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Factors influencing the emergence of suborbital space tourism

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Suborbital space tourism is becoming a reality. Virgin Galactic and Blue Origin are the major companies focused on suborbital space tourism. Virgin Galactic has flown people (employees of the company) on suborbital space flights twice in December 2018 and February 2019, but has yet to fly paying passengers. The company has not revealed when it plans to fly the first passengers, but comments it could be soon (Wall, 2019a). Unity, Virgin Galactic’s newest SpaceShipTwo, moved to Spaceport America in New Mexico on February 13, 2020 to begin its final test stages (Wall, 2020). The initial cost for a flight to space with Virgin Galactic is $250,000, and over 600 people have placed a deposit on a seat to space (Wall, 2019a). Blue Origin is focusing on verifying system safety before allowing human flight. However, after two more successful, un-crewed launches, Blue Origin is seriously considering the launch of New Sheppard with people on board (Wall, 2019b).

Suborbital space flight is defined as flight in an air vehicle to an altitude exceeding 100 kilometers (62 miles), the Karman Line, and the edge of space (Chang & Chern, 2018). A suborbital space tourist is a person paying to be brought “to sufficiently high altitudes [Karma Line] to watch the earth's curvature and blackness of space” (Chang, 2014, p. 79). Suborbital space tourists will experience about 5 minutes of weightlessness before the return trip to the same location of departure from earth. For example, Virgin Galactic’s SpaceShipTwo will land back at Spaceport America (Virgin Galactic, n.d.). It is the experience of going past the Karman Line, looking down at earth, and experiencing weightlessness; it is not about travelling to a specific location (Johnson & Martin, 2016). Suborbital space tourism is becoming a reality, and Union Bank of Switzerland (UBS) predicts it will be a catalyst for space industry growth from $340 billion to $1 trillion over the next 20 years (Berrisford, 2018). There are five factors requiring further research in order to provide clarity to the future of suborbital space tourism.

A literature search was conducted to identify articles published between 2012 and 2019. The year 2012 was chosen because it is one year before Virgin Galactic’s SpaceShipTwo first accomplished powered flight, and entered the industry into the modern era of suborbital space tourism (Amos, 2013). A total of 42 references were identified including 27 peer-reviewed journal articles, 1 dissertation, 10 other references (including 4 United States and European government references).

The literature review resulted in five prominent, suborbital space tourism factors. The factors are: demand, ticket cost, motivation and risk, health risk, and policy. The purpose of this paper is to summarize the research on these five factors, and discuss their future development and management for safe and effective suborbital space tourism.

Demand

The one certain aspects of the demand for suborbital space tourism is the uncertainty of who will participate (Guerster, Crawly, & de Neufville, 2019; Johnson & Martin, 2016; The Tauri Group, 2014; Webber, 2013). Numerous articles predict the demand for suborbital space tourism, but the answer to the demand question is complex. Different research focuses on different demographics, to include country, gender, and wealth (Friel, 2019). In the end, time will tell, but, for now, these predictions provide valuable data for the suborbital space tourism companies.

When it comes to tourism opportunities, 21% of Europeans felt suborbital space flight would be beneficial compared to 34% thinking it would be more useful for point-to-point travel. Of the 27 European countries asked, participants from Latvia, Estonia, Italy, and Slovenia thought suborbital space tourism was more useful when compared to point-to-point travel and transportation of goods. Additionally, men are more likely than women to see suborbital space tourism as more useful (European Commission, 2013). Members of the United States are the most likely suborbital space tourism participants when compared to other countries (Olya & Han, 2019; The Tauri Group, 2014). However, Chinese are as enthusiastic as members of the United States about suborbital space tourism. Interestingly, some Europeans might not fly due to environmental and safety issue, but this would have little impact on United States and Chinese space flight tourists (Le Goff & Moreau, 2013). The predicted number of space flight tourists varies, though.

The predicted number of space flight tourists varies from 335 to 58,340 per year. The Tauri Group's (2014) mid-level estimate is 40% of the 8,000 people (or 3,600) across the world who have the funds and interest to fly as a suborbital space tourist in the first 10 years. An additional 5% of space enthusiasts (or 335) who fall outside the high net worth population will also fly within the first 10 years. Combining the mid-level estimate of 3,600, and the space enthusiast number of 335 results in approximately 4,000 space flight tourists or 400 a year for the first 10 years. A more progressive estimate is 11,000 space flight tourists or 1,100 a year for the first 10 years. While The Tauri Group (2014) predicted minimal growth of demand over time, LeGoff and Moreau (2013) predict 606 to 756 in the first year of viable suborbital space tourism and 34,549 to 58,340 in the 12th year. The variation is a result of cost; the lower the cost, the higher the demand. When addressing demand, one aspect, ticket cost, increases certainty; demand and cost are linked because as ticket cost decreases, demand is predicted to increase (Guerster et al., 2019; The Tauri Group, 2014).

Ticket Cost

Guerster et al. (2019) and Chang and Chern (2018) both sought to understand the ticket cost of suborbital space tourism. They both use demand as a foundation to calculate ticket price, but the models used for the calculation are different. Additionally, the results and conclusion to reduce ticket price differ.

Guerster et al. (2019) based their demand model on a previous industry model, which used net worth as a driver for determining who is willing to pay for a suborbital space flight ticket. Previous research by the Futron Corporation assessed suborbital space flight is only feasible for those with a net worth greater than $1 million. Guerster et al. (2019) followed this model, but updated worldwide wealth distribution, and determined there are 31,365,072 people worldwide who can afford a suborbital space flight. The next measure in the model was fraction of net worth spent on a ticket. The baseline was people willing to pay a 1.5% fraction of net worth for a suborbital space flight. Based on these model inputs, Guerster et al. (2019) determined the percentage of people willing to pay at different ticket prices. For example, 10% were willing to pay at $500,000 and 18% were willing to pay at $200,000. They used objective data to determine this demand, but the assumption of 1.5% of the fraction of net worth is a best guess estimate.

Chang and Chern (2018) also looked at demand and ticket cost with one similarity and one difference from the previous article. Change and Chern based their demand model on people with high income being the first suborbital space flight passengers, but others would eventually fly. Both Chang and Churn and Guerseter et al. (2019) reported when ticket price decreases a higher percentage of the population will fly. However, unlike Guerseter et al., Chang and Churn tie the percentage of those willing to fly to previous international studies assessing willingness to fly as a space tourist; they reference studies from UK, Germany, England, Japan, and the United States where depending on the country and age anywhere from 50-80% are willing to fly as a suborbital space tourist. However, Guerseter et al. limit those willing to fly only to individuals who make more than $1 million.

Both articles differ in how they calculate the ticket price based on demand. Guerseter et al. (2019) developed a price model based on the number of people with a net worth over $1 million and willing to fly. Guerseter et al. applied a microeconomics theory, and considered suborbital space tourism as a pioneering adventure. Chang and Chern (2018) also factored suborbital space tourism as a pioneering adventure in their price model, however, their price model was based on ticket cost for suborbital space tourism as one-tenth that of orbital space travel. Both models developed similar results. The pioneers, those to fly first as suborbital space tourists, in the Guerseter et al. study will pay between $600,000 and $1,100,000. The pioneers in the Chang and Chern study will pay between $500,000 and $1,000,000.

Despite the similarity in ticket price, different conclusions are provided for the reduction of ticket cost. Guerseter et al. (2019) concluded the demand for suborbital space flight is the highest determinant of uncertainty in the viability of the industry. They recommend a better understanding of the demand for suborbital space tourism over other parameters, such as production cost of the vehicle, and launches per year per vehicle. Chang and Chern (2018) concluded ticket price could be reduced by focusing on making the vehicle reusable, shortening the turnaround time for flights, and improving safety and reliability of the vehicle.

Despite employing different models to determine the cost to fly as a suborbital space tourist, these two articles came to similar conclusions on the ticket price for pioneer passengers, $500,000 and $1,100,000. However, the conclusions are at odds with each other because they provide different recommendations on how to reduce ticket costs. Guerster et al. (2019) focus on increasing demand while Chang and Chern (2018) focus on development and production. Ticket cost could also be influenced by insurance rates. A poor safety record of initial launches could negatively influence ticket cost, and increase suborbital space tourism risk (Dillingham, 2012).

Motivation and Risk

Space flight is perceived as risky (Olya & Han, 2019). Some argue risk is part of the attraction to suborbital space tourism (Mekinc & Bončina, 2016). Others claim space flight risk can led to terrible consequences, and should be controlled and managed; however, it is the adventure of space flight that attracts tourists (Ao, 2018).

Motivation, as opposed to risk, appears to be the driving force for potential participation in suborbital space flight (Chang, 2017; Olya & Han, 2019). This motivation is based on adventure, gratification and social need for differentiation, which increase the perception of the novelty of the innovativeness of suborbital space flight. People have a more positive attitude toward suborbital space flight when they perceive it as a novel experience that is adventurous, gratifying and socially different (Ao, 2018; Baugh, Musselman, Simpson, & Winter, 2018; Chang, 2017; Olya & Han, 2019).

Some of the risks to space flight tourists are known and some are unknown, ultimately, though, the space flight tourism operator must inform participants on a suborbital space tourism flight about all the risks associated with the flight, and the participant must provide written consent stating they understand the risks (Federal Aviation Administration, 2017). The catastrophic risk of space flight was seen with the Space shuttle Challenger and Columbia accidents (Mekinc & Bončina, 2016), and, more recently, the Virgin Galactic's SpaceShipTwo fatal accident (Chang & Chern, 2016). However, before the flight even departs, space flight tourist's perceived risks are weighed against perceived gains to influence motivation for the flight.

Olya and Han (2019) researched psychological, financial, and safety risks against multiple motivation factors. Psychological risk is associated with anxiety and tension, financial risk is associated with unexpected costs, and safety risk is associated with perceived danger. When researching necessary conditions of risk factors and motivation factors, Olya and Han identified psychological risk can reduce desired behavioral intentions, but financial and safety risks do not significantly influence desired behavioral intentions for flight. There are risks associated with the launch and reentry of the space vehicle, and this can influence the space flight tourist's perceived psychological risk, and resultant intention to fly. There are also numerous health risks of space flight, which tourists should be aware of before departing on a flight.

Health Risks

Space flight tourists will experience numerous physiological challenges. The FAA does not require pre-flight medical screening for suborbital space flight tourists, therefore, participants need to be made aware of the physiological challenges of space flight (Carminati, Griffith, & Campbell, 2013). Space flight results in increased G_z loading, pressure change, motion sickness, weightlessness, reduced oxygen pressure, and potential risk to pregnancy.

Virgin Galactic (n.d.) advertises 3.5 G_z, and Blue Origin (2019) advertises 3.0 G_z during launch. Although, the flight provided by both companies is relatively short, those with cardiovascular compromise should, at least, be aware of the need to personally evaluate their risk of sustained G_z. However, numerous research studies demonstrate potential participant's positive physiological tolerance of G_z exposure on suborbital space tourism flights. Centrifuge studies, simulating launch G_z exposure, showed little concern for participants "with medical conditions including hypertension, heart disease, diabetes, pulmonary disease, various cancers, back or neck disease or prior surgery, and a wide variety of pharmaceutical use to control such conditions" (Blue, Jennings, Antunano, & Mathers, 2017). The results are promising as they demonstrate limited need for in-depth medical evaluation of cardiovascular compromised patients, and little concern for their G_z tolerance (Blue, Pattarini, et al., 2014; Blue, Riccitello, Tizard, Hamilton, & Vanderploeg, 2012).

Aside from cardiopulmonary concerns, there are other health risks associated with suborbital space tourism. In order to maintain adequate cabin pressure, there will be pressure change, which could negatively affect compromised ears and sinuses. Passengers should be aware of adverse effects of flying with congestion or other health issues, which compromise the ability to equalize pressure in the ears and sinuses. The intense launch sequence and/or the low gravity during the free fall could cause motion sickness. Motion sickness can occur without warning, and, with the small cabin of a suborbital space vehicle, could be a major disturbance for other passengers. Anecdotally, motion sickness occurred unexpectedly to an experienced pilot in October 2019 on the tenth parabola of a parabolic microgravity research flight (K. Ruskin, personal communication, November 9, 2019). A health risk not often considered, is the combination of weightlessness and musculoskeletal conditions. Floating free in the cabin could prove challenging for some. Finally, a pregnancy test should be performed before flight as the health risks to a fetus in suborbital space flight are not yet fully understood (Goehlich, 2014; Kluge et al., 2013).

At a minimum, a suborbital space flight tourist should be required to complete a thorough medical history with follow-up from a medical provider trained in aerospace medicine. The follow-up should include deeper assessment into potentially disqualifying health risks (Kluge et al., 2013). Informed consent for physiological challenges and health risks obtained from participants by suborbital space flight tourism operators can reduce liability. This same informed consent process applies to federal and state laws for informed consent of risks and hazards of space vehicle operations (Carminati et al., 2013).

Policy

"There is no specific legal framework under international law regulating suborbital space tourism activity" (Rosa, 2013, p. 238). The current nature of suborbital space tourism policy focuses on limited international space policy, responsibility and liability of the host state, and informed consent and waiver of claims.

International space policy is driven by four treaties developed as part of the UN Committee on the Peaceful Uses of Outer Space (COPUOS). The Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies of 1967 defines outer space as a common territory, in that, no state can claim sovereignty to outer space, and space should be used in the benefit of all states. Additionally, it holds states responsible for activities and liable for damages for space flights conducted from their territory by state and non-state actors. The second treaty, The Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space of 1968 has little applicability to (non point-to-point) suborbital space tourism. The third treaty, The Convention on International Liability for Damage Caused by Space Objects of 1972 further defines absolute liability on a state for damage caused in outer space by a vehicle launched from the state. The fourth treaty, The Convention on Registration of Launched Objects into Outer Space of 1975, obligates states to register space objects launched from their state. As with the second treaty, this treaty has little applicability to suborbital space tourism. Based on the current international law involving space, liability for the state is the major issue with suborbital space tourism (Genta, 2014; Goehlich, 2014; Masson-Zwaan & Moro-Aguilar, 2013; Rosa, 2013; Sikorska, 2014; Von der Dunk, 2013).

Until the emergence of commercial space tourism, states could manage the treaty requirements, however, states are now publishing internal legislation to manage these requirements. In 2004, the United States built upon the Commercial

Space Act of 1984, and included private human travel in the U.S. Commercial Space Launch Amendments Act of 2004. Some states within the US are even enacting laws to manage commercial space launches within their borders. To date, New Mexico, Texas, California, Florida, and Virginia have published laws about commercial space travel (Carminati et al., 2013; Johnson, 2013; Rosa, 2013; Sikorska, 2014, Von der Dunk, 2013). The European Union and European Space Agency need to work toward suborbital space tourism policy to balance emerging commercialization of space and liability of the member states (Forgani, 2017; Sagath, Vasko, van Burg, & Giannopapa, 2019). Sweden, United Kingdom, the Netherlands, and France have the potential for suborbital space tourism launches from their state, but have yet to update their current space law for private human flight (Von der Dunk, 2013).

For now, the way ahead is informed consent, waiver of claims, and licensing as there is "political unwillingness to create and obey international laws" (Sikorska, 2014, p. 1058). Space flight participants should sign informed consent stating they understand the risks associated with the flight, and a waiver of claims stating they will not file a claim against the federal government for an accident. There are legal details to address, though, with reference to informed consent and waiver of claims because they may not be applicable in all third-party legal situations. These issues will be addressed over time as the current political situation is not conducive to establishing space policy. The US is ensuring policy and guidelines are met by requiring commercial space launch companies to complete Federal Aviation Administration mandated licensing of the launch (Dillingham, 2012, 2016; Rosa, 2013; Sikorska, 2014).

Conclusions

The prospect of suborbital space flights for tourists is becoming a reality, and has the potential to become not only an enjoyable experience for participants, but a profitable endeavor for space flight tourism operators. Who will actually fly will be determined in due time, but for now, space tourism operators should focus on marketing to high net worth personnel in the United States, China and some select European countries (Latvia, Estonia, Italy, and Slovenia). More importantly, though, the demand for suborbital space tourism is contingent upon the ticket cost. A small, select group of non-high net worth individuals will be early adopters, but to increase participation beyond these two groups, space flight tourism operators should focus on reduced ticket cost as much as possible while maintaining safe operations.

It is generally accepted potential space flight tourists are not necessarily drawn to the risk of space flight, but to the adventure, gratification and social need for differentiation. It is the novelty of suborbital space flight tourism, which influences positive attitudes toward choosing to fly, not the risk, as is the case with other adventure tourism. However, psychological risk can reduce desired behavioral intentions, therefore, operators should focus on reducing anxiety and tension associated with suborbital space flight tourist. Space flight tourists should also understand the health risks of suborbital space flight.

Suborbital space flight will result in increased G_z loading, pressure change, motion sickness, weightlessness, and potential risk to pregnant. Research generally supports limited restriction on suborbital space flight for health risks, however, participants will still need to understand physiological effects of space flight. Suborbital space operators should educate and train participants on health risks and physiological effects of suborbital space flight, and gain informed consent from these participants. Because of limited international space policy, and existing space policy placing liability on the state of origin, space flight operators should use informed consent for all risks associated with suborbital space flight. Governments are or should use waiver of claims, and licensing to ensure protection from claims in the event of an accidents, and to ensure space flight operators are meeting policy and guidelines of suborbital space flight. Suborbital space flight is a new, exciting opportunity. This paper discussed five factors influencing this emerging industry (demand, ticket cost, motivation and risk, health risk, and policy), and aspects of these factors, which should be developed or managed, to ensure safe and effective flight operations.

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