SUITABILITY OF FUTURE TRANS-ATMOSPHERIC VEHICLES FOR MASS SPACE TOURISM FLIGHTS

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Keywords: *Space Tourism, Suborbital Flight, Trans-atmospheric Vehicle*

Abstract

Operating future trans-atmospheric vehicles might be a first step to realize mass space tourism. Thus, the aim of this paper is to investigate in potential hurdles and other aspects of importance to space tourism flights by using trans-atmospheric vehicles. The primary ones are social issues (e.g. "Is space tourism acceptable concerning ethical aspects?"), institutional issues (e.g. "Is environmental pollution caused by space tourism harmful compared to other emission sources?") and financial issues (e.g. "Are there any potential investors interested in space tourism?").

1 Introduction

For past decades, interest in the possibilities of space tourism has increased among engineers, scientists, entrepreneurs and public. A continuously growing collection of papers is being published on space tourism itself and associated subjects like reusable launch vehicles, space habitats, space entertainment and the corresponding law and regulation. Market research promises sufficient interest in tourist space travel to take off and develop into a multi billion-dollar business. This is understandable, not only because of the attractiveness of being in space but also from an exclusivity point of view. In some sense it is equal to the somewhat exclusive luxury cruise ship business, which also requires huge investments. It is all about doing something unusual, similar to an adventure trip or a challenge like climbing the Mount Everest or explorations of Antarctica.

Fig. 1 shows a selection of key hurdles and opposing forces, which could be harmful for a successful establishment and enhancement of space tourism activities. These potential hurdles in commercial space travel need to be considered thoroughly, preferably before actual activation of the first regular space tourist services [1].

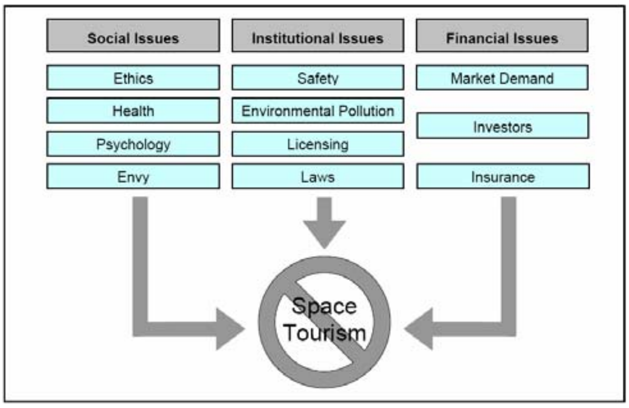

Fig. 1. Possible Hurdles for Space Tourism Development

2 Social Issues

2.1 Ethics

Apart from concerns regarding the feasibility of mass space tourism, there is also a more human ethical issue. This issue has been barely touched upon in literature. Despite the expected progress in safety and reliability of launching rockets, it will still be a risky procedure. Even small errors or faults can result in major dramatic events. The question arises, what level of risks for space travelers would be acceptable for the society.

These days, there are many adventure travelers and extreme competitive athletes climbing Earth's highest mountains as shown in Fig. 2, crossing its largest deserts, exploring the Antarctic and diving toward the darkest depths of oceans. One by one, dangerous activities with risks of death at every step are done, yet humankind hail them as highly admired heroes. Moreover, if atop of these activities there is a genuine interest for traveling to space, potential risks might be certainly no reason to abort.

Fig. 2. Mount Everest

Conquest of space might contribute to dissemination of a scientific and technical culture. It also could maintain an imaginative horizon and determination to make new discoveries, which might be driving forces of human society. There might evolve many social benefits of space travel in general and space tourism in particular. Travel does broaden the mind, would give people a better understanding of the complex world they live in, and in this case would give them a planetary conscience. In all, politicians, scientists and the public would need a fundamental change from today's views of space activities to enable mass space tourism. It is reasonable to characterize this challenge as a political, social and economical revolution.

2.2 Health

Space tourism flights would be intended for persons in generally good health and without physical disabilities. Topics relevant to medical safety and general well-being of space tourists are accelerations during take-off, reentry and landing, microgravity in space, cosmic rays and "jetlag" effect.

Loads (acceleration, noise level, mental stress) are similar to those of military aircraft flights for tourists. A maximum acceleration of 3,5 g should not be exceeded as shown in Fig. 3.

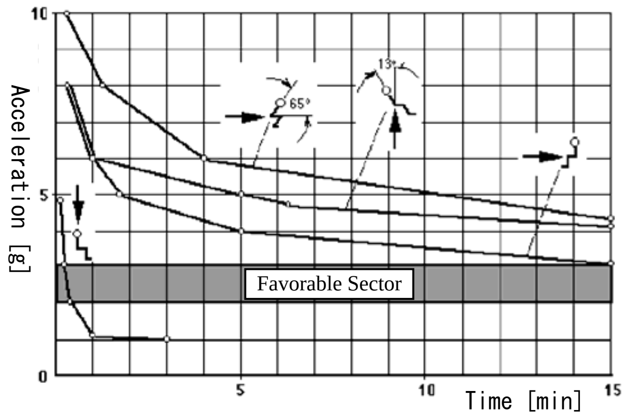

Fig. 3. Acceleration Limits for Human Body (Lo)

Sudden lack of correspondence between information received from the inner ear and visual cues caused by microgravity, provokes disorientation and discomfort and is called space motion sickness. Typical symptoms are pallor, dizziness perspiration, drowsiness, nausea and psychological stress and vary individually [2]. To protect passengers against space motion sickness, pre-flight training such as biofeedback, pre-flight prophylactic medication and in-flight medication such as Promethezyne could be used.

Along with space motion sickness, the most immediate effect of microgravity is redout, where blood rushes into the head, as opposed to away from it. Symptoms are puffy heads, "chicken legs" and an increased heart rate to compensate for changes in blood volumes and locations. After returning to normal gravity level, light-headedness and fainting can occur.

Unloading of the body in microgravity leads to decomposition of weight-bearing bones and muscles especially in legs, hips and the back. It leads to weakness upon return to normal gravity. An average of 1 % to 3 % of bone loss per month was observed on Mir space station crews [3]. Existing countermeasures consist of several hours of daily exercise on ergometers with bungee cords as shown in Fig. 4. Bone loss is one of the main hurdles for long stays in space, but space tourists spending only a day or a week in space would be not affected.

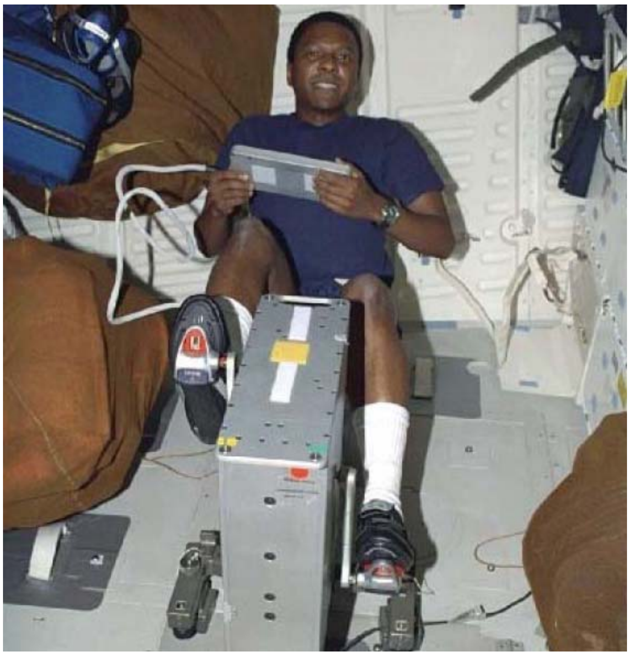

Fig. 4. Astronaut Exercising on Ergometer (NASA)

The average radiation dose to a human on Earth from soil (0,4 mSv), food (0,2-0,5 mSv) and cosmic rays (0,4-1,6 mSv) results in a total of about 1,7 mSv per year [4]. For comparison, each transatlantic flight can account for another 0,04 mSv. Space tourists on a one-day mission would receive a higher dose of about 0,3 mSv [5] but it is still negligible. Only for very long space flights, space radiation protection is needed.

Orbital flights of a duration of one day will induce disturbances of circadian rhythms, due to fast night and day cycles. Symptoms are similar to a “jetlag” after a long distance flight. Astronauts regularly use medication to assist sleep and tourists would be able to take sleeping pills if necessary.

2.3 Psychology

Besides medical standards, it would be necessary to establish psychological standards. Comfort boundaries are strongly affected by physiological issues. Initial difficulties in adapting to space could affect the tourists’ enjoyment. Therefore, a parabolic zero gravity flight should be part of pre-flight training for participants to prepare them for weightlessness. This experience before the spaceflight would help passengers to mentally adapt more quickly once in orbit. 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 preparations for the journey [6].

Overcoming claustrophobia is an area warranting additional study. Simple things such as meals and recreation can influence morale on a large scale and reduce this effect.

A special consideration should be given to religious and cultural ceremonies such as Christmas. Studies on philosophic experience indicate that residency in orbit tends to make individuals more reflective about philosophical questions, such as the meaning of man’s existence in the cosmos. Those sessions dedicated to spiritual activities would increase the intensity with which tourists would experience space [3].

2.4 Envy

Some persons within the government view space as an exclusive province of federal national security and private sector activities of any kind are considered competition and a threat to their own power base. For instance, the current astronaut corps has many members who have never flown. If capacities of government operated vehicles such as Space Shuttle are sold to civilians in lieu of astronauts who have undergone a rigorous selection and training process, it might cause disapproval outside the astronaut corps. Intensified integration of government astronauts into private space business by offering a goal-directed service for government space market in addition to private one could avoid these circumstances.

In case space tourism business would be actually supported by federal funding, some politicians might view it as a taxpayer subsidy to the wealthy who, barring lotteries or contests, would initially be the only ones who could afford space trips. Even if there is no government funding involved, there is historically such a strong linkage in the mind of the general public between government's space agencies and space, that any space tourism activity may be perceived as a waste of public funds. Therefore, economic returns, increased tax base and attractive opportunities should be promoted as byproducts of space tourism business.

3 Institutional Issues

3.1 Safety

Since space tourists are not going to be trained like professional astronauts, a familiarization with emergency procedures would be needed. While a space tourist would require more than the standard two-minute airline drill how to fasten seatbelts and use the oxygen system, an intense week of training should be sufficient to learn the basics of how to be a safe passenger. This course may include flight training, medical training and emergency procedures.

However, it will be more difficult to make vehicles themselves safer. There are two approaches: the first option is to reduce catastrophic failures by redundancy and over-designing of subsystems, improved maintenance by using an extensive health monitoring system and to improve operations with many soft abort sequences. The second option is to protect passengers, if a catastrophic failure has occurred, by using safety equipment for passengers and crew such as space suits, ejector seats, emergency shelters, etc.

Both options would result in an increased vehicle empty weight and therefore a reduced number of passengers. For vehicles with a large passenger capacity, option one might be more suitable (rescuing the vehicle with passengers as a whole), while for those vehicles with low passenger capacity, option two might be more suitable (rescuing only passengers). A higher safety standard would result in lower economic performance due to less profit resulting in higher cost. A lower safety standard results also in lower economic performance because the higher risk would be unattractive for passengers and ethically unacceptable resulting in lower demand. More research is needed to find out what is the "right" safety standard for space tourism vehicles.

3.2 Environmental Pollution

Any chemical propulsion launch system leaves traces of emissions in the atmosphere. Because much more energy is necessary to transport a passenger to suborbit or orbit compared to any other place on Earth by aircraft, there would also be more pollutants generated. For example, Kankoh Maru Plus as shown in Fig. 5, which is a Japanese Reusable Launch Vehicle concept, would need 71 Mg liquid hydrogen as fuel to transport 50 passengers to LEO and back to Earth. Thus, each passenger needs 1,4 Mg liquid hydrogen, which is equivalent to an energy of 202 GJ (Giga Joule). A Boeing B747-400 needs about 150 Mg kerosene as fuel to transport 400 passengers one-way from one continent to another. Thus, each passenger needs 0,4 Mg kerosene, which is equivalent to an energy of 17 GJ. However, from a global scale of view, the cumulative energy consumption of space tourism would be relatively small compared to today's annual 1500 million air passengers with expected future annual 0,1 million space passengers. This example is just intended for illustration of basic numbers and real relations have been simplified.

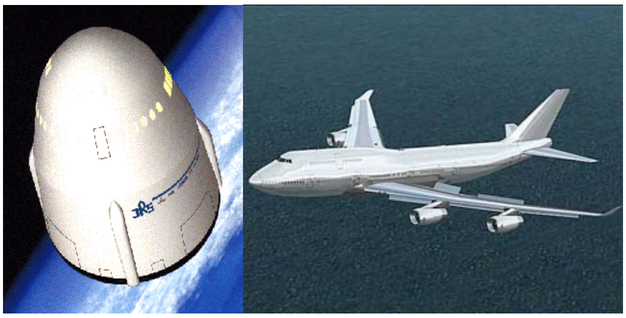

Fig. 5. Kankoh Maru Plus and B747-400 (Kawasaki, Rafi)

Table 1 shows a comparison of space transport (excluding the space tourism sector) with other anthropogenic as well as natural pollution sources estimated for 2065 [7]. It seems that space transport emissions are negligible on a global scale, even if the launch rate would increase by a factor of 100 caused by space tourism. Extensive studies have been investigated on emissions caused by space transport (including space tourism) and air transport in a period from 2010 to 2065 for a scenario with up to 200 000 space passengers per year. It shows that space tourism would only cause between 0,006 % to 1,5 % of total emissions caused by air transportation [8,9].

Table 1. Estimated Emissions for 2065 (modified from: Adirim, Lo, Paatsch, 1999) Unit: Mg/year

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	> 1070	n.a.	> 5
	Burning of Fossil Fuel	8300	n.a.	20 350	2	n.a.
	Others	n.a.	1490	n.a.	n.a.	85
Nat-ural	Volcanoes	n.a.	n.a.	n.a.	5	n.a.
	Oceans	525 000	n.a.	n.a.	330	n.a.

However, from a local scale of view, in altitudes above airline traffic, space vehicles are the only mayor emitters. These emissions along the trajectory in the sensitive upper atmosphere are not negligible; neither is the local pollution at spaceports. It is recommended that operators should be obliged to pay a “keep space clean” fee, depending on the amount of emissions. Unfortunately, effects of some types of emissions especially in the upper atmosphere are not well understood. Therefore, ecologically adapted flight profiles cannot be considered, unless emission penalties are quantitatively formulated by atmospheric chemists.

Any additional source of pollution such as space tourism transportation should not and cannot be excused by the pre-existence of other pollution sources. This matter is currently not discussed by developers and organizations promoting space tourism flights. However, this is a very sensitive and politically charged issue. Presenting this topic in a wrong manner could possibly lead to a strong rejection of tourist spaceflights.

3.3 Licensing

Developing vehicles needed for space tourism is an engineering challenge (low-cost operating procedures, high reliability, safe abort capability at any time, vehicle performance, etc.), but it is also an institutional one (applicable laws and regulations). Currently, there is a deep gap between rocket and aircraft design philosophy, which is illustrated in Fig. 6: the mission success of a rocket launch can be merely estimated by a reliability calculation. Thus, the probability of loss is a figure of the failure rate. This means that the rocket is launched by probabilistic operation for launch success. In contrast, airworthiness requires safe operation even for the case that some subsystems or components of an airplane get out of order during operation. It can be said that aircraft aims at a deterministic operation for safe flights.

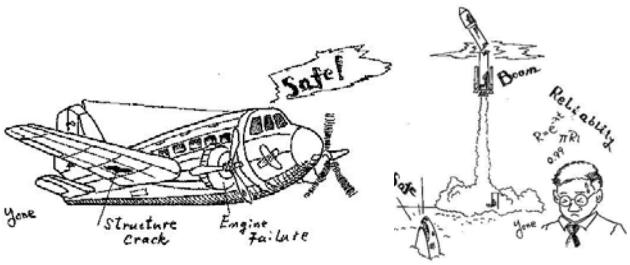

Fig. 6. Deterministic versus Probabilistic Operation

Therefore, the safety standard required for certification of space transportation vehicles should not only restrict their design, but should change the fundamental operation process from probabilistic launch to deterministic take-off and landing with enough safety, like aircraft. The existing regulatory and legal environment needs to be reformed to allow for the promotion of commercial passenger flights to and from space. Solving these hurdles is essential in order to allow developers and operating companies to raise the necessary investment from investors. Investors themselves want to understand and control their capital risk, which is only possible in a regulatory market environment. The absence of regulations may make investors afraid that any unknown future regulation may kill the business they are investing in. The following points should be considered:

- Systems will be needed for training, testing and licensing of pilots, cabin staff and maintenance staff.
- The Federal Aviation Administration (FAA) needs to extend their air traffic control system to include suborbital and orbital surveillance. The FAA is a US governmental institution in charge of regulating and overseeing the aviation industry in the USA.
- Need of certification regulations for passenger RLVs taking into account vehicle structural integrity and damage tolerance, fire suppression systems, noise-levels, evacuation standards, pollution levels and maintenance procedures.
- Passenger travel services in space need insurance similar to that, which was imposed as a part of the Warsaw Convention for air travel. However, in its early stages, the small scale of the space travel industry and the limited statistical base will not be sufficient to permit an insurance calculation with high confidence. As a result, insurance cost will be high.

For redundancy and safety design requirements and structural verification procedures, the civil aviation model provides a good guideline. Primarily, it is the responsibility of governments to negotiate and ratify such agreements in time to be effective and thus in preventing major accidents or international conflicts. However, regulations mean also a barrier for space tourism. A major issue is how to handle the classification of suborbital and orbital vehicles. Passenger aircraft must go through a certification process, which is handled by the FAA, before they are allowed to carry fare-paying passengers or cargo. More than 1000 test flights are typically needed to gather enough statistical data. The process may run for over 3 years. If the space tourism industry would have to go through the same procedure it would mean great economic difficulties, which would probably put a stop to any start-up company before it even got off the ground.

In March 2004, the House passage of legislation set guidelines for the future space tourism industry. The House bill gives regulatory authority over human flight to the Federal Aviation Administration's Office of Commercial Space Transportation. To make it easier to test new types of reusable suborbital rockets, this bill gives the FAA office the authority to issue experimental permits that can be obtained more quickly and with less bureaucracy than licenses [10]. This approach might be a major step in the further development of commercial human space flight.

In parallel with the US Government, private groups have also started to study the regulatory system of the aviation industry as an appropriate model for the passenger space travel industry. For instance, the Japanese Rocket Society (JRS) Transportation Research Committee in 1997 studied the requirements needed for the certification of “Kankoh-Maru” to enable passenger carrying [11]. The Universal Space Clipper Company divided in a study the requirements for passenger space vehicles into categories: type design certificate, production certificate, airworthiness certificate, commercial operator’s license, spaceport license and other approvals, such as component manufacturing and maintenance [12].

3.4 Laws

Laws already exist to regulate private sector space endeavors such as satellite launches. The major space laws treaties are:

- **Outer Space Treaty (1969)**
  The Outer Space Treaty stipulates the principle of "exploration and use of outer space". It can be considered as the backbone of international space law. However, liability of the launching state for damages caused by a space object is not clear. 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 Warsaw Convention (1929) provides guidelines regarding monetary compensation. This convention is an international private law treaty and has helped to establish international air travel, by limiting airlines' liability for damages in the event of injuries to passengers or loss of baggage [11]. Nonetheless, the Warsaw Convention is an encouraging precedent for the legal innovation needed to make space activities commercially feasible and it has been proposed that a space law agreement should be based on this Convention [13].

- **Rescue Agreement (1968)**
  The Agreement does not include passengers so space-tourists may not fall into the scope of the agreement and therefore may not take advantage of the rules stipulated there. On the other hand it would be a wrongful interpretation to assume the exclusion of passengers, just because they are not mentioned. This gap stems from the time-period in which the Rescue Agreement was created, when a touristic participation was not even considered [14].

- **Liability Convention (1972)**
  Article II provides the launching state's absolute liability for compensation of damage on the surface of the Earth or to aircraft in flight. Accordingly, states have the right to refuse private enterprises to practice space tourism. A gap of the Convention is that "nationals of the launching states are excluded from the scope of the Liability Convention" [14].

- **Registration Convention (1976)**
  The Registration Convention has on one hand the function to coordinate launches, and on the other hand to ensure identification of the launching state in respect of the Liability Convention. Private enterprises need to comply with the registration procedure. The addition of private registrations will greatly increase with space tourism [14].

- **Moon Agreement (1979)**
  According to the Moon Agreement, celestial bodies and their resources shall not be subject to sovereignty claims. The Moon Agreement refers to the surface, which could be interpreted in such manner, that buildings or facilities on the Moon's surface remain national property and consequently underfall national sovereignty. Lunar bases are subject to state jurisdiction and are legally treated as space objects. The Moon Agreement does not have a high practical relevance, because the agreement does not prevent states other than the contracting states from claiming national sovereignty for the respective celestial body [14]. This is relevant to space tourist projects such as a lunar hotel.

Space tourism is a new institutional challenge, because of its yet uncharted territory. There is no legal jurisdiction for regulating commercial human spaceflight. It is likely that analogies will be made to laws applicable to air transportation. However, it will require an extensive innovation in applicable regulations in both national and international law. For example, the question arises who would have jurisdiction if an international passenger on a space tourism flight commits a crime against another international tourist. In case for the International Space Station, the International Governmental Agreement states that criminal jurisdiction should remain to the state of nationality of the "alleged perpetrator" of a crime, provided that the state is an ISS partner state.

Law policy is a fundamental component in space commercial development through space tourism. Economic activity in space must be accompanied by the simultaneous implementation of a law framework in which these activities are going to take place. However, only elementary steps toward this direction have been undertaken. Law policy must be developed by an international organization and gain appropriate endorsement from every state. It is unacceptable to have legal regulation without binding compliance from space-faring nations [15].

4 Financial Issues

4.1 Market Demand

Space tourism market surveys have been performed in Japan, Germany, United Kingdom, USA and Canada [16]. The first market investigation was conducted by the National Aerospace Laboratory (NAL) in Japan in 1993. It surveyed 3030 Japanese across all age groups and revealed a significant desire to visit space; more than 70 % of those under 60 years old and more than 80 % of those under 40 years old said that they would like to visit space at least one time. In addition, they stated that they were prepared to pay three months salary for such a trip. The study showed, as shown in Fig. 7 that 3 % of the people interviewed were willing to pay three years salary for a trip to space, 11 % were willing to pay one years salary, 18 % would pay 6 months salary and 46 % would pay three months salary [17].

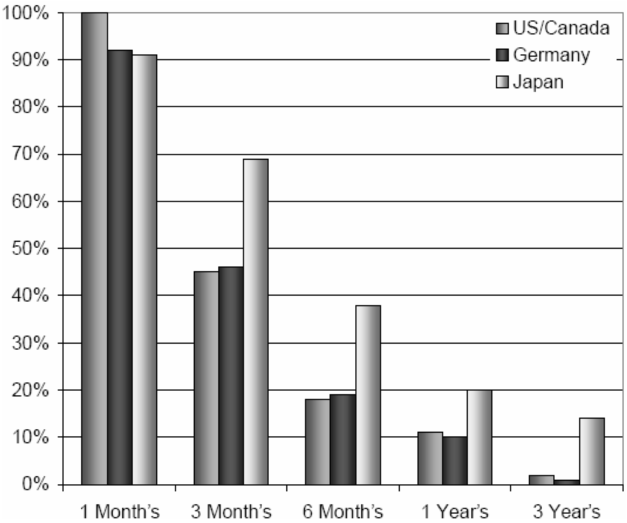

Fig. 7. Comparison of the Amount Tourists would pay to go to Space (Collins et al.)

However, in the early pioneer phase it is difficult to forecast the demand/price elasticity correctly because of the following two facts: Firstly, the passengers will be mostly multimillionaires for whom prestige and political causes determine the demand, rather than the ticket price itself. Secondly, there is a difference between saying "I would like to make a trip into space" and the actual payment for a ticket.

4.2 Investors

By far the hardest obstacle to any new rocket venture is its being properly financed. Although there is quite a number of start-ups which try to enter the rocket market, only a small fraction of their overall funding requirements were actually supplied by the world's financial markets. Since space tourism is a completely new industry, no data whatsoever on previous experiences are available. The only data available are a few space tourism surveys that have been conducted. No one knows exactly how large the market will be and no reusable rockets today have yet passed safety standards needed to be able to carry passengers. This makes the space tourism industry prospects very speculative. Investors become hesitant, especially considering large amount of funds needed to develop a completely new vehicle.

Unless a company is very committed to investing in space tourism, RLV opportunities will most likely have to show that their projected profits must be sufficiently higher than terrestrial alternatives to compensate for the added risk. Generally, venture capitalists are concerned about the lack of management experience in new space ventures [18].

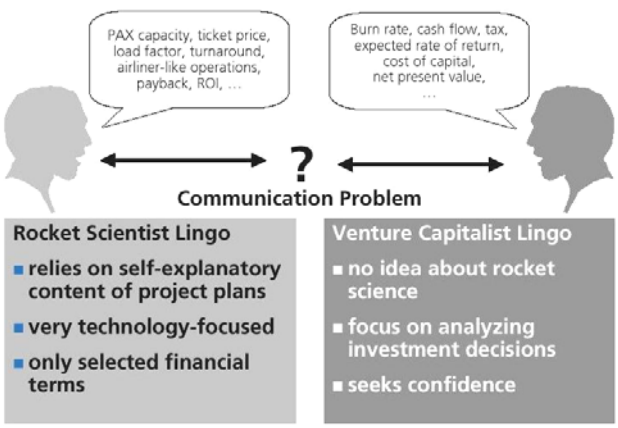

Fig. 8. Communication Problem (TIM Consulting)

There seems to be plenty of room for misunderstandings between rocket scientists and finance people as illustrated in Fig. 8. To a rocket scientist “burning rate” means something totally different from what “burn rate” means to a venture capitalist. Therefore, most commercial rocket ventures have failed to catch the attention of venture capitalists. A professional business approach is needed to make the case for non-space business and finance communities.

4.3 Insurance

Space tourism is a new venture and until it reaches a mature level of development, insurance is going to be a major issue. Both passengers traveling in space and the related equipment and facilities will need insurance. However, the likely small scale of the space travel industry will be insufficient to enable accurate calculation of insurance cost. Accordingly, for tourism to become a vital part of the commercial space equation, limits on the liability of owners and operators of space facilities and vehicles will become necessary [11].

In the case of commercial space launch companies, there exist a law under which these companies are required to carry liability insurance, capped at $500 million, with assurances that the government will compensate for losses above that [10].

5 Conclusion

There is currently no overall framework to deal with hurdles and other aspects influencing space tourism as discussed in this chapter. For mass space tourism to become a reality, it is important to develop such a framework, which needs to be accepted internationally. It should consist of at least ethical, health, psychological, safety, environmental, regulatory, laws, investors and insurance components.

5.1 Social Issues

- An ethical framework is needed to reflect motivations and consequences of public space travel. Ethics might fundamentally influence the development of future space tourism activities.

- A health framework is necessary. Early space tourists such as Dennis Tito were most likely well prepared ensuring a good level of health and tolerance. In case of mass space tourism, physical and psychological comfort for the average healthy person as well as for very young or elderly persons has to be ensured.

- A psychological framework is recommended. Persons with a prior history of personality disorders, claustrophobia and suicide attempts will have to be excluded.

- Envy cannot be put in a framework. It will depend very much on the way space tourism activities are reported in the media.

5.2 Institutional Issues

- The development of a space tourism market might be most sensitive to a safety framework. Much investigation is needed to find a balance between demanded safety standards for vehicles and the possibility to fulfill these requests by developers and operators using the available technology. Too high safety standards would mean a showstopper for space tourism because it is not technically and economically feasible. However, too low safety standards would mean a showstopper for space tourism too, because ethical aspects render it unfeasible.

- An environmental framework is necessary, similar to the one realized for aviation operations. In particular, issues relating to local spaceport emissions and noise pollution, space debris pollution and global emission pollutions must be addressed.

- Commercial space activities will require a regulatory framework as any commercial endeavor. Major issues to be resolved for space tourism include the training of passengers and crew, the certification of vehicles and launch facilities and the licensing of space operators.

- Legal framework for space tourism activities is not clearly defined in several fields. In particular, issues relating to jurisdiction, space traffic management and liability must be addressed.

5.3 Financial Issues

- Accurate and accepted market demand research is needed to fulfill the financial requirements of investors as well as the expected flight program outline from the passengers.
- A financial framework is needed for investors to reduce their risk. This could be realized through the development of an independent consultant agency.
- The topic of insurance as it pertains to space tourism has not been well documented and merits further critical review, because it is a major aspect to reduce financial risk.

Acknowledgment

The publication of this paper was funded by Japan Society for the Promotion of Science and Alexander von Humboldt Foundation, which is gratefully acknowledged by the author.

References

[1] Goehlich, R.A. *A Representative Program Model for Developing Space Tourism*, ISBN 3-936846-29-4, Wissenschaftlicher Verlag Berlin, Germany, 2003.

[2] ISU. *Space Tourism: A Literature Review*. ISU MSS, Strasbourg, France, 2001.

[3] ISU. *Space Tourism: from dream to reality*. ISU SSP, Chile, 2000.

[4] Tascione, T. *Introduction to the Space Environment*. Orbit Book Company, Malabar, USA, 1988.

[5] A Med-World AG. *Strahlenbelastung in der Raumfahrt*. http://www.m-ww.de/enzyklopaedie/strahlenmedizin/strahlenbelastung_raumfahrt.html, Berlin, Germany, accessed 05/14/2003.

[6] Abitzsch, S. *Prospects of Space Tourism*. presented at the 9th European Aerospace Congress, Berlin, Germany, 1996.

[7] Adirim, H., Lo, R., Paatsch, A. *Next Generation High Performance Low Pollution Launchers: Problems and Solutions*. presented at the 50th International Astronautical Congress, IAA-99-IAA.3.3.01, Amsterdam, The Netherlands, 1999.

[8] Lo, R., Paatsch, A. *Ermittlung der durch den Weltraumtourismus verursachten Emissionen*. IRTS, Berlin, Germany, 1998.

[9] Lo, R., Paatsch, A. *Raumfahrtinduzierte Belastungen der Atmosphäre unter besonderer Berücksichtigung des Weltraumtourismus: Berechnung des quasistationären Anfangszustandes der Abgaswolke entlang der Aufstiegsbahn von Raketen*. IRTS, Berlin, Germany, 1999.

[10] *House Passes Legislation Setting Space Tourism Guidelines.* http://www.space.com/news/tourism_congress_040305.html, New York, USA, accessed 03/05/2004.

[11] Collins, P., Yonemoto, K. *Legal and Regulatory Issues for Passenger Space Travel.* http://www.spacefuture.com/archive/legal_and_regulatory_issues_for_passenger_space_travel.shtml, presented at the 49th IAF Congress, Melbourne, Australia, 1998.

[12] Gaubatz, W. *Reusable Space Transportation – The Key Infrastructure Elements in Opening the Space Frontier to the Public*. 98-0-1-01v, http://www.spacefuture.com/archive/reusable_space_transportation_the_key_infrastructure_element.shtml, presented at the 21st ISTS, Sonic City, Japan, 1998.

[13] Roberts, L. *Space Business Incentives: It's Time to Act.* Ad Astra, Vol. 8, No. 2, 1996.

[14] Wollersheim, M. *Considerations towards the Legal Framework of Space Tourism.* http://www.spacefuture.com/archive/considerations_towards_the_legal_framework_of_space_tourism.shtml, 2nd International Symposium on Space Tourism, Bremen, Germany, 1999.

[15] Hudgins, E. L. *Space Policy and Space Tourism.* http://www.cato.org/testimony/ct-eh062601.html, CATO Institute, Washington D.C., USA, accessed 03/31/2004.

[16] Geoffrey, I. C. *Researching the Space Tourism Market.* http://www.spacefuture.com/archive/researching_the_space_tourism_market.shtml, presented at the Annual Conference of the Travel and Tourism Research Association, 2001.

[17] Collins, Stockmans, Maita. *Demand for Space Tourism in America and Japan and its Implications for Future Space Activities.* http://www.spacefuture.com/archive/demand_for_space_tourism_in_america_and_japan.shtml, Tokyo, Japan, accessed 04/01/2004.

[18] Livingston, D.M. *Space Tourism and RLVs: You can't have one without the other!* Livingston Business Solutions, Tiburon, USA, 2000.