Space Tourism:
Hurdles and Hopes

Robert A. Goehlich, Embry-Riddle Aeronautical University, Berlin, Germany

ABSTRACT

According to the Space Policy Institute (2002, Bib. section), "Space tourism is the term broadly applied to the concept of paying customers traveling beyond Earth's atmosphere." Operating reusable launch vehicles (RLVs) might be a first step toward achieving mass space tourism. Thus, the aim of this article is to investigate the potential hurdles and other aspects of importance that must be overcome in order to use RLVs for space tourism flights. The primary ones are social issues (e.g., "Is space tourism ethically acceptable?"), institutional issues (e.g., "Is environmental pollution caused by space tourism more harmful than other emission sources?"), and financial issues (e.g., "Are any potential investors interested in space tourism?").

Keywords: *Hurdles, Orbital Flight, Reusable Launch Vehicle, Space Tourism, Suborbital Flight*

INTRODUCTION

Interest in the possibility of space tourism has increased among scientists, entrepreneurs, and the general public (Cox, 2002). Today's space tourism flights are in the early pioneer phase, handling only one or two tourists per year. A trip for a space tourist to the International Space Station (ISS) costs typically $20-$40 million and lasts approximately 10 days. In April 2001, Dennis Tito was the first space tourist, and he was followed by Mark Shuttleworth in April 2002, Greg Olsen in October 2005, Anousheh Ansari in September 2006, Charles Simonyi in April 2007 and April 2009, Richard Garriott in October 2008, and Guy Laliberté in September 2009 (Space Adventures, 2013).

Compared to other tourist enterprises, space-related tourism is in its infancy as a commercial activity, but the space tourism industry is already larger than most people realize. The potential of space tourism in the coming decades does not rest on one or two flights per year for $20-$40 million per trip; rather a wide range of services and price levels will be provided (Gurtuna & Garneau, 2002). Peak turnover from ticket sales in the range of $10 billion per year and additional turnover from novel secondary markets, such as space fashions, space food, space entertainment, and space sports, are imaginable within this century.

Currently, there are only two means for humans to access orbital space, i.e., the Russian *Soyuz* and the Chinese *Long March*. Only Soyuz has been used for space tourism, and there are no indications that Long March will be used for this purpose in the near future. The *Shenzhou* spacecraft that is launched atop the Long March

DOI: 10.4018/ijasot.2014010103

launch vehicle has characteristics similar to those of the Soyuz-TMA that is launched atop the Soyuz launch vehicle, so the Shenzhou-Long March system is a potential candidate for human space flight (Anderson & Piven, 2005). However, the official announcement from the Chinese government looks less positive; Yang Liwei, Deputy Director of China's Manned Space Engineering Office, said in 2012 that "China's manned space engineering is still in a stage of technological breakthrough, and sending civilians into orbit for space tourism is not under consideration right now" (China Daily USA, 2012, para. 4).

Currently, there are no options for space tourists to access suborbital space. A breakthrough might be *SpaceShipTwo*, which is currently in the test and licensing phase and which Virgin Galactic plans to put into operation soon; in fact, "Virgin officials are hopeful that commercial missions could begin in 2014" (Messier, 2013, para. 9).

The following section shows an overview of possible hurdles, challenges, and hopes to space tourism. After a discussion of the social, institutional, and financial issues, my conclusions and recommendations are presented.

SELECTION OF KEY ASPECTS

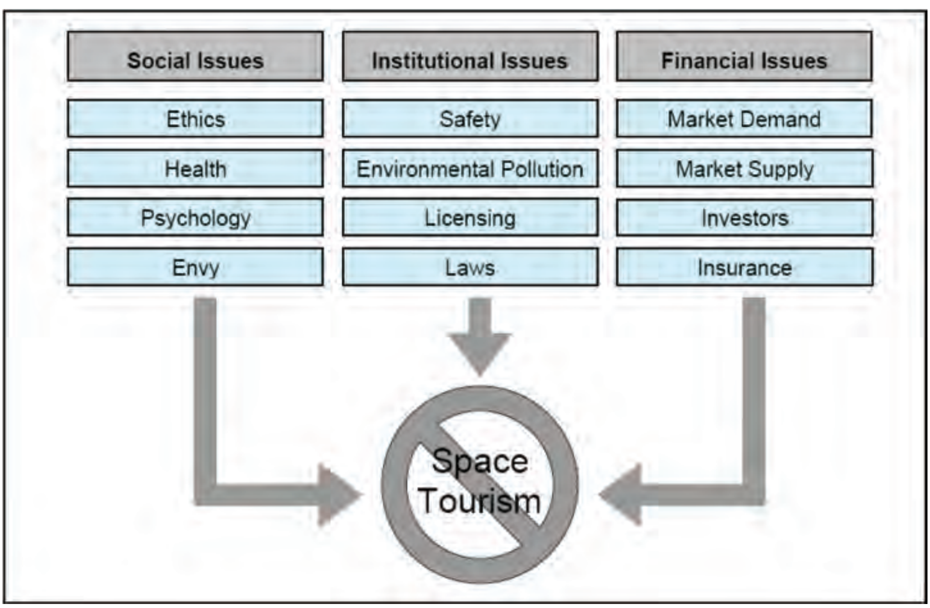
Figure 1 shows a selection of the key aspects of space tourism, including hurdles that could be harmful to the successful establishment and enhancement of space tourism activities (Goehlich, 2003). These potential hurdles to commercial space travel should be considered thoroughly by entrepreneurs and politicians before the actual activation of regular services for space tourists.

Social Issues

Ethics

Apart from concerns regarding the feasibility of mass space tourism, there is also the human ethical issue that rarely has been addressed in the literature. Despite the significant progress that has been made in the safety and reliability of launching rockets, it remains a risky procedure

Figure 1. Possible hurdles and opposing forces to space tourism



because even small errors or faults can result in major disasters. The question arises concerning what society would deem to be an acceptable level of risk for space travelers.

Many adventure travelers and extreme-sports athletes climb Earth's highest mountains (See Figure 2), cross its widest deserts, explore its most frigid lands, and dive to its darkest depths. Many dangerous activities are undertaken routinely that involve the real risk of death at every step, yet humankind hails these adventurers as heroes. Considering these activities, if there is a genuine interest in traveling into space, potential risks may be no obstacle, at least from the societal perspective so long as the associated advertising describes the risks accurately. Surprisingly, more than 78,000 people from more than 120 countries have applied at the Dutch company Mars One for a chance to go on a one-way trip to Mars in 2023 (Mars Daily, 2013).

Pompidou (2000, p. 10) stated that "The conquest of space contributes to the dissemination of scientific and technical culture." He also observed that the conquest would help maintain the "imaginative horizon and determination to make new discoveries," which, one could argue, are the driving forces in human society. Many social benefits of space travel in general and space tourism in particular may evolve, including broadening the mind, giving people a better understanding of the complex universe the Earth inhabits, and imbuing a planetary consciousness. However, to enable space tourism, politicians, scientists, and the public must navigate a fundamental change from today's views of space activities to that of mass space tourism as entertainment. It is reasonable to characterize this challenge as a political, social, and economic revolution.

Health

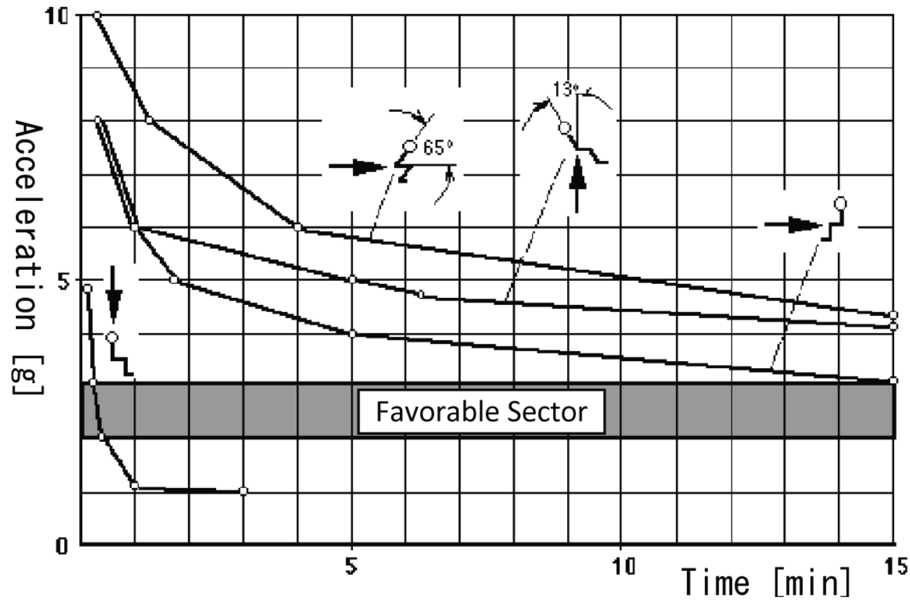
When they occur, space tourism flights will be intended for persons in generally good health. Topics relevant to medical safety and the general well-being of space tourists include acceleration during take-off, re-entry and landing; microgravity in space; cosmic rays; and the "jetlag" effect.

Sensual experiences during space flight (particularly acceleration, noise, and mental stress) will be similar to those incurred during the flights of military aircraft. The acceleration at take-off should not exceed 3.5 g (See Figure 3).

Space motion sickness (SMS), which results from a sudden lack of correspondence between information received from the inner ear and visual cues caused by microgravity, provokes disorientation and discomfort. Typical symptoms, which vary among people, are pallor, dizziness, perspiration, drowsiness,

Figure 2. Himalaya Mountains (Simon)

Figure 3. Acceleration limits for the human body (Lo)



nausea, and psychological stress (ISU, 2001). Pre-flight training, such as biofeedback, pre-flight prophylactic medication, and in-flight medications, such as Promethazine, an antihistamine, can protect passengers against motion sickness in space. The most common side effects associated with antihistamines are drowsiness, dizziness, headache, dry mouth, and blurred vision (Allen, 2011).

Along with SMS, the most immediate effect of microgravity is "red-out," in which blood rushes into the head instead of away from it. Symptoms are puffy heads, "chicken legs," and an increased heart rate to compensate for changes in blood volumes and locations (Larson & Pranke, 2000). After a space traveler returns to normal gravity, light-headedness and fainting can occur.

Microgravity can lead to decomposition of weight-bearing bones and muscles, especially in the legs, hips, and back, and result in weakness upon return to normal gravity. Bone loss of 1-3 percent per month was observed in crew members of the *Mir* space station (ISU, 2000). Countermeasures consist of several hours of daily exercise on ergometers with bungee cords while in space (See Figure 4). Bone loss is one of the main concerns related to long-term stays in space, but space tourists who spend only a day or a week in space should have no serious effects.

The average radiation dose measured in millisieverts (mSv) that a person receives on Earth is about 1.7 mSv per year, and the primary sources are soil (0.4 mSv), food (0.2-0.5 mSv), and cosmic rays (0.4-1.6 mSv) (Tascione, 1988). Each transatlantic flight can account for another 0.04 mSv (Schiller, 2013). Space tourists on a one-day mission would receive a higher dose of about 0.3 mSv (Onmeda, 2003), which is still negligible. Protection from radiation in space is necessary only for very long flights.

Orbital flights that last one day will induce disturbances in people's circadian rhythms because of accelerated night and day cycles. The associated symptoms, which are similar to "jetlag" after a long-distance flight, resolve soon after movement is halted. Astronauts regularly use medication to assist sleep, and space tourists will be able to take sleeping pills if necessary to maintain their circadian rhythms.

Figure 4. Astronaut exercising on ergometer (NASA)

Psychology

In addition to medical standards, psychological standards are necessary because psychology can be affected significantly by physiological issues. Initial difficulties in adapting to space could affect tourists' enjoyment, so a parabolic zero-gravity flight should be part of pre-flight training for participants in order to prepare them for weightlessness and help them to adapt mentally once they are in space. The pre-flight training must be organized in such a way that customers consider it part of the adventure—part of what they pay for—not only as preparation for the journey (Abitzsch, 1996). The presence of a pilot, in the role of a charismatic leader, who is intimately familiar with the procedures and processes and who maintains a rational confidence is essential for a pleasant experience during flight (Goehlich et al., 2013).

Claustrophobia is an area that warrants additional study. Simple things, such as meals and recreation, can influence morale and reduce the claustrophobic effect. Special consideration also should be given to religious and cultural ceremonies, such as Christmas (See Figure 5). Studies indicate that being in orbit tends to make people more reflective about philosophical questions, such as the meaning of humans' existence in the cosmos. Sessions dedicated to spiritual activities would increase the intensity of the tourists' experiences in space (ISU, 2000).

Envy

Some people in the government may view space as the exclusive domain of national security and consider private-sector activities of any kind a threat to their power base (Simberg, 2000). In addition, many in the astronaut corps have never had the opportunity to go into space, and private-sector activities reduce the chances that they ever will (Simberg, 2000). Selling the capacities of government-operated vehicles to civilians in lieu of government-employed astronauts (See Figure 6) who have undergone a rigorous selection and training process could engender disapproval both inside and outside the astronaut corps (Simberg, 2000). Intensified integration of government astronauts into the private space business by offering a goal-directed service for the government space market in addition to the private market could help to prevent such negative consequences.

If the space tourism business is supported by federal funding, some politicians will view

Figure 5. Advent calendar in the ISS (NASA)

Figure 6. An astronaut participates in an extra-vehicular activity (EVA) on the ISS (NASA)

it, barring lotteries or contests, as "a taxpayer subsidy to the wealthy," who would initially be the only ones who could afford space trips (Simberg, 2000, p. 8). Even if the government provides no funding at all, the public is likely to assume public funds are involved (Simberg, 2000). "There is historically such a strong linkage in the mind of the public" between government's space agencies and space that any space tourism activity may be perceived as "a waste of public funds" according to Simberg (2000, p. 8). Therefore, economic returns, an increased tax base, and attractive opportunities should be promoted as byproducts of the space tourism business (Simberg, 2000).

Institutional Issues

Safety

Although space tourists will not be trained like professional astronauts (See Figure 7), they must be familiar with emergency procedures. A space tourist would need much more information about how to fasten a seatbelt—at least a week of intense training on how to be safe as a passenger in a space vehicle (Simberg, 2000). This training may include flight training, medical training, and emergency procedures.

A major factor in keeping the passengers safe is to ensure that the space vehicles are safe and reliable. The first option is to reduce catastrophic failures by using redundancy and over-designing of subsystems, improving maintenance by extensive health monitoring of all vital systems in the vehicle and improving operations with many soft-abort sequences. Further examples of safety improvements are "decreasing complexity, using fail-safe systems (thermal, structures, power, life-support), simplifying the assembly and integration process, and investing in new technologies" (ISU, 2011, p. 6). The second option is to protect passengers in case of a catastrophic failure by means of appropriate safety equipment for passengers and crew, such as space suits, ejector seats, ejector capsules, and emergency shelters. Both options would result in an increased empty-vehicle weight and, therefore, fewer passengers. For vehicles with a large passenger capacity, the first option, i.e., rescuing the vehicle and the passengers together, might be more suitable, while the second option, i.e., rescuing only the passengers, might be more suitable for vehicles with low passenger capacity.

A higher safety standard would result in lower economic performance, less profit, and higher life-cycle costs. However, a lower safety standard also results in lower economic performance because the higher risk would be unattractive to passengers and ethically unacceptable, resulting in lower demand. More research is required to determine the "right" safety standard for space tourism vehicles.

Environmental Pollution

Any chemical-propulsion launch system leaves emissions in the atmosphere. Because much more energy is required to transport a passen-

Figure 7. ISS crew during survival training in Siberia (NASA)

ger to sub-orbit or orbit than to any location on Earth, more pollutants will be generated. A typical orbital RLV concept for space tourists, for example, *Kankoh Maru Plus*, would need 71 Mg of liquid hydrogen as fuel to transport 50 passengers to Low Earth Orbit (LEO) and back to Earth. Therefore, each passenger needs about 1.4 Mg of liquid hydrogen, which is equivalent to 202 GJ (gigajoules) of energy. A Boeing B747-400 needs about 150 Mg of kerosene as fuel to transport 400 passengers from one continent to another, so each passenger needs about 0.4 Mg of kerosene for a one-way flight, which is equivalent to about 17 GJ of energy. Therefore, the energy consumption per passenger of one round-trip space flight is equivalent to about six round-trip transcontinental flights. However, from a global point of view, the cumulative energy consumption of around 100,000 expected space passengers would be relatively small compared to today's annual 1.5 billion air passengers. (This scenario is intended only for illustration using estimates; real relationships have been simplified. For example, the energy consumption required to produce kerosene, liquid hydrogen, and liquid oxygen has not been considered.)

A typical sub-orbital vehicle for space tourists will produce fewer emissions than a typical orbital vehicle because it will require less energy. "We have reduced the (carbon emission) cost of somebody going into space from something like two weeks of New York's electricity supply… to less than the cost of an economy round-trip from Singapore to London," Branson told reporters in Singapore (Agence France-Presse, 2013, para. 3).

Table 1 compares space transport (excluding the space tourism sector) with other anthropogenic and natural pollution sources estimated for 2065 (Adirim, Lo, & Paatsch, 1999). The table shows that the emissions associated with space transport would be negligible on a global scale, even if the launch rate increased by a factor of 100 because of space tourism. Extensive studies of the emissions caused by space transport (including space tourism) and air transport in the period from 2010 to 2065 for a scenario with up to 200,000 space passengers per year have shown that the emissions for space tourism would range from 0.006 to 1.5% of the emissions from air transportation (Lo & Paatsch, 1998, 1999).

While the data in Table 1 show the emissions from space tourism in a comparatively favorable light, space vehicles are the only major emitters at altitudes above those reached by airline traffic. These emissions along the trajectory in the sensitive upper atmosphere are not negligible, and neither is the local pollution at spaceports (See Figure 8). Operators should be obliged to pay a "keep space clean" fee (Cox, 2002), depending on the amount of emissions they produce. Unfortunately, the effects of some types of emissions, especially when they occur in the upper atmosphere, are not well understood. Therefore, ecologically-adapted flight profiles cannot be developed until emission penalties are quantitatively formulated by atmospheric chemists.

Table 1. Estimated emissions in 2065 (modified from Adirim, Lo, & Paatsch, 1999)

Sources		H_2O	CO	CO_2	HCl	NO_x
Anthropogenic	Space transport	< 23	n.a.	< 0.0005	n.a.	< 0.005
	Air transport	> 436	> 0.26	> 1,070	n.a.	> 5
	Burning of fossil fuel	8,300	n.a.	20,350	2	n.a.
	Others	n.a.	1,490	n.a.	n.a.	85
Natural	Volcanoes	n.a.	n.a.	n.a.	5	n.a.
	Oceans	525,000	n.a.	n.a.	330	n.a.

Note: Units are Mg/year

Figure 8. Space Shuttle lift-off (NASA)

Any additional source of pollution, including transportation of space tourists, should not be excused by the presence of other pollution sources. This matter is currently not sufficiently discussed by the developers and organizations who are promoting space tourism flights. Since this issue is highly sensitive and politically charged, presenting it incorrectly could lead to the rejection of space flights by tourists.

Licensing

The development of the vehicles to be used for space tourism will present many engineering challenges in terms of the need for low-cost operating procedures, high reliability, safe abort capability, and vehicle performance, but it is also an institutional challenge in terms of developing applicable laws and regulations (Collins & Yonemoto, 1998). Currently, there is a deep gap between rocket and aircraft design philosophy (See Figure 9) in that the success of a rocket launch and space mission can be estimated by a reliability calculation, where the probability of loss is a factor of the failure rate and the rocket is launched by probabilistic operation for launch success (Torikai et al., 1999). In contrast, airworthiness requires safe operation even when some of the aircraft's subsystems or components fail during operation. Aircraft operators aim at safe flights above all else (Torikai et al., 1999).

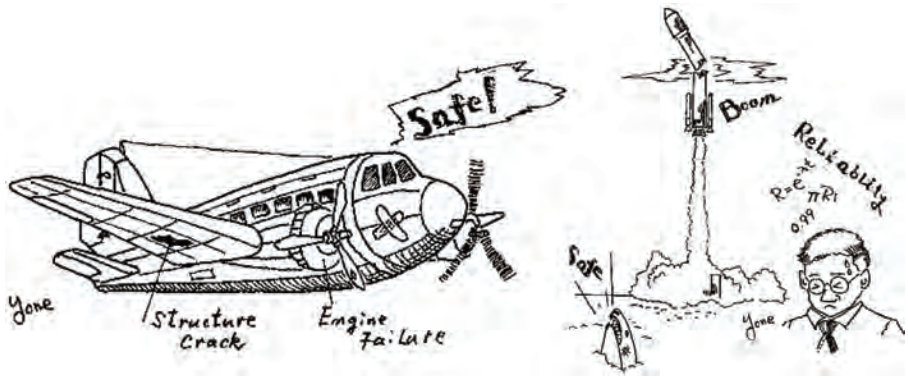
Therefore, the safety standard required for certification of space transportation vehicles should restrict their design and change the fundamental operation process from probabilistic launch to deterministic take-off and landing with levels of safety similar to those of aircraft (Isozaki et al., 1998). The existing regulatory and legal environments also must be reformed to allow for the promotion of commercial passenger flights to and from space (Isozaki et al., 1998).

Overcoming these hurdles would allow developers and operating companies to raise the capital required from investors since they would be able to understand and control their risk due to the regulatory market environment. The absence of regulations may cause investors to fear that an unknown future regulation will kill the business (Lindsköld, 1999).

Entrepreneurs and politicians should take the following points into consideration when developing regulations for civilian space flight (Collins & Yonemoto, 1998):

- Standards are needed for training, testing, and licensing pilots as well as the cabin and maintenance staff;
- The responsibility of the air traffic control system of the Federal Aviation Administration (FAA), the federal governmental

Figure 9. Deterministic (left) versus probabilistic (right) operation (Yone)



institution in charge of regulating and overseeing the aviation industry in the U.S., should be extended to include sub-orbital and orbital surveillance;

- Certification regulations for passenger RLVs must be developed, taking into account the vehicles' structural integrity and damage tolerance, fire suppression systems, noise levels, evacuation standards, pollution levels, and maintenance procedures;
- Passenger travel services in space should include insurance similar to that imposed as a part of the Warsaw Convention for air travel. However, the space travel industry's initial small scale and resulting limited actuarial information will preclude companies from offering insurance underwriting with a high level of confidence, so insurance costs will be high.

The civil aviation model provides a good guideline for redundancy and safety design requirements and structural verification procedures. It is primarily the responsibility of governments to negotiate and ratify such agreements in time to be effective and to prevent major accidents and international conflicts.

However, regulations also pose a barrier to space tourism. A major issue is how to certify sub-orbital and orbital vehicles with the FAA so they can carry paying passengers (Lindsköld, 1999). Aircraft must make more than 1,000 test flights, a process that may take more than three years, to gather sufficient statistical data (Lindsköld, 1999). Going through such a procedure would cause enough economic difficulty for the space tourism industry to be an insurmountable barrier to any start-up company (Lindsköld, 1999).

However, the U.S. House of Representatives' passage of legislation in 2004 set guidelines for the future space tourism industry that gives regulatory authority over human flight to the Federal Aviation Administration's Office of Commercial Space Transportation (USA Today, 2004). To make it easier to test new types of reusable sub-orbital rockets, this legislation gives the FAA the authority to issue experimental permits that can be obtained more quickly than "real" licenses can be obtained (Berger, 2004). This approach might be a major step in the development of commercial human space flight. For example, Virgin Galactic has such an experimental permit from the FAA to allow powered test flights of SpaceShipTwo (Foust, 2014).

In parallel with the U.S. Government, private groups are studying the aviation industry's regulatory system as an appropriate model for the civilian space travel industry (Collins & Yonemoto, 1998). For instance, in 1997, the Transportation Research Committee of the Japanese Rocket Society (JRS) studied the requirements needed for the certification of the Kankoh Maru vehicle concept to enable it to carry passengers (Collins & Yonemoto, 1998). The Universal Space Clipper Company conducted a study in which the requirements for passenger space vehicles were divided into categories, i.e., type design certificate, production certificate, air-worthiness certificate, commercial operator's license, spaceport license, and other approvals, such as those for component manufacturing and maintenance (Gaubatz, 1998).

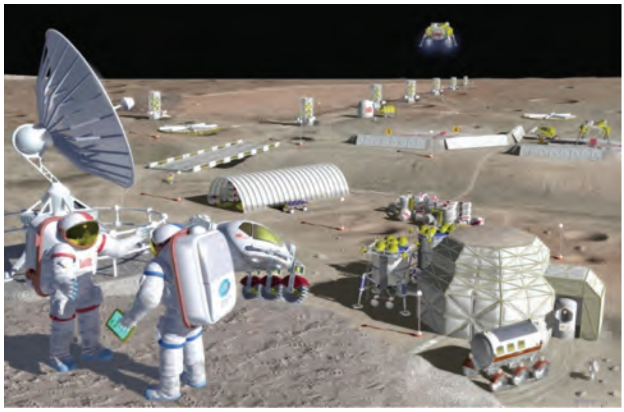
Laws

Laws already regulate space endeavors, such as commercial satellite launches (USA Today, 2004). The major space law treaties are:

- **Outer Space Treaty (1967):** The Outer Space Treaty, which stipulates the principle of "exploration and use of outer space," is considered the "backbone of international space law" (Wollersheim, 1999, p. 2). However, it is unclear which liability regime would apply in the event that a non-governmental entity's space mission resulted in harm to a foreign citizen. The 1929 Warsaw Convention, which provides guidelines regarding monetary compensation, is an international private law treaty that helped the international air travel industry get established by limiting airlines' liability for damages (Collins & Yonemoto, 1998). It has been proposed that a space law agreement be based on this convention in order to make space activities commercially feasible (Roberts, 1996);
- **Rescue Agreement (1968):** The Rescue Agreement does not mention passengers, so it may not apply to space tourists, but the agreement may not exclude passengers either. The omission is simply a factor of when the Rescue Agreement was created, when participation in space travel by tourists was not even considered. (Wollersheim, 1999);
- **Liability Convention (1972):** Article II of this convention gives the state that launches a space vehicle absolute liability for compensation for damage to "the surface of the Earth or to aircraft in flight." Accordingly, states have the right to deny private enterprises the right to practice space tourism. A gap in the convention is that "nationals of the launching states are excluded from the scope of the Liability Convention." (Wollersheim, 1999, p. 2);
- **Registration Convention (1976):** The Registration Convention coordinates launches and ensures identification of the state that launches a space vehicle in respect to the Liability Convention. Since private enterprises must comply with the registration procedure, the number of private registrations will increase with space tourism. (Wollersheim, 1999);
- **Moon Agreement (1979):** The Moon Agreement states that no nation can claim sovereignty over celestial bodies or their resources, but it could be interpreted that buildings or facilities on the moon's surface, such as lunar bases (See Figure 10), remain national property and fall under national sovereignty. Therefore, lunar bases are treated as space objects and come under state jurisdiction. The Moon Agreement is not particularly relevant because the agreement does not prevent states other than those that are parties to the agreement from claiming sovereignty over celestial bodies. However, this law might be relevant to space tourist projects, such as lunar hotels. (Wollersheim, 1999).

Space tourism is a new institutional challenge because there is no legal jurisdiction for regulating spaceflight for paying passengers (USA Today, 2004), but it is likely that laws that are analogous to air transportation laws will eventually be enacted. However, space tourism will require extensive innovations in applicable regulations in both national and

Figure 10. Commercial lunar base concept (NASA)



international law. For example, who would have jurisdiction if an international passenger on a space tourism flight committed a crime against another international tourist? In the case of the International Space Station (ISS), the International Governmental Agreement states that criminal jurisdiction should remain with the state of nationality of the "alleged perpetrator" of a crime, provided that the state is an International Space Station partner state.

Law policy is a fundamental component of the development of space tourism, so commercial undertakings in space should be accompanied by the simultaneous application of a legal framework. However, only elementary steps have been taken in this respect. Law policy must be developed by an international organization and be endorsed by every state so there is binding compliance from space-faring nations (Hudgins, 2001). "The first step towards greater clarity in law is through reaching agreement on the legal definition of the key words, such as 'outer space,' 'space object,' 'space tourism,' or making necessary modifications in the definition of 'aircraft'" (Sameh, 2013, p. 120).

Financial Issues

Market Demand

Space tourism market surveys have been performed in many countries (Crouch, 2001). However, in the pioneer phase, it is difficult to forecast the price elasticity of demand because most passengers will be multimillionaires for whom prestige and political causes, rather than the ticket price, determine the demand. Also, there is a significant difference between saying "I would like to make a trip into space" and actually buying a ticket for the trip.

Ziliotte (2010) investigated the relevance of the Futron/Zogby survey conclusions with recent market and customers' data; basically it shows a good matching. Only "the first customer data released by Virgin Galactic shows that the average age is lower than expected in the Futron study" (Ziliotte, 2010, p. 1549).

In addition, there is a risk that the sub-orbital space tourism market would be almost instantly displaced by the introduction of a product capable of reaching orbit. At this point, no one knows whether a sub-orbital market would last long enough for manufacturers to recoup their investments prior to the introduction of an orbiting transportation system.

Market Supply

There are more than 300 proposed vehicle concepts for RLVs worldwide that could be produced by manufacturers from various countries (Goehlich, 2006).

Even though the development cost for SpaceShipOne was much more than the $10 million return from the Ansari X Prize, and even though it will take many flights with test pilots before SpaceShipTwo could transport paying tourists, and even though there may be other technical, political, or economic problems that no one has though of yet, the three successful sub-orbital flights of SpaceShipOne in 2004 (one test flight and two qualifying flights) changed the view of the possibility of space tourism when the privately financed rocket became a success story rather than a dream of rocket enthusiasts and science fiction writers.

However, even though SpaceShipOne's flights were successful, they may not be a significant breakthrough for space tourism. After the 2001 flight of Dennis Tito, the first paying space tourist, many people thought there would be a rapid increase in these kinds of flights, but progress has been slow. Currently, none of the predictions of 2001, such as a space lottery for the general public, exists on a large scale. It is certainly difficult to forecast the demand for privately-financed, sub-orbital flight based on Dennis Tito's maiden flight as a space tourist. Even so, if space pioneers are determined to achieve something, they most likely will do so.

Investors

Acquiring the required financial resources is, by far, the most difficult obstacle that stands in the way of any new aerospace project (TIM Consulting, 2003). Although many start-ups have tried to enter the rocket market, the world's financial markets have provided only a small fraction of their overall funding requirements (TIM Consulting, 2003). Since space tourism is a new industry, the only available data related to this industry have been provided by a few surveys that have been conducted concerning space tourism (Lindsköld, 1999). No one knows exactly how large the market will be, and no orbital reusable rockets have yet met the safety standards required for carrying passengers (Lindsköld, 1999). Since one can only speculate about the space tourism industry's prospects for the future, investors are hesitant to provide the astronomical funding required to develop a completely new vehicle (Lindsköld, 1999). "Awareness that many ventures have quietly shelved their grandiose plans" might aid thinking about the projections for development of a space tourism industry (Billings, 2006, p. 162).

Although it is difficult to generalize about the financing of high-risk investments, some broad conclusions are evident. New companies are unable to raise financing through a stock exchange listing, so they must rely on venture capital. However, most venture capitalists have maximum limits on the amount of capital they will provide in any single case, and they are reluctant to invest heavily in new ventures (Moore, 1983). Therefore, financing a space tourism venture would require the participation of multiple venture capitalists.

Decision making when there are uncertainties is challenging because inadequate data are available for reliable forecasts (Bamberg & Coenenberg, 1996). Economic research has experienced many false starts and complications in its attempts to measure attitudes toward risk (Hartog, Ferrer-i-Carbonell, & Jonker, 2000). Sensitivity to how the concept is presented, the reversal of preferences, and the gap between the willingness to accept an idea and the willingness to pay for it can stymie any attempt to measure the attitude toward a particular risk (Hartog et al., 2000). Expressed another way, strategic decisions have a complicated structure, and the need to assess alternatives with limited information leads many organizations to use models to address strategic decisions. However, the assumptions to be made in the models require that their probabilities be developed based on the certainty of each input value (Lorance & Wendling, 2001). A solution might be a cost-risk analysis in which a range of costs is generated with a level of risk assigned to each cost value in the range (Dean, Wood, Moore, & Bogart, 1986). The challenge is to estimate the project's cost, predict a potential cost range, and determine the prediction's reliability (Dean, Wood, Moore, & Bogart, 1986).

Even for companies that are committed to investing in space tourism, prospective RLV operators will have to show that their projected profits are sufficiently higher than those of more conventional, Earthbound alternatives to make up for the added risk (Livingston, 2000). Generally, venture capitalists are concerned about management experience (Livingston, 2000), and no one can claim management experience in space tourism. In addition, there is plenty of room for misunderstandings between rocket scientists and finance professionals (See Figure 11), e.g., "burn rate" means something totally different to a rocket scientist and a venture capitalist (Eilingsfeld & Schaetzler, 2000). Since most commercial rocket ventures have failed to catch the attention of venture capitalists, a professional business approach is needed in order to gain the interest of the business and finance communities (Anselmo, 1999).

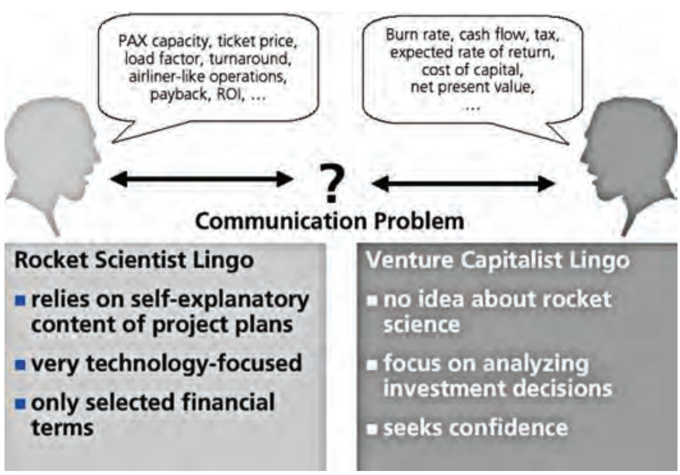
Insurance

Space tourism is a new venture, and insurance will be a major issue until it reaches a mature level of development. Insurance will be required for passengers who are traveling in space and for the related equipment and facilities, but the small scale of the space travel industry will be insufficient to enable accurate insurance underwriting. Therefore, for space tourism to become a vital commercial enterprise, limits will be necessary on the liability of owners and operators of space facilities and vehicles (Collins & Yonemoto, 1998).

A high failure rate will certainly not be favorable for space tourism, although many activities involve even greater risks. Because of the assumed high risk of space tourism ventures, insurance, if it is available at all, will be very expensive until the insurance companies have coherent underwriting information. Catastrophes in which people are killed, e.g., aviation disasters, are assigned greater importance in people's minds than other deaths (Moore, 1983). Even if the number of negative incidents is low, the consequences when such incidents occur can be significant, which has implications for any insurance underwriter.

Companies that launch commercial space ventures are required by law to carry liability insurance, with the government providing compensation for losses above $500 million (USA Today, 2004).

Figure 11. Communication problem (TIM Consulting)



CONCLUSION AND RECOMMENDATIONS

There is currently no overall framework to deal with the hurdles that space tourism faces. For mass space tourism to become a reality, such a framework must be developed and accepted internationally, and it must address, as a minimum, ethical, health, psychological, safety, environmental, regulatory, legal, investment, and insurance aspects of space tourism.

Social Issues

- An ethical framework that reflects the motivations and consequences of public space travel is needed, since ethics can fundamentally influence the future development of space tourism activities;
- A health framework is necessary if mass space tourism is to be pursued. Early space tourists, such as Dennis Tito, were well prepared with good health as well as physical and mental tolerance. The physical and psychological comfort of passengers—the average healthy person as well as the very young or very old—must be ensured;
- A psychological framework is recommended such that people with a history of personality disorders, claustrophobia, and suicide attempts can be excluded;
- Envy cannot be put into a framework, as its level will depend heavily on how space tourism activities are reported in the media.

Institutional Issues

- The development of a space tourism market is most sensitive to a safety framework. Considerable investigation is needed to find a balance between the required safety standards for vehicles and the possibility that the developers and operators who are using the available technology can fulfill these requirements. Unattainable safety standards are a showstopper for space tourism, but safety standards that are lax would be just as limiting in terms of ethical concerns;
- An environmental framework similar to that of aviation operations is necessary. In particular, issues that relate to local spaceport emissions and noise pollution, space debris pollution, and global emissions of pollutants must be addressed;
- Like any commercial endeavor, commercial space activities require a regulatory framework. Major issues to be resolved for space tourism include training for passengers and crew, certification of vehicles and launch facilities, and licensing of space operators;
- The legal framework for space tourism activities is not clearly defined. In particular, issues related to jurisdiction, space traffic management, and liability must be addressed.

Financial Issues

- Accurate and well-accepted market-demand research is needed to fulfill the fiduciary requirements of investors, and expected flight program outlines are needed to fulfill the requirements and expectations of potential passengers;
- Space flight demonstrations are needed to motivate investors to invest in these kinds of vehicles, to stimulate rocket engineers to think of alternative approaches, to increase the public's and governments' awareness of new space activities, and to create the desire in many of us to ask "Why not?" followed by "Why not me?"
- A financial framework is needed in order for investors to estimate their risk, a need that could be addressed through the development of an independent consulting agency;
- The topic of insurance associated with space tourism has not been studied thoroughly to date, and it merits further critical review because it is a major aspect of reducing financial risk.

ACKNOWLEDGMENT

This is an updated and edited version of a paper presented at the 24th Congress of the International Council of the Aeronautical Sciences (ICAS), 29 August – 3 September 2004 in Yokohama (Goehlich, 2003, 2004) and of a chapter in a book entitled "Commerce in space: Infrastructures, technologies and applications" published by IGI Global (Goehlich, 2007).

The author thanks conference participants, the associate editor, and anonymous reviewers for their helpful comments and suggestions on earlier drafts of this study. The study was supported by the Japan Society for the Promotion of Science (JSPS) and the Alexander von Humboldt Foundation (AvH Foundation) in 2004, which the author gratefully acknowledges.

The views reported in this paper are those of the author and not those of any institution. Any errors and omissions are the sole responsibility of the author.

REFERENCES

Abitzsch, S. (1996, May). *Prospects of space tourism*. Paper presented at the 9th European Aerospace Congress, Berlin, Germany.

Adirim, H., Lo, R. E., & Paatsch, A. (1999, October). *Next generation high performance low pollution launchers: Problems and solutions*. IAA-99-IAA.3.3.01. Paper presented at the 50th International Astronautical Congress, Amsterdam, The Netherlands.

Agence France-Presse. (2013, May 13). *Space tourism won't hurt environment: Richard Branson*. Author. Retrieved from http://www.rawstory.com/rs/2013/05/13/space-tourism-wont-hurt-environment-richard-branson

Allen, H. (2011, March 23). Promethazine [Web log post]. *Patient.co.uk*. Retrieved from http://www.patient.co.uk/medicine/Promethazine.htm#

Anderson, E. C., & Piven, J. (2005). *The space tourist's handbook*. Philadelphia, PA: Quirk Books.

Anselmo, J. C. (1999). RLV ventures strained by funding problems. *Aviation Week & Space Technology*, *151*(1), 24.

Bamberg, G., & Coenenberg, A. G. (1996). *Betriebswirtschaftliche Entscheidungslehre* [Managerial decision theory]. Munich, Germany: Verlag Vahlen.

Berger, B. (2004, November 20). House passes private spaceflight bill. *Space.com*. Retrieved from http://www.space.com/542-house-passes-private-spaceflight-bill.html

Billings, L. (2006). Exploration for the masses? Or joyrides for the ultra-rich? Prospects for space tourism. *Space Policy Journal*, *22*(3), 162–164. doi:10.1016/j.spacepol.2006.05.001

China Daily USA. (2012, October 29). *Shenzhou X to blast off with 3 in 2013*. Retrieved from http://usa.chinadaily.com.cn/china/2012-10/29/content_15854062.htm

Collins, P., & Yonemoto, K. (1998, September). *Legal and regulatory issues for passenger space travel*. Paper presented at the 49th IAF Congress, Melbourne, Australia. Retrieved from http://www.spacefuture.com/archive/legal_and_regulatory_issues_for_passenger_space_travel.shtml

Consulting, T. I. M. (2003). Home. Retrieved November 11, 2003, from http://www.rocketfinance.com (no longer available)

Cox, N. L. J. (2002, October). *Space travel & space tourism: Ethics and society*. IAC-02-IAA.8.1.07. Paper presented at the 53rd International Astronautical Congress, Houston, TX.

Crouch, G. I. (2001, June). *Researching the space tourism market*. Paper presented at the 32nd Annual Conference of the Travel and Tourism Research Association, Fort Myers, FL. Retrieved from http://www.spacefuture.com/archive/researching_the_space_tourism_market.shtml

Dean, E. B., Wood, D. A., Moore, A. A., & Bogart, E. H. (1986, May). *Cost risk analysis based on perception of the engineering process*. Paper presented at the 8th Annual Conference of the International Society of Parametric Analysts, Kansas City, MO.

Eilingsfeld, F., & Schaetzler, D. (2000, October). *The cost of capital for space tourism ventures*. IAA-00-IAA.1.4.02. Paper presented at the 51st International Astronautical Congress, Rio de Janeiro, Brazil.

Foust, J. (2014, March 7). Virgin galactic nearing approval for SpaceShipTwo launch license. *SpaceNews.com*. Retrieved from http://www.spacenews.com/article/launch-report/39769virgin-galactic-nearing-approval-for-spaceshiptwo-launch-license

Gaubatz, W. A. (1998, May). *Reusable space transportation – the key infrastructure elements in opening the space frontier to the public*. 98-0-1-01v. Paper presented at the 21st ISTS, Sonic City, Japan. Retrieved from http://www.spacefuture.com/archive/reusable_space_transportation_the_key_infrastructure_element.shtml

Goehlich, R. A. (2003). *A representative program model for developing space tourism*. Berlin, Germany: Wissenschaftlicher Verlag Berlin.

Goehlich, R. A. (2004, August). *Suitability of future trans-atmospheric vehicles for mass space tourism flights*. ICAS 2004-1.11.3. Paper presented at the 24th Congress of the International Council of the Aeronautical Sciences (ICAS), Yokohama, Japan.

Goehlich, R. A. (2006). *Spaceships – A reference guide to international reusable launch vehicle concepts from 1944 to the present*. Burlington, Canada: Apogee Books, CG Publishing.

Goehlich, R. A. (2007). Aspects of space tourism. In: P. Olla (Ed.), Commerce in space: Infrastructures, technologies and applications (pp. 293-311). Hershey, PA: IGI Global. doi:10.4018/978-1-59904-624-2.ch015

Goehlich, R. A., Anderson, J. K., Harrold, N. N., Bemis, J. A., Nettleingham, M. T., & Cobin, J. M. et al. (2013). Pilots for space tourism. *Space Policy Journal*, *29*(2), 144–153. doi:10.1016/j.spacepol.2013.03.011

Gurtuna, O., & Garneau, S. (2002, October). *Global survey on future trends in human spaceflight: The implications for space tourism*. IAA-1-3-08. Paper presented at the 53rd International Astronautical Congress, Houston, TX.

Hartog, J., Ferrer-i-Carbonell, A., & Jonker, N. (2000). *On a simple survey measure of individual risk aversion*. CESifo Working Paper No. 363, Munich, Germany. Retrieved from http://www.cesifo-group.de

Hudgins, E. L. (2001, June 26). Space policy and space tourism [Web log post]. CATO Institute, Washington, DC. Retrieved from http://www.cato.org/publications/congressional-testimony/space-policy-space-tourism?print

Isozaki, K., Yonemoto, K., Kitayama, O., Miyahara, A., Watanabe, H., & Okaya, S. Okaya, S. (1998, September). *Status report on space tour vehicle "Kankoh-maru" of Japanese Rocket Society*. IAA-98-IAA.1.5.06. Paper presented at the 49th International Astronautical Congress, Melbourne, Australia.

ISU. (2000). *Space tourism: From dream to reality (ISU Summer Session Program report)*. Valparaiso, Chile: Universidad Tecnica Federico Santa Maria.

ISU. (2001). Space tourism: A literature review (ISU MSS report). Strasbourg, France.

ISU. (2011). Kourou vision 2030 (ISU MSS report). Strasbourg, France.

Larson, W. J., & Pranke, L. K. (2000). *Human spaceflight – Mission analysis and design*. New York, NY: McGraw-Hill.

Lindsköld, A. (1999). *Space tourism and its effects on space commercialization* (Report). International Space University, Strasbourg, France. Retrieved from http://www.spacefuture.com/archive/space_tourism_and_its_effects_on_space_commercialization.shtml

Livingston, D. M. (2000). *Space tourism and RLVs: You can't have one without the other!* Tiburon, CA: Livingston Business Solutions.

Lo, R. E., & Paatsch, A. (1998). *Ermittlung der durch den Weltraumtourismus verursachten Emissionen* [Determination of emissions caused by space tourism] (unpublished report). IRTS, Berlin, Germany.

Lo, R. E., & Paatsch, A. (1999). *Raumfahrtinduzierte Belastungen der Atmosphäre unter besonderer Berücksichtigung des Weltraumtourismus: Berechnung des quasistationären Anfangszustandes der Abgaswolke entlang der Aufstiegsbahn von Raketen* [Launcher induced impact of the atmosphere with special emphasis on space tourism: Calculation of the quasi-steady state at the beginning of the plume along the ascent path of launchers] (unpublished report). IRTS, Berlin, Germany.

Lorance, R. B., & Wendling, R. V. (2001). Basic techniques for analyzing and presentation of cost risk analysis. *Cost Engineering Journal*, *43*(6), 25–31.

Mars Daily. (2013, May 11). *More than 78,000 people apply for one-way trip to Mars*. Author. Retrieved from http://www.marsdaily.com/reports/More_than_78000_people_apply_for_one-way_trip_to_Mars_999.html

Messier, D. (2013, February 12). *Spaceports, spaceports, everywhere a spaceport (but very little to launch)* [Web log post]. Parabolic Arc. Retrieved from http://www.parabolicarc.com/2013/02/12/spaceports-spaceports-everywhere-a-spaceport-but-very-little-to-launch

Moore, P. G. (1983). The business of risk. Cambridge, UK: Cambridge University Press. doi:10.1017/CBO9780511582448

Onmeda. (2003). *Strahlenbelastung in der Raumfahrt* [Radiation exposure in space]. In Onmeda. Retrieved July 6, 2013, from http://www.onmeda.de/lexika/strahlenmedizin/strahlenbelastung_raumfahrt.html

Pompidou, A. (2000). *The ethics of space policy*. UNESCO. Retrieved from http://www.unesco.org

Roberts, L. D. (1996). Space business incentives: It's time to act. *Ad Astra (Washington, D.C.)*, *8*(2), 38–39.

Sameh, S. M. M. (2013). *Suborbital flights: Selected legal issues* (Master's Thesis). Institute of Air and Space Law, McGill University, Montreal, Canada.

Schiller, C. (2013). *Motion mountain, Volume 5: The adventure of physics - pleasure, technology and stars* (25th ed.). Retrieved from http://motionmountain.net

Simberg, R. (2000). *Near-term prospects for space tourism*. Jackson Hole, WY: Interglobal Space Lines. Retrieved from http://www.spacefuture.com/archive/near_term_prospects_for_space_tourism.shtml

Space Adventures. (2013). *Orbital spaceflight*. Retrieved March 3, 2013, from http://www.spaceadventures.com/index.cfm?fuseaction=orbital.Clients

Space Policy Institute. (2002). *Space tourism initiative*. Retrieved November 14, 2002, from http://www.gwu.edu/~spctour/biblio.html (no longer available)

Tascione, T. F. (1988). *Introduction to the space environment*. Malabar, FL: Orbit Book Company.

Torikai, T., Yonemoto, K., Osamu, K., Akira, M., Kazutaka, I., Shunichi, O., & Kondo, S. (1999, October). *A draft of safety standard for designing space tour vehicles*. IAA-99-IAA.1.3.04. Paper presented at the 50th International Astronautical Congress, Amsterdam, The Netherlands. Retrieved from http://www.spacefuture.com/archive/a_draft_of_safety_standards_for_designing_space_tourism_vehicles.shtml

USA Today. (2004, March 5). *House bill sets guidelines for space tourism*. Author. Retrieved from http://usatoday30.usatoday.com/travel/news/2004-03-05-space-tourism_x.htm

Wollersheim, M. (1999, April). *Considerations towards the legal framework of space tourism*. Paper presented at the 2nd International Symposium on Space Tourism, Bremen, Germany. Retrieved from http://www.spacefuture.com/archive/considerations_towards_the_legal_framework_of_space_tourism.shtml

Ziliotte, V. (2010). Relevance of the futron/zogby survey conclusions to the current space tourism industry. *Acta Astronautica*, *66*(11-12), 1547–1552. doi:10.1016/j.actaastro.2009.08.027