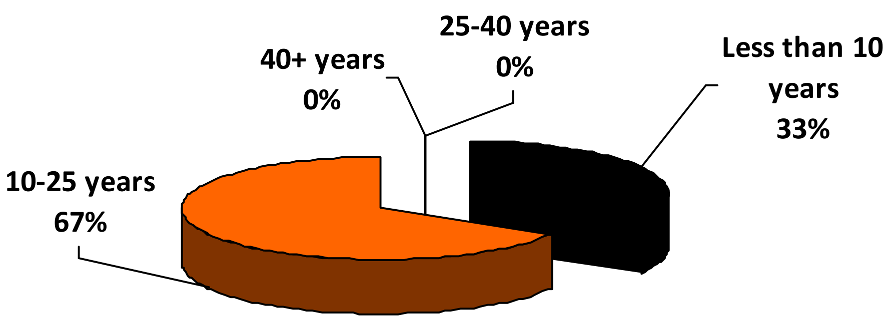

Figure 22. Results from survey conducted, by author, 2010.

Benefits of Spaceport in their communities:

- 45% selected "Jobs"
- 45% selected "Economy"
- 10% selected "None"

<u>In next thirty years, Space transportation will be accessible for:</u>

- 60% selected “Both”
- 40% selected “Ordinary Civilians”

<u>Perception of a Spaceport in their community:</u>

- 60% selected “Maybe”
- 40% selected “Yes”
- 0% selected “No”

<u>Factor which might impede Spaceport in their community:</u>

As shown in the Figure 23 below, the overwhelming majority selected “Environmental” as the main factor which might impede the development of a Spaceport in their respective community.

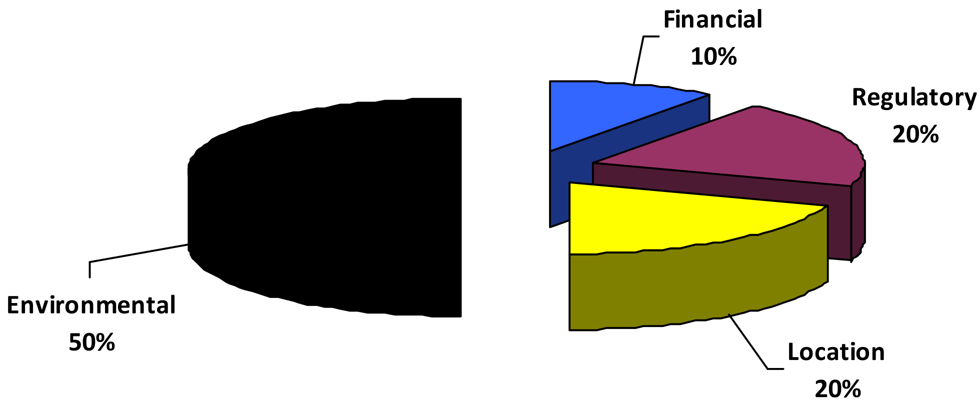

Figure 23. Results from survey conducted, by author, 2010.

<u>When asked if the benefits of a Spaceport might over weigh negative risks of public:</u>

- 60% selected “Yes”
- 40% selected “No”
- 40% selected “Maybe”

The above results indicates that although the majority of government/public officials (60%) consider that the benefits might over weigh the negative perception of the public, there is still a good amount (40%) which still might swing their opinion either in one direction or the other. For these 40% that are not decided, a substantial public relations effort might be a beneficial action in order to gain their favor. Nevertheless, if negative factors, such as environmental, tend to surface after studies conducted to their respective communities are performed, then it is safe to assume the latter percentage should be expected to swing towards a negative opinion instead of neutral.

Conclusion

In the researcher's opinion the first major area which we will see a sustainable commercial growth will be with the launch capabilities and technology. Initial government monopolies over the actual launch technology, but not over the requisite knowledge base to build such technology, has meant that launch services have long been a strong candidate for commercialization, but this is gradually changing.

In fact, the loss of assured military markets has made some newer launchers available that were developed specifically for defense projects. Moving forward, the key will be to develop rapid launch methodologies which reduce the time the launch vehicle spends on the pad prior to actual flight.

The project at hand also rendered important insights into how the space transportation is expected to grow as we move forward, sub-orbital flights will be the one to experience the most growth within the private sector on a ratio 80% private-20% government.

The surveys conducted also presented valuable information as to the overall perception of the public as far space-related activities is concerned, as well as their evolution in thinking (See *results* section). Furthermore, the industry professionals and government officials' surveys included valuable insights into how they view the space transportation industry, their specific concerns, and other opinions regarding the development of spaceports in their respective communities; comments such as:

- "The demographics and political environment might not be conductive to a spaceport in this state, thus public opinion will not support such a venture".
- "A Spaceport would be favorable and represent local jobs and GDP growth".

- “Spaceport might be beneficial only if minimal impacts result in the venture (e.g. legal, environmental) and the end result considerably over weighs potential negative drawbacks”.
- “Yes, it would foster positive growth for the local economy, from businesses indirectly dependent on the spaceport to jobs directly attributable to the spaceport itself”
- “A highly populated region or State might be more susceptible to a spaceport in its surroundings”.
- “Substantial studies on environmental impacts, such as noise, and potential health hazards should be fully assessed”.
- “A number of sub industries might be benefited by a spaceport in our community, from direct jobs to indirect such as restaurants, gift shops, hotels, etc”.
- “Would create a cluster of businesses in the region dependent of this activity, and favoring the overall economy”.

Hypotheses

From the survey conducted to ordinary civilians to determine their overall perception in space-related activities and their evolution in thinking, the researcher divided the targeted audiences into two different age range. In this sense, the following two hypotheses were contemplated to ascertain the validity of the tests:

<u>Hypothesis One:</u> The perception in thinking in space-related activities between one younger age range and the older age group are considerably different, thus have evolved over time.

Hypothesis Two: The perception in thinking in space-related activities between one younger age range and an older age group are equal, thus have not evolved.

As was demonstrated through the two-tailed test shown in Figure 13, Hypothesis One was proven to be valid.

Recommendation

The surveys conducted was an important part of this project, and provided us a direct feed into what the overall public thinks of the space transportation industry, and how they are willing to become involved with its growth in the next thirty years. The researcher also concludes that the most important obstacle, which we as future professionals must focus on, is the significant reduction in the cost of getting into space.

The only way that commercial space transportation can reach a sustainable growth in the next thirty years is if the masses become involved in the equation, and the only way this will happen is by offering point-to-point sub-orbital spaceflights at affordable prices.

As we have also seen throughout this project, other important barriers, such as technological, political and environmental also play a crucial role in their own right. Nonetheless, without reduced costs, which can only be present through the availability of affordable prices, then the latter barriers inherently come in a second plane.

There is also a significant part of the population which are neither in favor nor against the direct participation in spaceflight and of the development of spaceports in their respective communities. This part of the population, as was discussed in the *results* section of this report, reported a “maybe” response, which basically means that they are a swing part of the population and might be inclined one way or the other.

Therefore, the sub-orbital transportation companies and agencies involved in the development of spaceflight must be aware that a continuous public relations effort must always be present, in order to gain the favorable opinion of this part of the population; as well as science and technological programs from the basic elementary and high school levels so that future generations of professionals are inclined to be involved and make a difference in the overall development of the commercial space transportation industry.

References

ABA (2012). Annual meeting. *Commercial spaceflight comes of age: Implications for insurance, contract and tort law*. Retrieved from http://www.americanbar.org/content/dam/aba/events/science_technology/st_2012_am_brochure.authcheckdam.pdf

AIAA (2012). Can your airport become a spaceport. The benefits of a spaceport development plan (pp. 1-9), Orlando, FL: American Institute of Aeronautics and Astronautics.

Anderson, J. (2008). Space flight. *Introduction to flight* (pp. 589-591). New York, NY: McGraw-Hill.

Bigelow Aerospace (2012). Station development. The BA 330. Retrieved from http://www.bigelowaerospace.com/ba330.php

Blue Origin (2012). Suborbital vehicles. About blue origin. Retrieved from http://www.blueorigin.com/about/about.html

Boeing (2009). Percentages of accident and fatalities. *Commercial airplanes*. Retrieved from http://www.boeing.com/news/techissues/pdf/statsum.pdf

Caimi, R., Margasahayam, R., and Nayfeh, J. (2001). Rocket launch-induced vibration and ignition overpressure response (pp. 1-6). Cape Canaveral, FL: NASA Kennedy Space Center.

Clark, John D. (1972). Ignition: An Informal History of Liquid Rocket Propellants (pp. 1 3). Rutgers, NJ: Rutgers University Press.

Clement, G. (2008). Challenges facing humans in space. *Fundamentals of space medicine* (pp. 30-35). El Segundo, CA: Microcosm Press.

COMSTAC (2012). Spaceport review document white paper draft. *Spaceport licensing* (pp. 6-12). Washington, DC: COMSTAC Advisory Committee.

DiscoveryNews (2012). *Deep-Space orion capsule arrives for test flight*. Retrieved from http://news.discovery.com/space/deep-space-orion-capsule-arrives-for-test-flight-120702.html

EPA (2000). The effects of ammonium perchlorate on thyroids. *Environmental assessment*. Retrieved from http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm

FAA (2011). Spaceports. *U.S. Commercial Space Transportation Developments and Concepts: Vehicles, Technologies, and Spaceports* (pp. 47-59). Washington, D.C.: Office of Commercial Space Transportation.

FAA (2010). National space policy. Retrieved from http://www.faa.gov/about/office_org/headquarters_offices/ast/legislation_policies/

GAO (2006). Development of the commercial space launch industry. Retrieved from GAO-10-286T (pp. 2-16). Washington, DC: US Government Accountability Office.

Handberg, R. (1995). The commercial development of space: Implications and trends. *The future of the space industry*. (pp. 111-113). Westport, CT: Quorum Books.

InterFlightGlobal (2012, June 29). Interview by Author to O. Garcia. *Trends of commercial space transportation industry*. Miami, FL.

ITAR (2012). International Traffic in Arms Regulations Policy. Retrieved from http://pmddtc.state.gov/regulations_laws/itar_official.html

Johnson, J. (2012). Library. *The private space companies act (pp. 1-3)*. New York, NY: The Space Settlement Institute.

Leedy, P. & Ormrod, J. (2010). Practical research. *Organizing a research proposal* (pp. 116-119). Saddle River, NJ: Pearson Academic.

McDonald, A., and Bennett, R. (1995). Atmospheric environmental implications of propulsion systems Environmental impacts of rocket launches (pp. 3-9). Retrieved from ERAU Hunt Online Library http://online.ewrau.edu/services/general/library

NASA (2011). Horizontal launch: A versatile concept for assured space access. Pre-screening and screening. *SP 2011-215994* (pp.1-20). Washington, D.C.: Library of Congress.

NASA (2011). Private space companies act. Retrieved from http://www.nasa.gov/offices/c3po/partners/ccdev_info.html

Peters (2004). Spacecraft design and operations. Propulsion. (pp. 489-492). New York, NY: McGraw-Hill.

Salas, E. & Maurino, D. (2008). Flight simulation as safety generator. *Human factors in aviation* (pp. 293-300). Burlington, MA: Academic Press.

Sellars, J. (2005). Getting into space. *Understanding space* (pp. 298 308). New York, NY: McGraw Hill.

Space Propulsion Group (2012). Hybrid rocket propulsion group overview. Retrieved from http://www.spg-corp.com/space-propulsion-group-resources.html

Space Settlement Institute (2012). Space settlement act. Building space infrastructure. Retrieved from http://www.space-settlement-institute.org/space-settlement-prize-act.html

Stewart, B. (1998). *Evaluation of the Potential Impacts of Launches of the USAF atmospheric interceptor technology from the Kodiak Launch Complex* (pp. 3-5).

Retrieved from ERAU Hunt Online Library http://online.erau.edu/services/general/library

Toohey (2011). Article: Rocket Launches may need regulation to prevent ozone depletion. Retrieved from http://www.sciencedaily.com/releases/2009/03/090331

Virgin Galactic (2012). Overview of air launch. *Safety*. Retrieved from http://www.virgingalactic.com/overview/safety/

XCOR Aerospace (2012). Suborbital vehicle. *Products. Retrieved from www.xcor.com*

Appendix A

Interview Questionnaire I: To Ordinary Civilians

1. How old are you?

- ☐ 21-33
- ☐ 33-50
- ☐ 50-65

2. What is the highest level of education you have completed?

- ☐ High school
- ☐ 2 years of college
- ☐ 4 years of college
- ☐ Graduate studies

3. When going to the movies, would you prefer watching a movie concerning:

- ☐ Romance
- ☐ Science Fiction Adventure/Exploration
- ☐ Action
- ☐ Horror

4. You consider that humans going into Space is:

- ☐ Adventurous
- ☐ Dangerous
- ☐ Beneficial
- ☐ Unnecessary

5. Do you believe ordinary civilians will one day go into space? (If no skip to question 7)

- ☐ Yes
- ☐ No

6. In how many years do you think ordinary civilians will be able to go into space?

- ☐ Less than 10 years
- ☐ 10-25 years
- ☐ 30-40 years
- ☐ 40+ years

7. If ordinary civilians do not go into space in the next 30 years, do you think it will be because:

- ☐ Lack of technology
- ☐ Disinterest

- Financial Resources
- Safety Concerns
- Regulatory Issues

8. If space tourism becomes affordable in the next thirty years, would you consider going (If no skip to question 10)?

- Yes
- No
- Maybe

9. You would consider returning into space for a second time if:

- The price is right
- Are accompanied by family/friends
- No. One time is enough

10. If going into space becomes common for ordinary civilians, and you choose not to go, it will be because:

- Lack of interest
- Safety concerns
- Financial resources

Interview Questionnaire II: To Industry Professionals

1. What Aerospace Company do you work for/are involved with?

2. What is your role in the Aerospace industry?

- Engineering
- Managerial
- Consulting
- Supplier/Provider
- Other

3. Is your company/spaceport considering launches to:

- Orbit
- Sub-Orbit
- Both

4. If your company is considering Sub-Orbital flights, which concept will they adopt?

- Concept "X" (Horizontal Launch, Jet Powered Take-off, Suborbital)
- Concept "Y" (Horizontal Launch, Rocket Powered Take-off, Suborbital)
- Concept "Z" (Horizontal Launch, Jet Powered Take-off, Either)

5. Is your company/spaceport considering:

- Expendable Launch Vehicles (ELV)
- Reusable Launch Vehicles (RLV)
- Both

6. Do you think future spacecraft launches should:

- Continue with Vertical Launches
- Adopt Horizontal Launch
- Both

7. What method of launch is your company currently using, or considering?

- Vertical
- Horizontal
- Both

8. What spacecraft Designs is your company currently considering or promoting?

9. Do you think your company would consider launches from a private/newly certified spaceport?

- Yes
- No
- Maybe

10. If in the future, aerospace companies prefer launching from private spaceports, it will be because:

- Costs
- Logistics
- Location
- Other

Interview Questionnaire III: To Political Figures/Representatives

1. What County, State or Federal agency/department do you work for?

2. What is your role in the department you work with?

- Managerial
- Technical
- Legal
- Other

3. Do you consider that commercial space transportation to be:

- Adventurous
- Dangerous
- Beneficial
- Unnecessary

4. Do you believe ordinary civilians will one day go into space for tourism or commercial purposes? (if no skip to question 7)

- Yes
- No

5. Do you consider commercial space transportation will become accessible for ordinary civilians in:

- Less than 10 years
- 10-25 years
- 30-40 years
- 40+ years

6. If ordinary civilians do not go into space in the next 30 years, do you think it will be because: (5 most likely, 1 least likely)

- Lack of technology
- Disinterest
- Financial resources
- Safety concerns

7. Do you think Commercial Space Transportation might be beneficial to the communities they are involved with? (if no, skip to question 10)

- Yes
- No
- Maybe

8. What type of community benefits do you think might be attained from Commercial space transportation?

- Jobs
- Economy
- None
- Other

9. In the next 30 years, do you consider commercial space transportation will be accessible for:

- Ordinary Civilians
- Rich & Famous
- Both
- Others

10. Would you be in favor of a spaceport in your community?

- Yes
- No
- Maybe

11. Do you think a spaceport in your community will represent economic development? (explain)

12. Select the most important factors you think might impede a spaceport in your community? (1 being the most likely, 4 the least)

- Financial
- Regulatory
- Environmental
- Lack of adequate locations

13. Do you think the benefits of a spaceport in your community would over weigh the negative risks/perception of the public and officials? (explain)

- Yes
- No
- Explain: ____

14. Open Comments/Questions:

Appendix B

Solicitation Script

Hello and thank you for volunteering some of your time today. My name is Joseph Jourdain and I am working on a research project as part of the requirements for a Master's degree from Embry-Riddle Aeronautical University.

My research has to do with the "Inherent Barriers for the Growth of Space Transportation Industry"; and to this end, part of my study will contain three respective interviews to be conducted to: A. Ordinary civilians, B. Industry professionals, and C. Government/Public Officials in order to ascertain the public's evolution in thinking of space related activities, as well as their perception of the industry for the next thirty years.

Before we get started, I would like to go over the Informed Consent form. The Informed Consent form summarizes the experiment and also addresses eligibility requirements; any potential discomforts caused by the research (not applicable); and estimated time involvement to complete the experiment. In addition, as a volunteer, you understand and agree that no compensation will be provided for participating. Please take a moment and review the form. If you agree with the contents and would like to proceed with the experiment, please go ahead and print and sign your name. I would be happy to provide you a copy of the form for your records.

All participants need to be 18 years of age or older. In addition, I'll use a digital link provided by Surveymonkey.com to collect the information on this form to sort the data for my analysis. I'll be using a number code as your Participant ID on the survey Questionnaire. That code will also be used as your ID for the test. Your name and all other personal information will remain confidential and will not be included in the report. Please let me know if you would like to receive a copy of the final report findings.

The interview has three parts. Part A will be targeted to ordinary civilians to show their perception in thinking of space related activities; Part B will be targeted to Industry Professionals to show their personal and professional opinions in spacecraft design and spaceport certification, and Part C will be targeted to Political figures and representatives of County, State or Federal agencies to ascertain their perception in the future of the commercial space transportation industry and of spaceport certification in their community.

Do you have any questions before we begin?

_______ No, I am not interested in receiving a copy of the final report findings.
_______ Yes, I would like to receive a copy of the final report findings.

Contact information: ____

Appendix C

CONSENT FORM
Embry-Riddle Aeronautical University

I consent to participating in the research project entitled:
Inherent Barriers for the Space Transportation Industry
The principle investigator of the study is: Joseph Jourdain and InterFlightGlobal Corporation.

The survey will require each participant to answer a brief questionnaire to obtain their personal opinion on the space transportation industry. The participant will open a direct link to answer each question through the websites fluidsurvey.com and surveymonkey.com

All participants will volunteer their time and receive no compensation for the study. All personal information collected during the study will remain confidential and will not be included in the final report.

The individual above, or their research assistants, have explained the purpose of the survey, and the procedures to be followed. Possible benefits of the study have been described, and the results will be available if requested.

I acknowledge that I have had the opportunity to obtain additional information regarding the survey and that any questions I have raised have been answered to my full satisfaction. Furthermore, I understand that I am free to withdraw consent at any time and to discontinue participation in the study without prejudice to me.

Finally, I acknowledge that I have read and fully understand the consent form. I sign it freely and voluntarily. A copy has been given to me.

Date: ________________________________

Name *(please print)*: ____
(Participant)

Signed: ____
(Participant)

Signed: ____
(Researcher/Assistant)