SPACE TOURISM IN INDIA

A REPORT OF AN INTERDISCIPLINARY RESEARCH STUDY BY THE UNIVERSITY OF PETROLEUM AND ENERGY STUDIES, DEHRADUN, INDIA

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The contents of this Study Report neither represent the personal views or opinions of the external advisors-reviewers and the Project Director, nor of the organizations with which they are associated or affiliated. The University of Petroleum andEnergy Studies, Dehra Dun, India, and the members of the Research Team from this University remain ultimately, individually, jointly and exclusively responsible for the propriety of any material used (or abused, as the case may be) in this Report.

RAM S. JAKHU
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Executive Summary

This project, the first of its kind in India, consists of a Study about the potential, and possible operation, of a space tourism industry in India. It has been carried out from an interdisciplinary perspective covering the business, technical, legal and regulatory aspects of this newly emerging industry. This Report is thus a preliminary appraisal of the technological, infrastructural, financial, marketing, safety, and legal requirements for the establishment of a space tourism industry in India. Focusing on the transportation of tourists to and from space, the Report analyzes the conditions that should be put in place in order to foster and sustain the establishment and development of this industry in India. It commences with an overview of the current status of global space tourism and, as part of it, significant and important terms which lie at the foundation of the Study are defined and set out. The Report then records and analyzes data obtained from a survey conducted as part of the Study to determine whether there is a potential market for space tourism in India. The survey provides the basis for a number of important forecasts made in the Report. Of particular significance in this regard are the demand, cost and revenue forecasts for both suborbital and orbital space tourism in India extending to the year 2030. It is important to note that the figures in the Study Report are mere forecasts and projections and should not be regarded as accurate estimates. Following the survey, the Study assesses the facilities, infrastructure and human resources required for a successful launch of the space tourism industry in India. The two Chapters that follow address safety, liability and insurance concerns in connection with space tourism in India on the one hand, and regulatory/compliance concerns on the other. In this regard, the Report describes the existing challenges under each sub-heading and discusses possible options for overcoming them. Since space tourism is seen as a futuristic concept by a great majority of people, the Report attempts to identify and address both present and future challenges associated with it. Thus, the Report contains a broad assessment of the feasibility of space tourism in India from the perspective of cost, technological development, and the possibility of growth. The conclusions of the Study are synthesized into a series of recommendations aimed at instigating policymakers, stakeholders in the aerospace industry as well as the general public in India to start thinking critically about the potential role of space tourism in generating employment in, and enhancing the global credibility of, India as a major space-faring and advanced nation.

Preface/Acknowledgements

Can the space tourism industry be viable in India? This Study Report attempts to answer this question by: conducting an analysis of the business potential of space tourism; forecasting the expected revenue; estimating the investment costs for developing space tourism; and analyzing its financial implications. The fact that space travel for purposes of tourism has not been established in India is due mostly to the high cost of manned spaceflights (in both monetary and safety terms) and the lack of versatile space transportation facilities. Once space tourism becomes safe and affordable to the general public, space tourism activities, especially those involving manned space programs, will develop and increase in a manner which may exceed present day imaginations. In this Report, we have analyzed various impediments to the development of the space tourism industry in India taking economic, legal and policy considerations into account.

This Study Report is the result of the cooperative efforts of several students and faculty members from the University of Petroleum and Energy Studies (UPES), Dehra Dun, India, carried out under my direction and supervision (See the list of Team Members). As the Project Director, it has been a great pleasure to work with them all and I wish to express my appreciation to them for their hard work and cooperation. I also wish to express special thanks to: Dr. Parag Diwan for his mentorship and encouragement; to Prof. Dr. K.C. Gandhi for his superb coordination of the Research Team at UPES and the collection of materials; to Mr. Mukesh Pandey for his tireless efforts in putting together the first consolidated draft of the Study Report and splendid work in revising it; and to Mr. Yaw Nyampong for his outstanding editing of the entire Study Report.

I particularly acknowledge the immense contribution made by the external advisors-reviewers, comprising a hand-picked team of international experts in space tourism related matters, who helped the Research Team in the execution of the project and carefully reviewed the draft Study Report. A caveat must be sounded at this juncture. In spite of the various contributions made by the external advisors-reviewers and myself towards the completion of this Study Report, it should be noted that the UPES and the members of the UPES Research Team remain ultimately responsible for the propriety of any material used (or abused, as the case may be) in this Report.

The contents of this Study Report were developed with the intention of initiating discussion and further elaborated analytical studies of each of the subjects dealt with herein. They do not represent the personal views or opinions of the external advisors-reviewers and myself. Neither do they represent the views of the organizations with which they are individually associated or affiliated.

RAM S. JAKHU
Project Director
10 July 2010

Foreword

"Space tourism is a fledgling industry, born out of necessity, yet driven by the same curiosity and ambition that took humanity to the Moon; it appears to be here to stay".

– http://www.space.com/spacetourism/

Countries like the U.S., Russia and Japan have already started work aimed at establishing habitats on the planet Mars by the year 2030, and are devising various transportation systems in order to reach Mars. Private companies from these countries are vying to become leaders in the global space tourism industry. Virgin Galactic for instance has already made its maiden attempt by successfully deploying SpaceShipOne. A few wealthy individuals have flown into outer space as space tourists.

Having missed the opportunities presented by the first industrial revolution, India continues to remain a developing country. The next industrial revolution seems to be taking root now as developed countries race towards the Moon and Mars. India has the opportunity now to join this exclusive club of nations to possibly establish colonies and eventually industries on the Moon and Mars.

In the last twenty five years, Indian space and missile technologies have matured and as a result, the nation now possesses a tremendous integrated potential for developing new world class systems. India's space programmes have achieved several successful missions and accomplishments. Today, the country is self-reliant in space technology as recently demonstrated by the "Chandrayaan" programme – encompassing the successful development from scratch and testing of a launch vehicle at a cost which is below the cost of developing a passenger jet aircraft. With this unprecedented strength in integrated technology, India is presently in a position to advance further and embark upon new missions. With its immense competitive advantages, particularly in the space sector, India needs to move from the old era of technology demonstration to the modern era of commercialisation by exploring new strategies and technologies for human spaceflight programmes and low-cost access to space. Space tourism is one such area where India can play a niche role with its affordable yet reliable solutions.

In keeping with the foregoing, the Centre for Aviation Studies of the University of Petroleum and Energy Studies, Dehra Dun, India, with the extensive support and superb direction of Prof. Ram S. Jakhu of the Institute of Air & Space Law, McGill University, Montreal, Canada, has conducted this interdisciplinary Study in order to assess the feasibility of launching the space tourism industry in India.

This is the first such Study in India in which a team of Research Assistants and Teachers from the fields of Management, Law and Aerospace Engineering have collaborated and brought their respective interdisciplinary perspectives to bear on an emerging area of commercial endeavour. It is hoped that the Study Report will instigate critical thinking and also serve as a basis for carrying out further research in this field.

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Definitions and Acronyms

- **SUBORBITAL:** A spaceflight in which the spacecraft reaches space, but its trajectory intersects the atmosphere or surface of the gravitating body from which it was launched, so that it does not complete one orbital revolution
- **LOW EARTH ORBIT (LEO):** An orbit within the locus extending from the Earth's surface up to an altitude of 2,000 km.
- **ORBITAL:** A spaceflight in which a spacecraft is placed on a trajectory where it could remain in space for at least one orbital revolution
- **TRANS ORBITAL:** This term is generally associated with the orbit far away from the Earth's orbit
- **ISS**: International Space Station
- **HNIs:** High Net worth Individuals
- **CSLAA:** Commercial Space Launch Amendments Act of 2004 (U.S.A.)
- **EASA:** European Aviation Safety Agency
- **FAA:** Federal Aviation Administration of the United States
- **GDP:** Gross Domestic Product
- **HTHL:** Horizontal Takeoff, Horizontal Landing
- **ICAO:** International Civil Aviation Organization
- **SS1/SS2:** SpaceShipOne / SpaceShipTwo
- **ROI:** Return on Investment
- **VTVL:** Vertical Takeoff Vertical Landing
- **RLV:** Reusable launch vehicle
- **NPV:** Net Present Value
- **IRR:** Internal Rate of Return
- **SFP:** Spaceflight Participants
- **ECLSS:** Environmental Control and Life Support System

CHAPTER

1 Overview

1.1 NEED FOR AND SIGNIFICANCE OF THIS STUDY

Irrespective of the recent financial crisis that has afflicted countries around the world, the fact remains that the world economy has grown during the past decade and so is the case of India's economy. In several countries around the world, significant developments have already taken place in the area of space tourism. It is believed that as countries emerge from the financial crisis, there will be a boom in economic and technological development, which in turn, might also generate immense interest in space tourism in India. With the current availability of moderate to high levels of income surpluses in India, and with the rapidly increasing middle and upper classes of the general populace, it is expected that a new space tourism industry (or a sub-sector of the existing adventure travel industry) will evolve. In this new era of travel, adventure seekers and travellers can look forward to the possibility of enjoying the thrill and adventure of the high ground and microgravity environment of outer space. It is therefore timely to objectively determine the required investment, market, infrastructure and regulatory regimes needed to facilitate the evolution and establishment of this rather fascinating industry in India

1.2 MISSION STATEMENT

The purpose of this Study Report is encapsulated in the following mission statement: 'Identification and brief discussion of business, technical, regulatory and policy issues with respect to the potential for, and possible operation of, the space tourism industry in India.'

1.3 SCOPE OF THE STUDY

Space tourism involves travel adventures into, and the experience of weightlessness in, outer space where there is almost no gravitational pull of the Earth and space. Over the last few years, a lot of productive work has been done in this field, yet the concept of transporting passengers into space primarily for tourism still sounds futuristic. This notwithstanding, there are clear and positive indications that a space tourism industry is emerging in the world. The important segments/elements of the space tourism industry are the passengers (market), the infrastructure and manufacturers (facilities), and the space travel service operators and agencies (service providers). Each of these constituent elements is significantly influenced by secondary factors/requirements such as organization, financing, legal and policy matters, etc. The scope of this Study is to explore and discuss these factors that may facilitate or hinder the establishment and operation of the space tourism industry in India, using an interdisciplinary collaborative methodology. Before we proceed any further, it is necessary to describe what the term "Space Tourism" is all about.

1.4 WHAT IS SPACE TOURISM?

Space tourism encapsulates the notion that human passengers will have the opportunity to travel beyond the Earth's atmosphere and experience orbital flights, prolonged stays in rotating space hotels, and as well participate in research, entertainment and even sports while in outer space. At the outset, it is important to emphasize that this conception of space tourism necessitates a paradigm shift in how space is perceived. Beyond considering space as a medium of flight akin to the air space (and thus constituting the journey), the concept of space tourism requires that space be seen also as the destination of the journey. The first terrestrial vehicle penetrated the orbit surrounding the Earth in 1957. Since then, the exploration and use of space has remained largely within the domain of national governments and professional astronauts. Over the course of human history, there has always been a strong desire to explore and travel to new and exciting places. Space exploration has captured the imagination of the general public for the last 50 years; it is only natural that members of the general public are beginning now to ask if and when they too might venture into space. In order to gain a practical understanding of the term "Space Tourism", it is essential to split the term into its two components: *space* and *tourism*, and each one of them explored separately.

1.4.1 Space

Space has been defined in many dictionaries as:

- "A boundless three-dimensional extent in which objects and events occur and has relative position and direction." (Merriam-Webster dictionary)
- "The infinite extension of the three-dimensional region in which all matter exists." (Free dictionary.com)
- "The empty area outside the Earth's atmosphere, where the planets and the stars are." (Cambridge Dictionaries).

The word "space" invigorates in any curious individual enthusiasm towards the darkness of the universe. In other words, curiosity gets the better of us humans when we consider the extent and composition of space and one literally tries to see the light beyond this darkness. Although it is said that curiosity kills, it is the same curiosity that drove mankind to reach the heights it has attained so far. Space exploration, aerodynamics, technology, communication, satellites, orbits and the list goes on-and-on are all attributable to human curiosity and enthusiasm for aviation and space exploration and use.

Space is a term that can refer to various phenomena in science, mathematics, and communications. In astronomy and cosmology, space is the vast three-dimensional region that begins from where the Earth's atmosphere ends. Space is usually thought to begin at the lowest altitude at which satellites can maintain orbits for a reasonable time without falling into the Earth's atmosphere. This is approximately 60 miles (about 100 kilometres) above the surface of the Earth. Although the frontier between the atmosphere and space is not officially defined, it is generally accepted that for all practical purposes space begins at an altitude of about 100 km from the surface of the Earth.

1.4.2 Tourism

Tourism derives from the word "tour" which means a journey in a circuit. The operative word in that definition is "circuit" and it signifies a return journey to the point of origin. The United Nations World Tourism Organization (UNWTO) defines tourists as people who "travel to and stay in places outside their usual environment for more than twenty-four (24) hours and not more than one consecutive year for leisure, business and other purposes not related to the exercise of an activity remunerated from within the place visited”.[1]

Tourism has become a popular global leisure activity. According to the UNWTO, international tourism has been expanding annually at a rate of 6.5% (from 25 million tourists in 1950 to 806 million in 2005), contributing about US$ 680 billion to the world economy in 2005 alone. Moreover, it has been reported that in 2009, international tourism generated an amount of US$ 852 billion in revenue and it is expected that by 2020, the number of international tourists will surpass 1.5 billion.[2]

In India, the adventure travel industry has only recently emerged as an important sub-sector of the local ‘travel & tourism industry’. Forecasts suggest that this is likely to represent 0.2% of the overall aggregate revenue of the industry. A Demand Note for 2010-2011 presented by the Ministry of Tourism to the Ministry of Finance emphasises the Indian government’s focus on the developing/strengthening the ‘leisure and cultural’ tourism sector. ‘Adventure tourism’ and ‘Medical tourism’ have been identified as new focus segments. Presently, only a few five star hotels and upmarket travel agents are offering for sale products falling within this unique sector of the market.

Space and tourism have both developed at an equally rapid pace, and the potential for growth of the two endeavours when combined is definitely huge. Although currently, human spaceflight is only possible in a handful of space-exploring nations, recent advances in space technology and entrepreneurship are about to change the *status quo*. China for instance was able to place an astronaut in space in 2003 in a fraction of the time that it took other traditional space powers (such as the U.S. and the U.S.S.R.) to achieve this feat. The first credible private space-tourist venture is already a reality. Mr. Denis Tito became the first private space tourist when, in 2001, he travelled to space as a fare paying tourist. Although the flight involved a government vehicle, his participation in it was privately funded.

Thus, “space tourism” connotes the provision of facilities and services that enables humans to access and experience space for purposes of adventure and recreation, and in like manner, a “space tourist” is a person who travels to and experiences space for adventure and recreation. In this Report, the term “space tourist” is used interchangeably with space traveller, space passenger, and spaceflight participant.

Essentially, space tourism flights can be grouped into two categories: i.e. suborbital and orbital flights on the basis of how they travel in space.

1.4.2.1 Suborbital Tourism

As the term suggests, a suborbital flight is a flight into space that does not attain orbital altitude. Currently priced at around US$ 200,000 per passenger per flight, a suborbital flight would take a tourist to an altitude above the Earth on a trajectories path, at the peak of which one would experience microgravity and can see the Earth’s curvature and the hollow black space around it. The spacecraft will probably shut off its engines before reaching maximum altitude and then coast up to its highest point. Participation in a suborbital flight requires about a week’s worth of training.

(Courtesy: Virgin Galactic Scaled Composite Design)

Figure 1: SpaceShipTwo slung beneath the WhiteKnightTwo Carrier Craft

As seen in Figure 1 above, the flight would be in an aircraft-like vehicle with rocket engines, which would be ferried by a carrier aircraft to an altitude of 50,000 feet from where it would be jettisoned and launched for the suborbital flight phase with the aid of rocket power achieving a speed of Mach 3.5 in the process. The rocket fuel would be depleted as the vehicle completes its ascent, and at the top of the trajectory, the spaceship would have reached its maximum altitude where the effect of microgravity would be felt. The spacecraft would then glide back to the Earth and would make a conventional landing either at the take-off airport or at any other alternate airport/spaceport chosen for the purpose.

Initially, suborbital tourist flights will focus on attaining the altitude required to qualify as having reached space. The likelihood is that the flight path will be either vertical or very steep, with the spacecraft landing back at its original take-off site. In addition to being used for space tourism, future suborbital flights may hold the potential to reduce existing intercontinental flight times using conventional aircraft to a fraction of what they are today and they could also provide a platform for biotechnology and medical science experiments.

1.4.2.2 Orbital Tourism

Orbital tourism on the other hand involves a vertical launch of passengers into orbit aboard a reusable launch vehicle (RLV) such as the American space shuttles. The vehicle would dock with a space-based habitat such as the International Space Station (ISS) and the space travellers would stay there for a week or more before returning to the Earth. So far, only a handful of tourists have been to the ISS, paying a price of about US$ 20 Million per passenger.

The orbital experience is totally different from the suborbital experience in the sense that in the former, participants will experience microgravity throughout their stay, orbit the Earth and see the sunrise every 90 minutes. They will eat and live like astronauts do and tell the world about the uniqueness of the trip. But, participating in an orbital flight comes with a hefty set of health and fitness requirements. Flying to space requires a high level of physical fitness due to the extreme amounts of stress that the body is subjected to as a result of the absence of gravity. A person participating in an orbital trip would be required to undergo rigorous training for about 6 months so as to become acclimatized to zero gravity living, manoeuvring and also some operational functions and controls in the ISS.

From Table 1 below, it can be seen that an orbital trip would exert more pressure on the human body in the terms of speed, heat, gravity-forces and temperature. The risks are also very high for the orbital trip; an orbital trip is exposed to an increased level of danger during re-entry. An orbital vehicle would be more susceptible to debris due to its attitude and duration, but the overall experience in participating in such flights would be exhilarating for those seeking high adrenaline adventures.

Table 1: Comparison between Suborbital and Orbital Flights

Comparing Orbital Launch Systems (Reusable) with Suborbital Spaceplane Systems		
Differences in Characteristics	**Reusable Orbital Launch System**	**Sub-orbital Spaceplanes**
Maximum velocities	Up to Mach 30	Mach 4 to 6
G forces	Very High G forces	3 to 5 g (during descent)
Thermal Gradients on Re-entry	Thousands of Degrees Celsius	Hundreds of Degrees Celsius
Environmental Protection Systems and Structural Strength of Vehicle	Very demanding in terms of design and materials	Much less demanding in terms of structural strength, atmospheric systems, life support, etc
Exposure to Radiation	Can be at high levels	Minimal exposure due to short flight duration and lower altitudes
Exposure to Potential Orbital Debris collisions	Exposure increases as length of mission increases	Exposure risk is very low due to short duration and lower altitudes
Escape systems	Parts of the flight are exposed to high thermal gradients making escape systems extremely difficult and expensive to design	Escape systems are much easier to design due to lower thermal gradients, lower altitude, etc
Types of flight suits required	Complex and expensive flight suits required	Simple and lower cost flight suits are required due to lower altitudes, lower thermal gradients, much shorter exposure to low oxygen atmosphere
Launch Risk Factors (overall)	Very high	Considerably lower and different

CHAPTER 2

Market

An understanding of the potential demand and market for space tourism is the key to examining the feasibility of space tourism in India. As such, in order to make market forecasts for space tourism in India, a preliminary survey was conducted as part of this Study. In this Chapter, the methodology adopted for the conduct of that survey and to arrive at the resulting forecasts is discussed. This Chapter also provides forecasts for each type of space travel (i.e. for suborbital and orbital tourism in India). It is important to note that the figures in the Study Report are mere forecasts and projections and should not be regarded as accurate estimates

2.1 METHODOLOGY OF THE SURVEY

To explore the feasibility of establishing an Indian space tourism industry from scratch, very high weight was attributed to the analysis of factors affecting demand for travel/trips similar to space tourism in the sense that people generally have a very low level of awareness about such adventures. Accordingly, the survey questions were designed in such a way that they also contained a brief description about the pros and cons of the two types of flights that can be used for space tourism; i.e. suborbital and orbital flights. The current demand for space travel in India was examined by selecting a group of High Net worth Individuals (HNIs), the segment of the general population that can afford such trips. The objective was to subjectively analyze current demand to provide a foundational basis for making verifiable market and demand forecasts for the future. The survey focussed on the following general themes:

- What are the characteristics of potential customers?
- What would be the best time to introduce the venture in India?
- What is the revenue expected from the market?
- Although orbital and suborbital transportation is open to many potential applications (e.g., point-to-point travel on the surface of the Earth) the survey was restricted to only two types of travel:
    - ❖ A suborbital trip of 15-minutes duration
    - ❖ An orbital trip with possible stay of at least one week at the ISS

The survey participants were also exposed to some near future possibilities (i.e., those likely to materialize over the next 20 years) and asked to make forecasts and give opinions about developments required to facilitate the occurrence of those future possibilities.

Each participant was given a questionnaire containing a set of objective questions with a brief description about the experiences of the trip so as to allow for a better conceptual understanding of the question. The HNIs selected to participate in the study were those with a minimum net worth of US$ 1 million or annual income greater than US$ 0.1 million. The data was obtained from a combination of sources including: the Capitaline financial advisory database; the 2008 Annual World Wealth Report published by Capgemini & Merril Lynch; and, the 2008 Forbes List of Indian billionaires.

According to the 2008 Capgemini & Merril Lynch Annual World Wealth Report, there are 84,000 Indians with disposable net worth greater than US$ 1 million. Therefore, the population size for the study was fixed at 84,000. At a confidence interval of 95% and a margin of error of +/- 8%, the sample size for the study was 150. The sampling method adopted was the probability simple random sampling without replacement method. In this type of method, the selection sample is randomly selected from the population and is never again selected.

A questionnaire was prepared in order to extract from the survey participants the appropriate information required for a robust market analysis and to allow for better conceptual understanding. Realities such as fitness and training requirements, the physical hardship of the trip itself, and the current price of orbital and suborbital flights are all factors that could greatly affect customer interest in, and thus the demand for, space travel services. Realizing that an accurate assessment of the current demand for space travel is dependent upon an accurate portrayal of every aspect of space tourism, the survey sought to incorporate objectivity and realism by presenting a complete picture of space travel — both its glamorous and less-glamorous sides, thus making it more realistic and accurate. A pilot test of the questionnaire was also conducted.

The timeframe of the survey was from 21st June 2009 to 15th September 2009. Since HNIs usually have very little time to participate in such surveys, we were only able to collect responses from a mere 10% of our sample size during the three-month duration of the survey. Consequently, the responses of the remainder of the sample size were simulated on the basis of their correlation with each particular respondent's age, education, gender, profession and location.

2.2 SUBORBITAL DEMAND FORECAST METHODOLOGY

A survey was undertaken to try to determine and portray the current market for space travel in India. This survey comprises of fifteen-year forecast of market demand. The results of the survey are significant elements in the forecasts for public space travel. Together with additional data incorporated into the questionnaire to reconfirm the respondent's participation, the survey results were analyzed to determine the number of suborbital space travel passengers per year for the next fifteen years. A summary of the methodology used to formulate the forecast is presented in Figure 2 below along with detailed descriptions in the subsections that follow. Factors identified and considered in order to obtain the forecasts from the baseline population have been statistically validated.

2.2.1 Estimating the Potential Market for Suborbital Travel in India

The suborbital travel forecast attempted to predict the potential pool of customers for the service. Although a great portion of the general population may be interested in suborbital travel, the current price tag prevents many from becoming viable customers for this service.

In order to extrapolate the forecast from the results of the survey for suborbital travel by HNIs, it was assumed that one qualifying individual is equal to one household and that the attitudinal and behavioural component of each respondent towards space travel remained constant over a period of time.

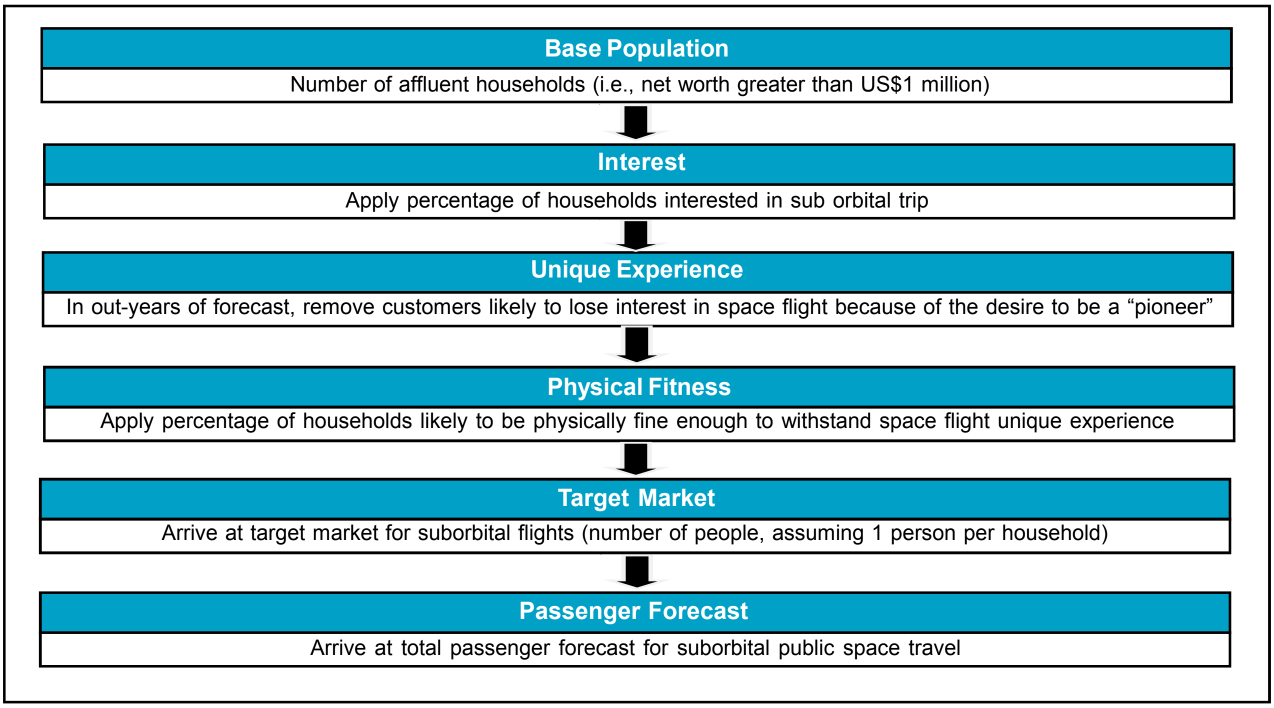

Figure 2: Suborbital Forecast Methodology

Table 2: Cross Tabulation of Variables with Participation in Suborbital Travel after Flipside

Participation after flip side description 'Likeliness to pay for suborbital trip' Visit to the Doctor Reason for space travel Crosstabulation

Reason for space travel	Visit to the Doctor			Likeliness to pay for suborbital trip				
				INR 1 crore	INR 75 lacs	INR 50 lacs	INR 25 lacs	Total
Unique experience	Once in a fortnight	Participation after flip side	Never				25	25
		Total					25	25
	Once in a month	Participation after flip side	Very likely		5		0	5
			Doubutful		0		10	10
		Total			5		10	15
	Once in a six month	Participation after flip side	Very likely			8		8
		Total				8		8
Space enthusiam	Once in a fortnight	Participation after flip side	Never				39	39
		Total					39	39
	Once in a month	Participation after flip side description	Very likely		0	7		7
			Doubtful		11	0		11
		Total			11	7		18
	Once in a six month	Participation after flip side description	Definitely	0		10	0	10
			Very likely	0		0	7	7
			Doubtful	0		8	0	8
			Never	20		0	0	20
		Total		20		18	7	45

The potential market was then narrowed to a target market for suborbital space travel by applying limiting factors such as 'interest in suborbital travel', 'willingness to pay current prices', 'reasons for interest in spaceflight' and 'physical fitness'. Specifically, the individual levels of interest were measured on the basis of responses such as "definitely" and "very likely" given by respondents to questions pertaining to their participation in suborbital space travel, after having been presented with both the attractive and non-attractive aspects of suborbital flight. Their responses were then analyzed in addition to their responses to the range of suborbital price points given in the survey.

Overall, this analysis revealed that although 25% of respondents were interested in participating in a space tourism trip even after hearing the flipside description of such travel, none of the survey respondents were willing to pay the current price charged for a suborbital trip. However, with a reduction in price to US$ 150,000, it was found that 3% of the individuals sampled were willing to undertake a suborbital trip. With a further reduction of the price to US$ 100,000 it was found that 11% of the respondents were willing to take part in a suborbital trip.

Meanwhile, according to the 2009 World Wealth Report published by the McKinsey Global Institute, the number of households in the millionaire category will continue growing at a compounded annual growth rate of 10% till 2025. Therefore, in the survey we also compounded our baseline potential customer population with the same rate. Thereafter, we applied these percentages to the baseline potential customer population to arrive at a baseline demand for suborbital space travel from 2010 to 2025 assuming the attitudinal and behavioural patterns of potential customers remained constant throughout.

2.2.2 Pioneering Reduction

Customers' interest in new products and services vary for any number of reasons and can change quickly. The reasons provided by respondents in support of their interest in space travel included: fulfilling a lifelong dream; wanting to see Earth from space; and, experiencing weightlessness. However, more than 5% of the respondents who were interested in, and willing to pay US$ 100,000 for, suborbital travel indicated that the primary reason for their interest was to do something that only a few people had done before; in other words, to become a pioneer. This reasoning presents a potential threat to interest levels as the service becomes regular. Thus, to account for this likely drop-off in interest due to the loss of "pioneers", a pioneering reduction was inculcated into the forecast. This reduction begins after the tenth year of service in 2021 for the suborbital travel market, with complete removal of the pioneer-driven demand in the period between 2021 and 2025. Therefore, it can be observed from the cross tabulation that although 16% of people were willing to pay US$ 100,000 and are interested in participating in a suborbital trip, 5% of that 16% were willing to go because it is unique and exclusive. Taking this phenomenon into account, only 11% (as against 16%) of the sample size was taken as the demand for suborbital trips in the given period.

2.2.3 Physical Fitness

At this time, affordability and interest in suborbital travel are the primary constraints on demand for suborbital travel. However, suborbital spaceflight is an inherently risky activity and will require participants to have attained a certain level of physical fitness in order to withstand the physical stresses of the flight at least until such time that the vehicles have undergone substantial changes that would reduce those stresses. Therefore, interested customers who can afford a ticket may be effectively prevented from participating in suborbital flights on account of their low levels of physical fitness.

Therefore, as part of the survey respondents were questioned regarding the frequency of their visits to the doctor. Respondents who indicated that they visit the doctor at least once in a month were considered fit to withstand the stresses of suborbital travel. It must be noted however that, as an indicator, regular visits to the doctor is just one of many criteria for assessing individual fitness.

2.2.4 Suborbital Demand Forecast

The baseline forecast for suborbital public space travel assumes a 15-minute trip on a suborbital trajectory, preceded by three to seven days of training. Although it is likely that at some point in the future, suborbital vehicles could be used to serve other niche markets such as rapid package delivery and point-to-point passenger transport, it is not clear when expansion into these applications will likely occur. Therefore, the suborbital forecast focuses solely on the suborbital scenario described above and does not reflect changes in demand attributable to the extension of suborbital transportation to other applications.

The initial service price of US$ 200, 000 per passenger per trip has been maintained for the first three years of service; however the price is reduced to US$ 150,000 and kept constant at that level till 2020. Thereafter, it is reduced further to US$ 100,000.

Figure 3 below illustrates the number of passengers likely to demand suborbital public space travel service over the forecast period. This forecast does not assume any supply constraints following the initial launching of the service as service capacity and technical details of potential vehicles have not been established at this time. However, demand is constrained until the assumed or expected date of commencement of service in 2010 at which point demand would be nil. However, with a slight reduction in price to US$ 150,000, the demand forecast shoots to 4,192 passengers in 2010 and to over 49,749 passengers in 2025 at which time full regular service is finally assumed to have begun. We see a dramatic rise in demand from the year 2021 onwards mainly due to the fact that respondents were highly sensitive to prices; with a reduction in the price of a suborbital trip from US$ 150,000 to US$ 100,000, of the great majority of respondents opted to undertake the travel.

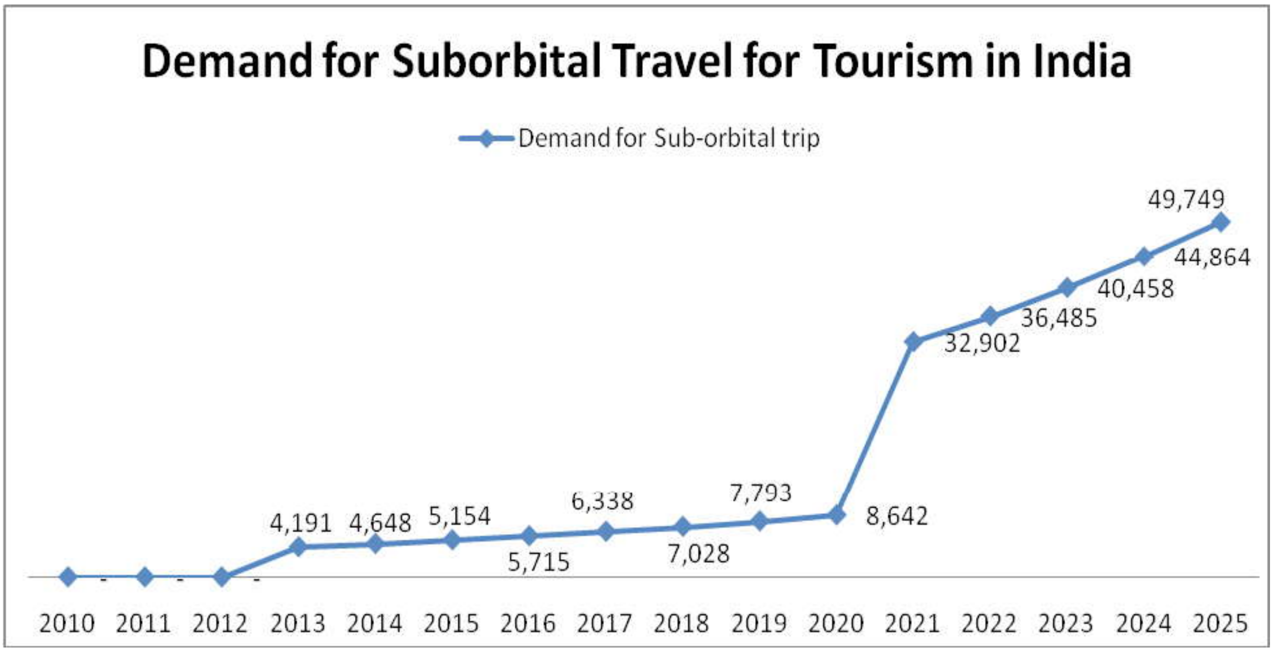

Figure 3: Demand for Suborbital Travel for Tourism in India

The revenue projections for the suborbital travel market demonstrate the potential revenue that could be realized if all of the forecasted demand for flights could be met. Thus, in Figure 4 below, it will be observed that total revenues from suborbital trips start from US$ 629 million in 2013 and increases to US$ 4,975 billion in 2025. It should be noted that supply constraints on the market could significantly lower the potential number of passengers and therefore, revenue.

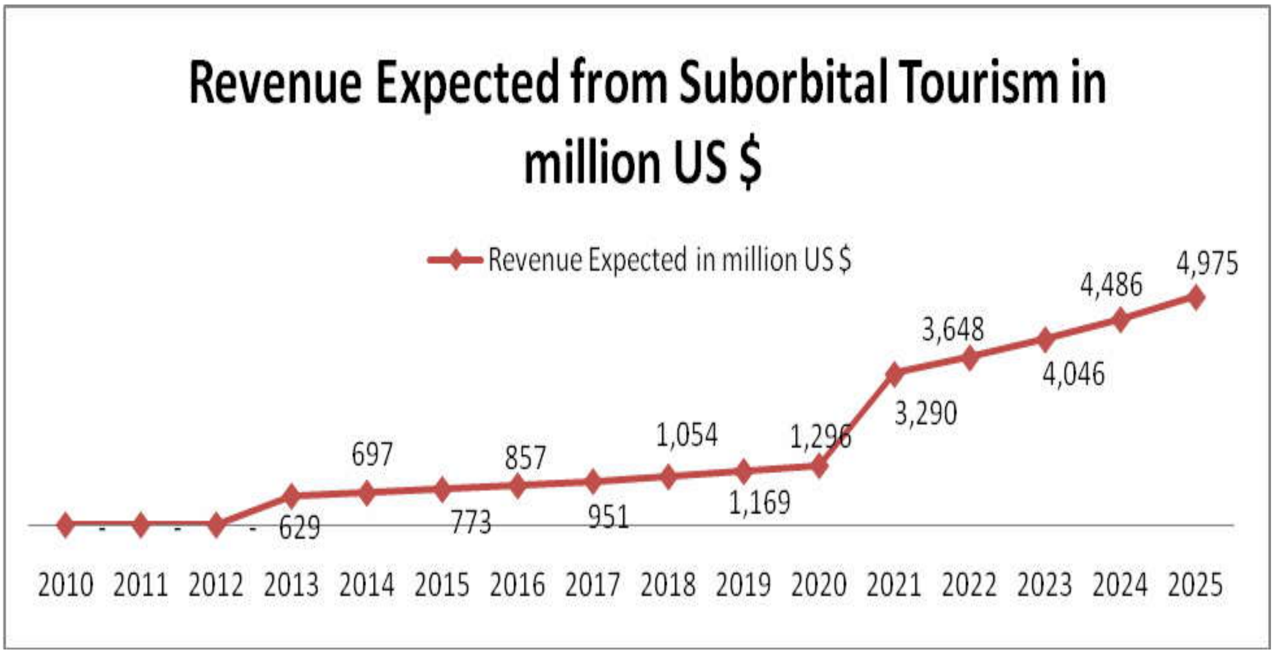

Figure 4: Revenue Forecast from Suborbital Tourism in India

2.3 ORBITAL FORECAST METHODOLOGY

As with the suborbital forecasts, the results of the survey were analysed along with additional data using a methodology that is tailored to the orbital market in order to develop a demand forecast for orbital space travel assuming that supply would not be a constraint. A summary of the methodology used to formulate the forecast is shown in Figure 5 below, with detailed descriptions in the subsections that follow. The factors identified and considered in order to arrive at forecast from the baseline population were statistically validated using the chi-square test of significance.

2.3.1 Estimating the Potential Market

Given the current ticket price of US$ 20 million per passenger per trip, affordability is the major barrier to becoming a viable customer for orbital space travel. According to a *Space Tourism Market Study* conducted by Futron Corporation a "[c]ombined analysis of the ticket price, the net worth ratio of past space tourists Dennis Tito and Mark Shuttleworth, and the vacation and discretionary income spending habits of the Futron/ Zogby survey results indicate that the ticket price should be no more than ten percent of an individual's net worth for that individual to be considered a viable customer."[3] Therefore, at a current ticket price of US$ 20 million, the potential customer's net worth would have to be US$ 200 million at the very least.

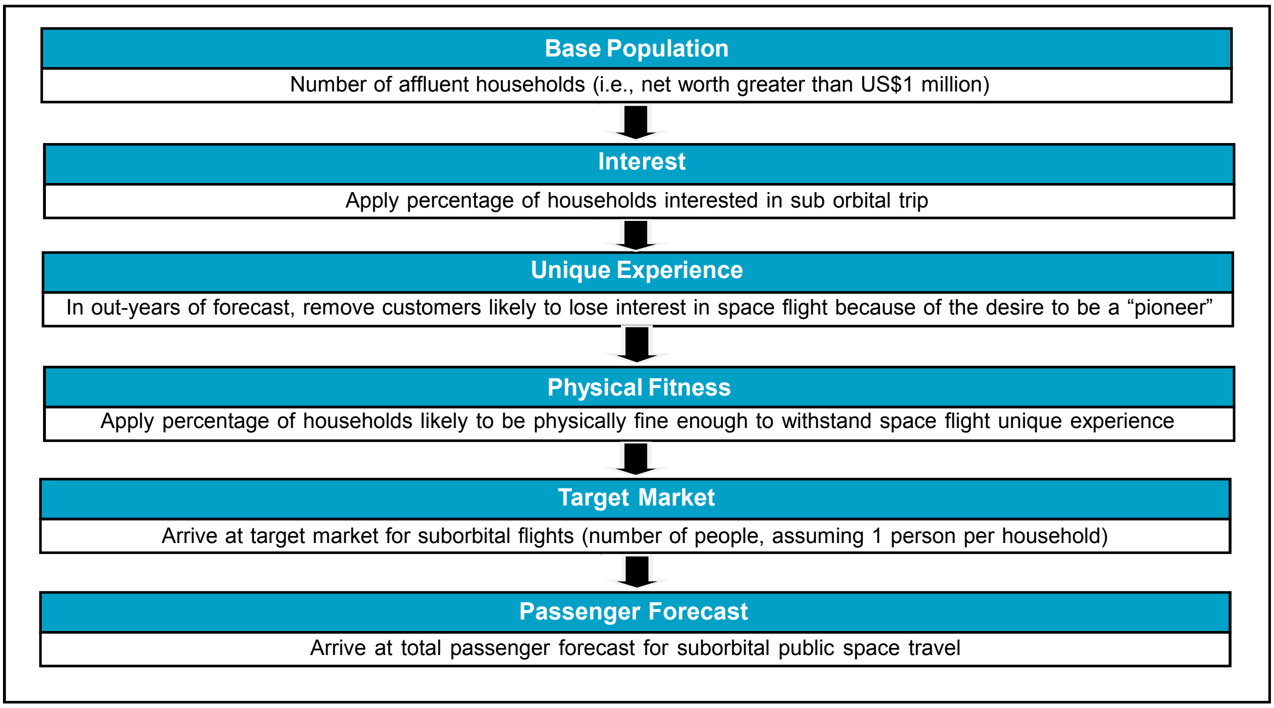

Figure 5: Methodology of Orbital Forecast

Respondents with individual net worths greater than US$ 200 million are a rare group and belong to a super affluent class in India. Information and data concerning such respondents was gathered from Forbes 2008 list of Indian billionaires and Capitaline's 2008 report. These individuals were used as the pool of potential customers for orbital trips.

From the base pool of potential customers in India, the target market of customers was identified using limiting factors such as interest in orbital travel, willingness to pay current prices, reasons for interest in spaceflight, and level of physical fitness.

The survey measured interest in orbital space travel by questioning respondents about their interest and participation. Specifically, the level of interest of individual respondents was measured based on the types of responses provided by the respondents. Those individuals who responded "definitely" or "very likely" to questions pertaining to their willingness to participate in orbital travel after having been presented with both the positive and negative aspects of orbital spaceflight were selected to form the target group.

Overall, the analysis revealed that 13% of survey respondents were both interested in the flight and willing to pay the current price of US$ 20 million, and their interest remained unaffected by price reductions going as low as US$ 10 million. Therefore, the price of US$ 20 million for this type of travel was kept constant throughout the forecast period.

Thereafter, the percentage of people interested in and willing to pay the price of the flight was applied to the total target market to arrive at a potential baseline demand for orbital public space travel in the period spanning 2010 to 2025.

2.3.2 Pioneering Reduction

As with suborbital travel, the respondents' reasons for wanting to participate in orbital travel included fulfilling a lifelong dream, wanting to see Earth from space, and experiencing weightlessness. It was also found that a few respondents wanted to participate just because only an exclusive group of people have previously undertaken orbital flights; in other words, they too wanted to become pioneers or members of this unique class of people. This reasoning presents a potential threat to interest levels as the service becomes regular. Thus, to account for this likely drop-off in interest due to the loss of "pioneers", a pioneering reduction could have been introduced into the forecast. However, the survey indicated that the overwhelming majority of interested respondents wanted to participate in an orbital flight due mainly to their enthusiasm for space, and not exclusively because they wanted to be unique. As such, no pioneering reduction was applied in the analysis.

2.3.3 Physical Fitness

Presently, affordability and interest in orbital travel are the major factors that determine the viability of demand for orbital travel. However, orbital spaceflight is an inherently risky activity and currently requires thorough medical certification and up to six months of extensive training. Even though potential customers may be interested in undertaking an orbital trip and are able to afford the ticket price, they may be prevented from doing so on the basis of their current state of physical fitness.

Respondents were assessed in terms of physical fitness on the basis of the frequency of their visits to the doctor. Since regular visits to the doctor is only one of many criteria that could be used in assessing individual levels of physical fitness, it was assumed in this survey that respondents who visited the doctor at least once every six months were physically fit to participate in such trips.

Table 3: Cross Tabulation of Variables with Participation in Orbital Travel after Flipside

Participation in orbital trip after flip side description "Likeness to pay for Orbital trip 'Visit to the Doctor" Networth "Reason for space travel Crosstabulation

Reason for space travel	Networth	Visit to the Doctor						
					Likeness to pay for Orbital trip			Total
					INR 100 crore	INR 50 crore	INR 25 crore	
Unique experience	5-35 Crore	Once in a fortnight					25	25
			Total				25	25
		Once in a month	Participation in orbital trip after flip side description	Doubtful			10	10
			Total				10	10
	36-1000 Crore	Once in a month	Participation in orbital trip after flip side description	Doubtful		5		5
			Total			5		5
		Once in a six month	Participation in orbital trip after flip side description	Doubtful			8	8
			Total				8	8
Space Enthusiam	<5 Crore	Once in a month	Participation in orbital trip after flip side description	Never		39		39
			Total			39		39
		Once in a month	Participation in orbital trip after flip side description	Doubtful	1		11	12
			Total		1		11	12
	5-35 Crore	Once in a month	Participation in orbital trip after flip side description	Very likely			6	6
			Total				6	6
		Once in a six month	Participation in orbital trip after flip side description	Definitely		10	0	10
				Doubtful		0	7	7
			Total			10	7	17
	35-1000 Crore	Once in a six month	Participation in orbital trip after flip side description	Very likely	20			20
				Doubtful	8			8
			Total		28			28

2.3.4 Conversion to Launches

Currently, the only vehicle used in providing orbital space travel flights is the Russian-developed Soyuz rocket. This reality places a rigid supply constraint on orbital space travel launches available for public participation. In the forecast, a number of key factors including the existence of an orbital travel market and a vehicle to provide the service, as well as known supply constraints were applied to the passenger forecast.

Using the passenger demand statistics, passengers were allocated extra seats on Soyuz capsules that would be flying on ISS supply missions in the initial years of the forecast. It was assumed that Soyuz flights to the ISS would continue at the current rate of two tourists per year until 2015, and would exclusively serve Indian passengers throughout the forecast period. From 2015 to 2020, it was assumed that four Soyuz flights carrying four passengers per year would accommodate all the crewmembers of the ISS. However, the current trend of carrying a single passenger on a Soyuz flight is subject to change with the introduction of a single astronaut and two passenger configuration. We assumed that this change will occur in 2020; therefore the Soyuz capsule would carry eight passengers per year.

2.3.5 Orbital Forecast

The forecast for orbital space travel is based on a two-week orbital trip preceded by six months of training. The forecast assumes a current ticket price of US$ 20 million at the beginning of the forecast in 2010, which remains unchanged till 2025. The forecast for orbital space travel results in a cumulative 8 passengers over the entire forecast period as the only means of providing the flight till now is through a Soyuz capsule.

Figure 6: Expected Tourists on Soyuz

The revenue forecast for the orbital travel market demonstrates the potential revenue that can be realized if all of the demand for orbital flights could be met. However, supply continues to remains a severe challenge. Up until now, it is only the Soyuz rocket/capsule that is capable of ferrying passengers into and out of orbit. Accordingly, we assumed that up till the year 2025, it is possible that no other agency would commence such type of travel. Thus, we found that, at most, supply projections can only fulfil demand for 8 passenger seats per year between 2020 and 2025. This is shown in Figure 6 above. We also found that total revenue from orbital trips would start at US$ 40 million in 2010 and increase to US$ 160 million by 2025. (See Figure 7 below).

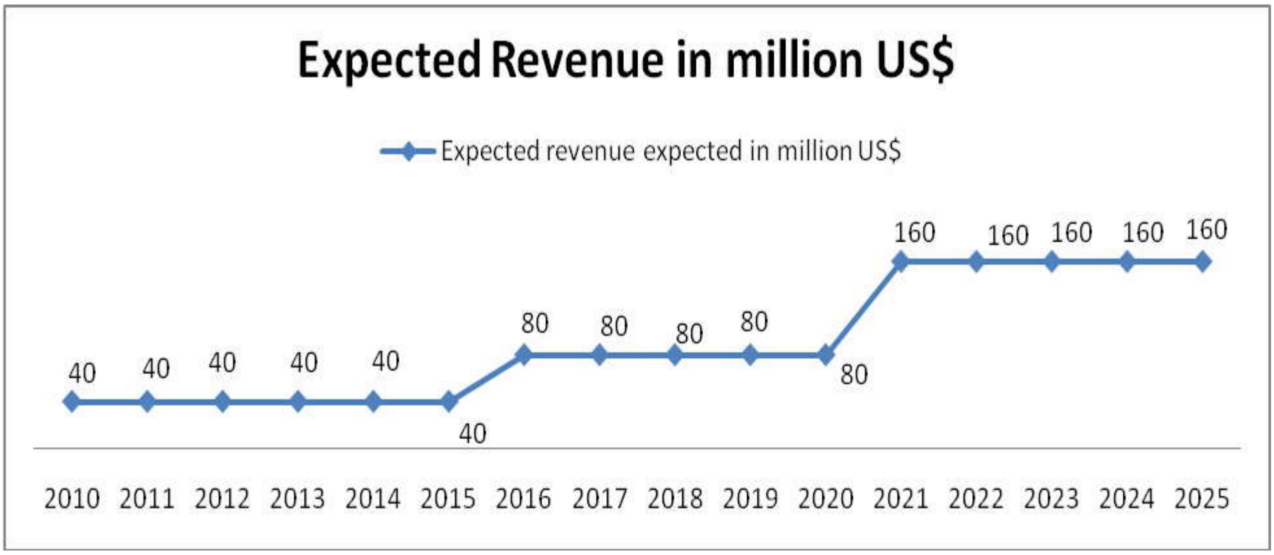

Figure 7: Expected Revenue in million US Dollars

These revenue forecasts are exclusively based on the hardcore operations of space-flight. Various ancillary revenue sources like theme and virtual reality space parks; space camps; training, production and launch recovery facilities, trip training facilities, and other such public quasi-entertainment facilities have not been taken into account in the revenue forecasts. In the realm of air transportation for example, such ancillary revenues represent quite an important means of revenue generation in the aviation industry as a whole. In similar fashion, the inclusion of secondary revenue sources in the projection of revenue forecasts for orbital space travel could provide a very promising picture.

CHAPTER 3 Facilities, Infrastructure and Human Resources

The facilities, infrastructure and human resources required for a viable space transportation network are a significant part of the challenge facing the development of the space tourism industry. In this connection, the key considerations relate to the requirements for a safe transportation system (vehicle), appropriate spaceports and other related ground infrastructure, suitable air and space traffic management systems, and the impact of these elements on other areas of human activity and on the Earth and space environment. This Chapter discusses these issues and describes some of the challenges, potential solutions, and conditions that must be met if the space tourism industry is to be viable in India.

3.1 VEHICLES FOR SPACE TOURISM

Over the last few years, various technological developments have occurred in the field of transportation for space tourism and the technology continues to evolve at a rapid rate. Numerous private companies are venturing into this field and investing huge amounts of capital. Some of the major names in this field are Virgin Galactic, Bristol Spaceplanes, Rocketplane, XCOR Aerospace, Space X, and Blue Origin. Also, governmental organizations like the European Aeronautic Defence and Space Company N.V. (*EADS*) are building and testing various kinds of space vehicles that could be used to provide transportation for space tourism. In this sub-section, the discussion of vehicles is restricted to sub-orbital travel since we believe that within of the next 7 to 10 years, sub-orbital flights will become a routine due to its lower cost to prospective tourists and the proven safety and reliability associated with the technology. As such, in comparison to orbital travel, it is expected that the suborbital travel sector will attract more space tourists in the years to come.

3.1.1 Spaceship[4]

The Spaceship vehicle is an air-launched suborbital space-plane developed by Scaled Composites Inc., meant for transportation of passengers to an altitude of about 100 kilometres above the Earth's surface where they will experience micro gravity. "SpaceShipOne features a rubber-nitrous oxide hybrid rocket engine and cold gas attitude control thrusters; a graphite/epoxy primary structure; 3-place, sea-level, shirt-sleeve cabin environment; a low maintenance thermal protection system; and a unique feathered reentry system."[5] The modified version, SpaceShipTwo, which will be used commercially for space tourism, will carry 2 crew members and 4 passengers.

The space-plane is carried under the belly of a Scaled Composites WhiteKnight carrier aircraft. The WhiteKnight is a piloted, twin-turbojet aircraft. Its first flight took place on 1st August 2002. It provides a high-altitude airborne launch of SpaceShipOne. The WhiteKnight is also equipped to flight-qualify all the SpaceShipOne systems, except those driven by rocket propulsion. The aircraft's cockpit, avionics, life support systems, pneumatics, trim servos, data system, and electrical system components are identical to those installed in SpaceShipOne.

At 50,000 feet, the WhiteKnight drops SpaceShipOne, which then climbs almost vertically under power at 3-4g acceleration. The hybrid engine burns out at Mach 3.5, 65 seconds after ignition. The spaceplane coasts to an altitude of approximately 100 km. (328,000 ft.) before free-falling back to the Earth. The pilot and passengers experience microgravity above the atmosphere for about 3 to 5 minutes.

While in space, the wings of SpaceShipOne are folded to provide a shuttle-cock or "feather" effect, giving the spaceship extremely high drag for re-entry. This allows re-entry deceleration to occur at a higher altitude and greatly reduces the forces and heating to which the structure would have been otherwise exposed. Also, in the feathered configuration, the ship aligns itself automatically so that the pilot has a less-critical flight control task. Once in contact with the atmosphere, the feathered wings position the vehicle to the correct altitude without pilot input.

Virgin Galactic, founded by Sir Richard Branson, is perhaps the most visible company in the private space race, attempting to be the first to send tourists into sub-orbit. The company is selling tickets aboard its SpaceShipTwo suborbital vehicle for about US$200,000 per passenger, with the first flights expected to occur soon.

The concept of a spacecraft which takes-off and lands horizontally has also been explored and used by Scaled Composites Inc., (under contract with Virgin Galactic). It involves an aircraft called WhiteKnightOne, a mother ship, taking off from an airport with a spacecraft, SpaceShipOne. When WhiteKnightOne reaches an altitude of 50,000 feet, SpaceShipOne that takes off (is launched into) towards space and the mother ship, WhiteKnightOne, returns to an airport and lands horizontally like an aircraft. SpaceShipOne climbs to an altitude of more than 60 miles (approximately 100 kilometers) with its passengers (occupants or spaceflight participants) where they experience weightlessness before re-entering into the Earth's atmosphere and SpaceShipOne like WhiteKnightOne returns to an airport and lands horizontally like an aircraft.

As a sleek and more powerful six-passenger craft, the SpaceShipTwo (second generation of SpaceShipOne) is designed to travel at about four times the speed of sound and to zoom completely out of the Earth's atmosphere — reaching true space more than 60 miles (approximately100 kilometers) above the Earth.

The price tag for developing Virgin Galactic's high-profile venture, including a hulking, four-engined plane intended to carry the rocket-powered vehicle during the initial part of its ascent, could end up being more than US$ 50 million per spacecraft.

3.1.2 Rocketplane XP[6]

The Rocketplane XP is a suborbital space vehicle being developed by Rocketplane Inc. It promises a flight carrying one pilot and 5 passengers up to an altitude of 100 kilometres, including a four-minute experience of weightlessness and a spectacular view. The vehicle's fuselage is a modified Lear 25 series aircraft that will use two General Electric CJ-610 turbojet engines. These will be used for take-off and will be shut down after ignition of the rocket engine at an altitude of about 12 kilometres. One of the jet engines would be restarted at high altitude after re-entry as the craft makes its way on the approach corridor of the spaceport. Rocketplane Inc., has secured a rocketdyne RS-88 rocket engine from NASA for a period of 3 years for use in flight tests.

Further developments to this design include a delta wing that attaches to the Lear jet fuselage. In addition, a new aft fuselage structure is being fabricated to accommodate the rocket engine thrust load. The vehicle also is getting a new vertical tail structure. The starting fare per passenger is targeted to be between US$ 150,000 and US$ 160,000 with an estimated 200 passengers per year initially. In spite of the foregoing, Rocketplane Inc., has not been able to gather the required funds to start the project.

3.1.3 Lynx[7]

The Lynx vehicle is a two person suborbital space-plane designed by XCOR Aerospace as a follow up to an initial design of space ship Xerox. The Lynx will only fly to an altitude of 60 miles and passengers will experience weightlessness and have a broad view of the Earth below. It will use a new engine, designated as 5K18 which produces between 2500 to 2900 pounds per foot (lb/f) thrust by burning a mixture of liquid oxygen and kerosene. The engine has been successfully tested at XCOR's rocket test facility located at the Mojave Air and Space Port in the U.S. As a possible pre-emption of any criticism of the vehicle on environmental grounds, the company has stated that the Lynx's liquid-propellant engines will "minimize" the environmental impact of the flights. They are fully reusable, burn cleanly, and release fewer particulates than solid fuel or hybrid rocket motors. Tickets are expected to sell for US$ 95,000 each.

3.1.4 Astrium[8]

Although different space jet designs were studied by EADS, the current shape of the Astrium spacecraft is the outcome of computer simulations and final wind tunnel verification work at the German Aerospace Centre's Cologne facility in the last quarter of 2006. The fuselage will have a high composite content and its moving canards are intended to aid vertical climb and to play a key role in helping to change the vehicle's descent mode from re-entry to conventional flight. Reaching 39,300ft (12,000m) with two turbofans, the vehicle's single pilot will fire an EADS Ottobrunn-design, liquid-oxygen, methane rocket motor. The plane will then rise along a vertical trajectory. For 90 seconds of flight with a top speed of Mach 3, the plane will be rocketed upwards. The maximum acceleration is 3 g (30 m/s^2). At an altitude of 60 km, the rocket engine is shut down and the plane continues to climb up to a maximum altitude of 100 km. Then the plane descends to an altitude of 15 km at a high angle of attack, being progressively decelerated by atmospheric drag. At this altitude, the plane transitions to aeronautical mode and the jets are reignited to bring the plane back to a classical landing strip. At present, the Astrium business plan envisages one flight per week.

3.1.5 Which Vehicle will be the Most Desirable for Space Tourism in India?

It is obvious that internationally, there is an ongoing rush to develop space vehicles of various kinds. However, the new spaceflight technologies are still in their developmental stages – to date, there has been only one test flight involving the SpaceShipOne vehicle. As such, it is difficult to assess and verify the safety of these emerging means of space transportation. There is no solid accumulated knowledgebase that can be relied upon to demonstrate that, from an engineering point of view, the SpaceShipOne vehicle is safe for human travel to space, and that effects on the human body as forecasted are correct from the perspective of the safety of passengers, and that tour operators know exactly how to train passengers in order to make their flights safe.

In this context, one may recall that before Yuri Gagarin took flight into space, there were more than 10 launches of the spaceship Vostok with mock-up human passengers and dogs Belka and Strelka who returned safely aboard the craft. However, a few other dog-crew members died because a booster rocket was blown at the launch pad. It should also be kept in mind that currently the private sector is rapidly developing technology without consulting the well established space industry which has developed fairly proven, reliable and safe technology dating back more than 50 years.

From the economic perspective, it is clear that things are going to change for the better. Globally, positive indicators such as rising per capita income and groveling GDP suggest that change is about to occur. But the question that arises is whether India will be prepared to take full advantage of this new era of opportunity. For present purposes, this translates into an inquiry about the possibility of offering space travel services from India. In order to offer space travel services from India, three options are available: (a) Provision of the service by a foreign operator; (b) Provision of the service by an Indian company with foreign built vehicles; and, (c) the possibility of developing a vehicle in India by independent means or through a joint venture with an international entity having the expertise and experience in this field. The following sections briefly explore each of these options.

Provision of the service by a foreign operator: This is one of the most pragmatic options available for purposes of starting a space tourism industry in India. Already, Virgin Galactic is trying to market its space travel services for tourists based in India. It has a dedicated Indian-based marketing wing for the purpose, operating under name of Spazio Travel.

Provision of the service by an Indian company with foreign-built vehicles: Although this option has not been experimented with in India as yet, it seems pragmatic enough. A space travel company could procure spacecraft from foreign manufacturers and offer services in India. However in order for this to happen, some sort of regulation, certification, operating permits and development of spaceports will be required. In this regard, India could develop space tourism together with entities from Russia and this may include private investments in sub-orbital flights or private mini stations. At least from an experience point of view, Russia currently possesses the best knowledge in space transportation and it is the only country that has expressed a continuing interest in extending international cooperation in space exploration after the expiration of the ISS Agreement. Russia is also working on new Soyuz capsule with 5 or 6 seats.

The possibility of developing a vehicle in India by independent means or through a joint venture: There is also the possibility that a space vehicle could be designed and built in India. Companies like Hindustan Aeronautics Limited (HAL) and Indian Space Research Organization (ISRO) have broad expertise and thus might be capable to develop such vehicles, if they decide to do so. However, in order to embark upon a speedy construction of space aerospace vehicles, these organizations might explore possibilities of forming joint ventures with foreign companies/countries to develop these vehicles in India. But, for this to happen, the encouragement and support of the Government of India would be required. And exercising this option might provide immense spin-off benefits to the country from the space travel sector.

Additionally, it will be imperative to appropriately categorise space tourism as 'aviation', 'space' and/ or 'tourism.' The current policies of the Indian government and regulatory regimes for these three sectors will need to be examined and perhaps a 'hybrid' policy and regulatory framework put in place to start the process in India. The foreign direct investment policy in this context will also need to be revisited.

3.2 SPACEPORTS AND GROUND INFRASTRUCTURE AND FACILITIES

The locations and facilities for launching - taking off - and receiving or landing spacecraft, aerospace vehicles, are indispensable for space travel. Such a site or facility is called spaceport or aerospace port. Spaceports are designed as per the vehicle design, in accordance with the mission of the vehicle, the type of propulsion mechanism used in vehicle etc. Vehicles designed to be launched horizontally for suborbital flight will primarily be used for short duration space tourism or point-to-point transportation of human passengers or cargo. On the other hand, vehicles designed to be launched vertically for longer duration orbital flights would have higher risks associated with them and the energy needed to reach orbit is much more than that required for suborbital flight. Multi-stage vehicles are required, probably restricting the location of the spaceport to an isolated area or near the ocean due to the possibility of debris falling during stage separation. See Table 4 below.

Table 4: Requirement and Consequences of Orbital Vehicles

	Requirement	Consequence
1.	Higher Energy	Multiple State rockers Space port should be a isolated area depending on debris analysis
2.	Higher Safety Requirements	Fail safe abort procedures High reliability engines Reliable thermal protection systems during re-entry
3.	Launch Recovery models	VTVL Air launch with very large aircraft

3.2.1 Present Scenario

The Mojave Airport and Spaceport located in California, U.S., was the launch site of SpaceShipOne, the first privately funded spaceflight. Developed from an existing airport, the spaceport has a 12,500-foot (3,810-meter) runway for horizontal launches.

Current Capabilities: Already in place are an air traffic control tower, a terminal and hangars, a high bay building, offices, a maintenance shop, fuel service facilities, rocket engine test stands, and an aircraft storage and reconditioning facility. Also available nearby is an industrial area that includes facilities for: BAE Systems, Fiberset, Scaled Composites, XCOR Aerospace, Orbital Sciences Corporation, and General Electric.

Planned Future Capabilities: A series of additional facilities are planned for the spaceport particularly to support manufacturing by XCOR Aerospace and Scaled Composites - the Spaceship Corporation.

Spaceport America (see Figure 8 below) was constructed in 2008 on the ground of a barren (an uninhabited wilderness that is worthless for cultivation) desert in New Mexico, the U.S. Costing an estimated US$ 225 million, it has already attracted Virgin Galactic and Up Aerospace. If completed on time in or about 2011, Spaceport America will become the first "purpose-built commercial spaceport", meaning a spaceport specifically constructed to facilitate space tourism.

(Courtesy of Foster and Associates)

Figure 8: Design of Spaceport America

Current Capabilities: Major facilities that are under construction include a spaceport central control facility, airfield, maintenance and integration facility, launch and recovery complex, and a cryogenic plant.

Spaceport Singapore (see Figure 9 below) has been publicized since 2006. With financial assistance from the United Arab Emirates, Spaceport Singapore reportedly joined with Space Adventures Space Tourism Company in a public-private partnership to create a mixed tourist and commercial attraction similar to Spaceport America. However, no progress has been reported since.

(Courtesy of Space Adventures)

Figure 9: Architectural Rendering of Singapore Spaceport

Spaceport Sweden, located in Kiruna, Sweden, is a joint-project of the Swedish Space Corporation, the Kiruna Airport and the neighbouring ICEHOTEL and business development company 'Progressum'. With its first suborbital flight scheduled for 2012, Spaceport Sweden plans to become Europe's base for space tourism. The Swedish spaceport has also entered into a partnership agreement with Virgin Galactic to facilitate its suborbital flights.

3.2.2 A Spaceport in India

We can infer from the above descriptions that most of the spaceports are located near to the ocean besides the fact that they all are in vicinity of the busiest airport of the country concerned. In addition, spaceports benefit from and actually cannot function without an air traffic control tower, maintenance hangars, industrial area, long runway etc. Therefore, any proposed spaceport in India must have abundant space to accommodate all of the foregoing.

Although the vehicle to be used plays a significant role in the selection of a suitable site for a spaceport in India the following factors are also equally important and will have to be taken into consideration:

- It is believed that future hypersonic aircraft will require a very long runway.
- Spaceports will present unique challenges in noise abatement, zoning, and passenger access, with as much as a 30- mile wide corridor surrounding a 5-mile long runway.
- A dedicated mass transit system from the nearest public access point to the spacecraft boarding area will be required.

In India, the development of a spaceport near Mumbai would be most appropriately placed since Mumbai is a large metropolis situated close to the sea and also to one of the busiest airports in the country. In addition, the existing airport facility is already being expanded considerably and modernised. Thus, there is no need to develop a spaceport right from scratch. However, a spaceport intended for use by VTVL (vertical take-off and vertical landing) spacecraft could be located at the Sriharikota launch centre, which already has in place well developed and tested infrastructure and facilities.

In addition, it should also be kept in mind that in recent years, the Government of India has been unfolding its policy for privatization and development of airports in India. This has led to the emergence of 'airport developers' including big ticket Indian companies like GVK and GMR as well as efforts by private individuals (Non-Resident Indians and locals) who have come together to form new companies to develop airports; e.g. Cochin airport. In such cases, the State government typically holds 26% of the equity. Progressive state governments like that of the State of Gujarat have also planned for the development of 'aerotropolis' to capitalize on the 'aviation, tourism and development' matrix. Locating a spaceport in a designated Special Economic Zone (SEZ) will qualify for tax benefits although certain special concessions may be required.

There have been some rumours that a U.S. entity was keen to develop a spaceport in Kerala, India. However, an ISRO official expressed scepticism when asked whether they were going ahead with this project.

In any case, having regard to the experience in attracting foreign airport developers and airport operators to participate in the consortia that are now engaged in airport development in the country, it would seem that India already has in place a workable model to attract foreign spaceport developers to form consortia with Indian entities with equity participation of the relevant state governments and the Government of India.

It may be noted that the Airports Authority of India (AAI), which previously actively operated the Delhi and Bombay airports has now left that role and has been replaced by the GMR/GVK consortiums respectively. The AAI now functions only as an air navigation services (ANS) provider. Attention ought to be given to the question as to which entity will provide the required ANS services for space transportation vehicles and which entity will be the regulator (ISRO or Airports Economic Regulatory Authority of India (AERA)?

3.3 MEDICAL FACILITIES AND TRAINING

During a suborbital or orbital flight, passengers will be exposed to high rates of acceleration, the microgravity environment, and again to heavy gravity-loading upon re-entry. The effects of these multiple stressors on the human body have been studied extensively and they include cardiovascular, musculoskeletal and neurological disorders. These can broadly be classified as follows:

3.3.1 Space Adaptation Syndrome/Space Sickness[9]

Space adaptation syndrome (SAS) or space sickness is a condition experienced by about 50% of all space travellers during the process of their adaptation to microgravity. It is related to motion sickness, as the vestibular system adapts to weightlessness. Changes in gravitational forces, such as the transition to weightlessness during a space voyage, influence our spatial orientation and require adaptation.

The vestibular system or the balancing organ present in the ear detects either rotational or linear movement. It consists of three semicircular canals that sense which way the head is turning and sac-like organs, called otoliths that sense linear movement. The canals and otoliths are filled with fluid. This fluid is set in motion when the head moves, bending the hair-like structures called cilia, which are attached to cells; this stimulates the cells and communicates the movements to the brain.

To date, about 60% of all Space Shuttle crewmembers have experienced space sickness on their first flight. It is likely generated by the ability to move around in larger spacecraft. As with motion sickness, symptoms can vary from mild nausea and disorientation to vomiting and intense discomfort; headaches and nausea are often reported in varying degrees. Space sickness relieves itself after about 3 days. Putting space tourism (i.e., both suborbital and orbital flights) in perspective, it is apparent that moving around in the space vehicle will be an attraction and the trip will not last up to 3 to 5 days, at least during the initial stages.

Hence, there is need for medicine to cope with space sickness. Modern motion-sickness medications can counter space sickness but one may suffer drowsiness and other side effects. Transdermal dimenhydrinate anti-nausea patches and other medical remedies are typically used whenever space suits are worn by astronauts because vomiting into a space suit could be fatal.

3.3.2 Effects of High Gravity Loads on the Human Body[10]

Human tolerance to high gravity loads depends upon the magnitude of the gravity-force, the length of time it is applied, the direction in which it acts, the location of application, and the posture of the body. To some degree, gravity-tolerance can be trainable, and there is also considerable variation in innate ability between individuals. In addition, some illnesses particularly cardiovascular problems reduce gravity-tolerance.

One immediate but not so severe effect of high gravity-force is difficulty in breathing, which is caused by the pushing of the rib cage onto the lungs, thus emptying the lungs of air. The passenger feels fatigued and worn out as a result of the oxygen deprivation. Another effect is the variation of blood pressure in the body. Blood is pulled down towards the feet, away from the brain. This causes loss of peripheral vision. Tunnel vision is experienced followed by greying out (vision is black and white). If the g-force acts longer, there is complete loss of vision (called black out) and the passenger eventually loses consciousness. This is called G-LOC ("LOC" stands for Loss of Consciousness).

This scenario comes into consideration in the event that a Horizontal Take off and Landing (HTOL) or a mother ship like the WhiteKnight carries the space vehicle. The human body thrives better at surviving gravity-forces that are perpendicular to the spine. In general when the acceleration is forward so that the gravity-force pushes the body backwards (colloquially known as "eyeballs in"), a much higher tolerance is shown than when the acceleration is backwards, and the gravity-force is pushing the body forwards ("eyeballs out"), since blood vessels in the retina appear to be more sensitive in the latter direction. Hence, in the case of VTOL vehicles, the passenger seats have to be designed in such a manner that the passengers undergo "eyeballs in" acceleration at all times.

3.3.3 Effects of Microgravity[11]

In relation to long voyages into space and stays at space habitats in the LEO, microgravity will have severe effects. The human body is used to a continuous load of 1g. The muscles and bones work against this amount of force even if one is just standing.

In microgravity environments, this familiar pull of gravity is absent. This induces the muscles to atrophy quickly and lose 20% of their mass if not regularly exercised. Bones in space atrophy at a rate of 1% a month and can lose as much as 60% of the bone mass. Under the pull of gravity, blood pools up in the feet. The blood pressure in the feet can be as high as 200 mm Hg whereas in the brain it is 60-80 mmHg. In space, the blood pressure equalizes and becomes about 100 mmHg throughout the body. That is why astronauts can look odd: their faces filled with fluid, puffed up, and their legs (which can lose about a litre of fluid each) thinned out.

But that shift in blood pressure also sends a signal. Our bodies expect a blood pressure gradient. Higher blood pressure in the head raises an alarm: The body has too much blood! Within two to three days of weightlessness, astronauts can lose as much as 22 percent of their blood volume as a result of that errant message. This change affects the heart, too. It is going to atrophy because it does not need to pump so hard when there is less blood to pump.

This underscores the need for artificial gravity in space destinations like LEO habitats. Exercise is key. Various devices have been developed to mimic the help that gravity provides. One Russian experiment provides resistance by strapping jogging cosmonauts to a treadmill with bungee cords. Another promising device, the Lower Body Negative Pressure (LBNP) device, attempts to mimic gravity even more closely. It provides body weight by applying negative pressure over the lower body.

If an individual suffers or has suffered from hypertension, coronary artery disease and insulin-treated diabetes, he/she needs to undergo special tests in order to determine whether he or she is fit enough to participate in such trips. There must be a basic level of fitness in regard to these health issues, which must be satisfied in order to allow tourists to engage in space travel.[12]

3.3.4 Medical Requirements for Space Tourists[13]

In 2006, the FAA (U.S.) published a document entitled *Guidance for Medical Screening of Commercial Aerospace Passengers*.[14] This paper provides an overview of the general medical assessments needed for orbital and suborbital passengers. For suborbital passengers, the document recommends the use of a medical history questionnaire relating to issues such as heart, circulatory disorders, mental disorders, surgical history, and respiratory disorders. The success of this questionnaire is incumbent upon the spaceflight participant's provision of honest responses. Passengers participating in suborbital aerospace flights (or exposed to a gravity load of up to +3Gz during any phase of the flight) need not be required to undergo a physical examination or complete medical laboratory testing. However, nothing in this guidance precludes the physical examination of any prospective aerospace passenger as deemed necessary by the physician who is authorized by a commercial aerospace vehicle operator to conduct medical assessments.

The neurological, cardiovascular and musculoskeletal systems are at greater risks during an orbital flight due to the longer duration of the flight. The screening process for passengers participating in orbital aerospace flights (or exposed to a gravity-loads exceeding +3Gz during any phase of the flight) is more comprehensive and consists of a medical history assessment, a focused physical examination and testing. This is due to the higher g-loads associated with re-entry from orbital flight. The medical history assessment is similar to the suborbital questionnaire but includes additional items such as history of pneumothorax, kidney stones, and prior exposure to radiation. The FAA recommends that the physical examination must include vital signs, ophthalmological evaluation, heart, lungs, chest, and peripheral vascular system. A battery of medical testing is recommended in addition to the questionnaire and general examination. Examples of examinations include chest X-rays, resting EKG, and urine analysis. It should be stated that these are only guidelines for medical procedures and the launch vehicle operators might have their own medical standards that could be expected to be more demanding due to liability concerns.

3.3.5 On-Site (Ground) Medical Services[15]

3.3.5.1 Preventive Medicine

Preventive medicine programmes provide support for spaceport personnel, spaceflight crew, and spaceflight participants. Effective prevention includes employee-targeted training, certification, and knowledge dissemination to ensure that spaceport operations are in compliance with applicable health and safety standards. Frequent inspection and rehearsal of spaceport procedures are supplemental strategies to ensure compliance with standards and improve procedures.

3.3.5.2 Occupational Medicine

In addition to preventive medicine strategies, the spaceport will provide occupational medicine infrastructure. This will help to maintain the health and safety of spaceport personnel, spaceflight crew, and spaceflight participants. This infrastructure should include programs for screening (e.g. periodic surveillance of hearing loss in at-risk ground crew), acute management of on-site mishaps (e.g. treatment of toxic fuel exposure), and *in situ* job monitoring systems (in-flight and post-flight monitoring and management of spaceflight and microgravity related illness).

3.3.5.3 Emergency Medical Services

Spaceport activities are inherently hazardous and they require substantial supporting capabilities for emergency medical response. The essential components of an effective emergency medical response include on-site medical services, communications, search and rescue, and mechanisms for transfer of patients to a definitive care facility. As such, the spaceport should have the capability to respond to emergency medical events ranging from burn injuries, toxic exposures, blast trauma to flight-related illnesses.

3.4 SPECIALIZED WORKFORCE

Expanded space commercialization will considerably change the space era in coming years. Along with the advent of the new space age, there will be increasing demand for a number of new skills from the future space work force. For space tourism, we envisage that demand will come from all over the world. As such, the transnational activities involved in the conduct of space tourism will have to be carried out from an international perspective.

Transfer of workforce from other sectors remains difficult mainly due to the uniqueness of the space sector. A specifically tailored space education curriculum will therefore be needed to prepare the new space workforce for timely take over from the present rapidly aging space professionals. It must be noted that currently, there is no solid research anywhere in the world on the effects of suborbital flight on the human body. Also, until we start actual suborbital flights we will not know what the consequences on the human body will be, what the risk factors will be, and how long participants need to be trained, etc. All the counter-measures or precautions that are being taken for long duration orbital flights are known because of the cumulative experience obtained from numerous orbital flights undertaken within the American and Russian space programmes.

Finally, the above-mentioned elements and associated facilities need to be in place for the space tourism industry to take off in India. During the conduct of research for this report, it was learnt that the All India Institute of Medical Sciences has plans to carry out research work in this area. Presently, only the Indian Air Force is working in the field of aerospace medicine at their centre in Bangalore. More needs to be done in this area. A better understanding of global cultural and linguistic differences among the Indian workforce will therefore facilitate space tourism in India.

CHAPTER

4 Safety, Liability and Insurance

Safety and reliability are of paramount importance to any transportation industry, but for human spaceflight (transportation) they may become the defining issue of the industry's success or failure. Spaceflight is seen as a risky endeavour, and the tragedies involving the U.S. space shuttles Challenger and Columbia reinforced the association of space with danger in the minds of the public, with no distinction being made between orbital and suborbital flights. In this Chapter, safety issues in relation to spaceflight are discussed. After the occurrence of any odd accident, various liability issues may arise. They are also discussed along with role of insurance in managing risks and thus promoting transportation for human spaceflight.

4.1 SAFETY ISSUES RELATED TO SPACEFLIGHT

Outer space is an inherently dangerous place - it is not a suitable habitat for the survival of human beings. In space, a human being is exposed to levels of radiation far greater than he gets on the Earth; the lack of gravity causes bloating and loss of bone mass and many people become disoriented. There is no breathable air in space, so people need to carry air with them in order to be able to breathe. But, that also means that humans in space are constantly exposed to the danger of leaks in their spacecraft, leaks caused by impacts, etc. And, if something should go wrong with their air handling system, immediate suffocation and death is almost guaranteed to happen.

Then, there are dangers involved in the process of even getting to space. Space is a relatively very tough way up, so high rates of acceleration are needed to overcome the gravitational pull of the Earth and to get there within any reasonable timeframe. This exposes the human body to speeds and forces to which it is unaccustomed. Moreover, there are dangers in returning from space primarily due to strong forces exerted on the human body as a result of the interaction between the Earth's atmosphere and the spacecraft.

A spacecraft in orbit moves so fast that heat is generated upon its re-entry into the Earth's atmosphere. So much heat is generated during re-entry that it can damage or destroy the spacecraft unless some heat-shielding is used or other protective measures are taken. This is evident from the loss of the two U.S. space shuttles: the Challenger was destroyed on launch, and the Columbia upon re-entry. The Challenger was torn apart by atmospheric forces when hot gasses leaked from one of its external fuel tanks causing its eventual explosion. The Columbia was lost when atmospheric forces ripped it apart after structural failure due to burn resulting from damage to its heat protecting tiles. During the Soviet era, the U.S.S.R. also lost several of its cosmonauts in space re-entry and landing failures.

4.1.1 Technical Factors Related to Space Safety

4.1.1.1 Thermal Protection Systems Design (Heat and Conduction)[16]

As mentioned above, when spacecraft travel at high speeds through the Earth's atmosphere they generate high temperatures on their surfaces due to frictional heating. Thus, space vehicles must have thermal protection systems (TPS) to protect them from this heat.

4.1.1.2 Spacecraft Design Structures (Newton's Law)[17]

The structural elements that hold an (aero) space vehicle together must be strong and as light as possible in order to minimize the amount of fuel needed to get to orbit. Engineers continually to strive to develop new materials and methods for structural design of spacecraft. "In practice a lift to drag ratio of 7 means that a thrust force equal to 1/7th of the weight of the aircraft is sufficient to support it in flight. This low thrust requirement significantly reduces the amount of fuel required to carry the weight of an aerospace plane in comparison to rocket launch systems which must provide thrust greater than the weight of the vehicle."[18]

4.1.1.3 Electrodynamic Propulsion Systems (Electromagnetism)[19]

Current rocket-fuelled propulsion spacecraft are expensive to launch because of the weight of the fuel that they have to carry. Also, the amount of fuel that can be carried is limited by the amount of physical space available on the spacecraft. Engineers are devising a system that uses the Earth's natural magnetism to push satellites into higher and lower orbits around the planet using an electronic conducting wire or "tether"

4.1.1.4 Personal Satellite Assistant (Forces and Motion)[20]

This challenge is based on a new NASA technology called the Personal Satellite Assistant (or PSA). This technology is currently being developed at NASA's Ames Research Centre and when complete, will be a robotic assistant for astronauts while on the International Space Station. It will be able to propel itself around the microgravity environment by using small propulsion fans and will assume many tasks, such as monitoring and recording air quality, temperature, atmospheric pressure, and humidity, among a list of others.

4.1.1.5 Living off the Land: Water Filtration Challenge (Properties and changes of properties in matter)[21]

The functions of an Environmental Control and Life Support System (ECLSS) include: atmosphere revitalization; atmosphere control and supply; temperature and humidity control; water recovery and management; waste management; and, fire detection and suppression. The purpose of an ECLSS is to provide these needs when outside the Earth's biosphere.

These and other technologies and processes are being developed to minimise (if not eliminate) the safety risks that are involved in space travel. However, the hard fact is that space travel cannot be made fully fail-proof. If accidents could happen, they would happen. Consequently, such accidents will give rise to legal issues, one of which would be the question of liability for injury to humans and damage to property caused by space transportation system failures.

4.2 LIABILITY FOR DEATH, INJURY AND DAMAGE

In the event of any accidents, there are broadly two types of liability issues that come into play namely, civil liability and criminal liability. Civil liability deals with allocation of liability and compensation issues arising out of space operations under the applicable legal framework of international and national rules and regulations. Criminal liability, on the other hand, essentially involves the punitive consequences of human actions in space operations which are carried out in breach of the law.

4.2.1 Civil Liability

In relation to civil liability, the most important international space treaties are the 1967 Outer Space Treaty[22] and the 1972 Liability Convention[23] which bring under their umbrellas the entire array of issues arising out of launching (including the attempted launching) of space objects (which include component parts of space objects or launch vehicles) and assign liability to the launching State(s)[24] for damage[25] caused to a third party as a result of such activities. They cover liability issues for both pre-orbital and orbital accident/damage. The Liability Convention ascribes to the launching state absolute liability for damage caused on the surface of the Earth and to any aircraft in flight (i.e. pre-orbital damage) and fault liability for damage caused elsewhere (meaning orbital damage). Liability in the case of injury or damage caused by space debris is covered under the Liability Convention, though it may not be easy to determine the launching State(s) because of the difficulty in identification of the origin of the damaging space debris. However, an attempt may be made to take advantage of the 1978 Registration Convention[26] to assign liability to the State of registry (which will also be the launching State having jurisdiction and control over the space object concerned) if the space debris causing such damage could be identified on the basis of its registration under this Convention.

There has been a conscious attempt on the part of different States to bring about national regulatory frameworks for implementing their international obligations relating to liability arising out of space activities.

India has ratified the 1967 Outer Space Treaty, the 1972 Liability Convention, and the 1978 Registration Convention. Consequently, the Government of India could be held liable under the 1972 Liability Convention to third parties if launch-related injury or damage is caused by a space object for which it is the launching State. However, India does not have a national space law in place that devolves its international liability unto the space agency or private entity actually engaging in the space activity that causes damage; thus the Government of India would remain liable to pay compensation to a third party and might not be in a position to claim reimbursement from the entities due to whose action it was successfully held liable. One reason for the absence of national space law on liability is that commercial space launches are conducted by the Indian Space Research Organization and not by the private sector. However, when space launches are carried out from Indian launch sites, India currently provides third-party insurance of up to US$ 100 million. This figure may vary in relation to the expected trajectory of the space launch and an estimate of the likely damage an accident could cause.

Many other countries, like Australia, Japan, the U.K., Russia, South Africa, South Korea, Sweden, and the U.S., have taken steps towards delineating the civil liability of the space agencies from their respective States. It should be noted that the U.S. has the most advanced and complex legal regime governing liability matters in relation to space activities, including space travel. Some aspects of the U.S. law are discussed below to serve as illustrations of the most important legal issues and possible solutions proposed through national law.

4.2.2 Criminal Liability

In the conduct of space tourism, criminal liability may arise in one of two ways. First, it may arise when passengers aboard a space vehicle destined for pre-orbital or orbital destinations commit offences. Secondly, criminal liability may arise when passengers who are availing themselves of, utilizing or staying on board a space station or platform commit an offence. The international legal regime of outer space comprising the five international space treaties[27] do not specifically provide for criminal liability. As such, in the first scenario, guidance may be sought from the different international aviation security instruments adopted primarily pursuant to the initiatives of ICAO.[28] However, it should be noted that they will be applicable to space tourism operations only if the vehicles used can be categorized as "aircraft". These international legal instruments while creating the special criminal jurisdiction of, and in some cases an international duty upon, the State of registry in respect of or arising out of offences and other acts which endanger the safety of civil aviation, have also introduced a system of universal jurisdiction in international law and granted particular rights, functions and entitlements to the pilots-in-command which they did not possess earlier under international law. This issue, however, reveals another very important aspect relating to the scope of authority and power to be vested in the commander of a space tourist vehicle. It may be advisable to adopt the same scheme in connection with the application of criminal jurisdiction, liabilities and vesting of authority in the commander, as they basically address the handling of misconduct or criminal behaviour on the part of passengers in civil aviation.

An answer to the second part of the issue, which deals with criminal liability and/or jurisdiction on space stations or platforms may be found in the multilateral agreement between the five Partners States to the International Space Station venture, commonly known as the Inter Governmental Agreement of 1998 (IGA).[29] The 1998 IGA is the first exhaustive legal document dealing with different aspects of space activities. Generally, criminal matters are dealt with under the respective national criminal laws and jurisdictions. However, matters relating to criminal liability and/or jurisdiction over crimes occurring on the space station have been given a somewhat uniform treatment under Article 22 of the 1998 IGA. Article 22 not only provides that Partner States "may exercise criminal jurisdiction over personnel in or on any flight module element who are their respective nationals,"[30] but also allows other Partner States to prosecute the perpetrator in certain cases. This means that no perpetrator of a criminal act could escape prosecution by taking advantage of his/her national criminal legislation or the absence of an extradition treaty. Once this framework is fully implemented, criminal jurisdiction and liability issues in the operation of space tourism could be easily and properly addressed.

Since the IGA will not be applicable to suborbital and orbital flights that are not in any way related to the ISS, a new international treaty has to be negotiated. Moreover, since India is not party to the 1998 IGA, it needs to work out some international arrangement to cover criminal liability matters in connection with space tourism flights operated under its jurisdiction and control or from its territory.

In order to manage all risks, including possible liability, an insurance scheme ought to be followed. The most developed space regime covering space safety risks and insurance is that of the U.S. In the sections that follow, some relevant aspects of this regime are very briefly discussed to provide an example of the solutions that might possibly be adopted by India.

4.3 LIABILITY AND INSURANCE[31]

The issue of providing insurance for space travellers has been dealt with under U.S. law by a 2004 amendment to the 1984 *Commercial Space Launch Act*.[32]

4.3.1 Liability Insurance for Spaceflight Participants under U.S. Law

Under U.S. law, human spaceflight operators are required to take out liability insurance for death, bodily injury, or property damage to third parties.[33]

The insurance must include within its coverage contractors and subcontractors of the spaceflight operator as well as the United States government. There is, however, no indication that spaceflight participants must also be covered under the insurance.[34] While not mandatory, the spaceflight operator may choose to commit itself contractually to protecting the spaceflight participants against third party liability. Spaceflight participants are also not considered beneficiaries of the mandatory third party liability insurance required under the amended *Commercial Space Launch Act*.[35]

The U.S. government provides potential indemnification for third party liability in excess of the insured amount (i.e. liability which surpasses the amount of insurance or demonstration of financial responsibility but does not exceed US$2.5 billion).

4.3.2 Statutory Waiver Against Liability

Under U.S. law, there is a statutory waiver that generally restricts a satellite customer from suing its launch provider. However, this waiver does not apply to human spaceflight. When the U.S. Congress added the human spaceflight provisions to the *Commercial Space Launch Act* in 2004[36], it decided that the passenger, referred to as a "spaceflight participant,"[37] would not need to waive its right to sue the spaceflight operator. This leaves the spaceflight operator exposed to risks. The spaceflight operator may request spaceflight participants to agree to a waiver of liability as part of the spaceflight agreement. But in the event of an accident where the spaceflight participant is killed or injured, such waivers might be challenged, especially given the lack of federal statutory support. Waivers of liability for negligent conduct are generally disfavoured by U.S. courts. Furthermore, some U.S. States (e.g. New York) have laws that simply prohibit waivers of liability in contracts with recreational and similar establishments.[38] At the very minimum, such waivers must use precise, plain, and unequivocal language and must be unambiguous, specific, conspicuous, and explicit.

The spaceflight operator is required by law to inform the spaceflight participant of the risks "of the launch and re-entry, including the safety record of the launch or re-entry vehicle type," and the spaceflight participant must provide his or her "*written informed consent*." When all these procedures are complied with, they amount to a voluntary assumption of the risks normally inherent in spaceflight on the part of the spaceflight participant.

4.3.3 Protection of Spaceflight Operators from Liability

To encourage human spaceflight and help attract spaceflight operators to spaceports in their respective territories, the States of Virginia[39] and Florida have enacted legislation that seeks to immunize spaceflight operators from liability. The legislation achieves this object by exculpating spaceflight operators from claims brought by spaceflight participants for injuries or damages sustained as a result of materialization of the risks of spaceflight activities except in cases of gross negligence or wilful misconduct. Both statutes require the spaceflight participant to sign a warning statement.

4.3.4 Insurance for Space Fight Participants/ Operators

So far, the space tourists who have visited the International Space Station reportedly took out their own insurance.[40] A number of U.S. companies such as Virgin Galactic, Blue Origin, and XCOR Aerospace are now at various stages of design, testing, development, and prototyping of commercial suborbital vehicles intended to carry people into space and back.[41] While these companies initially may require spaceflight participants to obtain their own insurance, at least some are presently considering models for providing, or offering at a premium, insurance to their spaceflight participants.

Spaceflight operators are also evaluating ways to protect themselves against liability from claims by spaceflight participants or their survivors or financial sponsors (the sponsor may be required to agree to a liability waiver), subrogates, and others.[42]

4.3.5 Space Tourism Insurance Market

The insurance industry has been accepting the risks inherent in the space industry for coverage since 1965.[43] Space insurance has been available for satellite launching activities. In view of the high level of risks inherent in space activities, the availability of insurance has been a critical element for the involvement of private parties. Two main types of insurance exist for space activities: insurance of space objects and liability insurance (including third-party liability and product liability). Insurance of space objects can be further differentiated as follows: 1) pre-launching insurance; 2) launch failure and initial operation insurance; and 3) insurance of the space object itself.

Human space travel has its set of risks and liabilities associated with it: what if something happens to the craft and it lands in the territory of another country; who pays; sabotage can never be negated. With such kinds of danger many insurance companies could gain some valuable business while securing the interests of all involved.

In March 2007, it was reported that BUPA Travel Insurance Company was considering the space tourist market as its next project in the area of commercial insurance. A BUPA travel spokesman then commented: "We are looking into space tourism as a real market for the next generation of travellers, especially as Russian cosmonauts have already taken tourists into space."[44]

The insurability of suborbital transportation will depend on a combination of factors including: (a) Management team; (b) Technology platform; (c) Testing (the price for cover will depend on the safety reliability of the venture which will be established during the testing phase); (d) Established training standards for maintenance personnel and crew including pilots; and, (e) Passenger training for emergencies.

With private companies routinely taking passengers to space and back, the availability of insurance would become a necessity for purposes of re-assuring passengers, companies providing such services as well as the general public. Insurance companies would therefore play the key role of relieving space travel service providers, their investors and the tourists of the financial risks inherent in this expensive and risky venture so that they in turn can focus on the development of the industry.

Obviously, insurance companies are expected to be hesitant in providing cover for human space travel due to the low levels of revenue expected to be generated from a single flight especially at the initial stages.

Though space tourists (spaceflight participants) are not legally obliged to waive their right to sue the space flight operator, but the operator may require the tourists to waive liability claims through signing written informed consents. [45] It should be noted that waiver of liability through informed consent might be challenged in several States of the U.S. Thus space tourists will essentially be 'flying at their own risk.' On the other hand, the tour operators will be responsible for procuring insurance coverage for damage to uninvolved third parties upto an amount to cover a "maximum probable loss" as assessed by the FAA. Damages above this limit will be paid by the U.S. government under a scheme similar to what governs today's commercial satellite-launching industry.[46]

Despite the high insurance premiums that might be required of space tourism operators, people are very optimistic about the future of space travel. In its present stage, this young industry requires support from various corners. The insurance industry is indispensable to space carriers, given the high market value of spacecraft and the great financial risks involved. Previous experience shows that the space insurance industry hinges closely on the evolution of space technology, and vice versa.

4.3.6 Space Travel Insurance in India

At present, Indian satellites launched from foreign countries are insured with New India Assurance, a public sector Indian company that has been the traditional insurer for ISRO's projects. Since the risk involved is huge and complex, not many private insurance companies have taken keen interest in it. This company could double as a potential insurer for the space tourism sector in India otherwise, globally, space insurance is provided by the Allianz group. However, the Allianz group has recently entered into joint ventures with Bajaj, therefore it is possible that Bajaj-Allianz may accept space travel projects for coverage in India.

In order to encourage and support space tourism in India, the Government of India should consider the introduction of: (a) a statutory waiver of liability by spaceflight participants through the requirement of 'informed consent' or liability caps, as is the case in the U.S.; and, (b) legal protection for spaceport operators in India against claims by spaceflight participants for injuries or damage resulting from the materialization of the risks of spaceflight activities as has been done in Virginia and Florida in the U.S. This will require the passage of new legislation or at the very least, the amendment of relevant existing statutes to address issues of actionable legal rights, jurisdiction and forum. In addition the Ministry of Finance should to allow the domestic insurance industry and its regulator room to develop insurance products suited to the unique needs of the emerging space travel sector.

CHAPTER

5 Regulatory Requirements and Compliance

Legal and political considerations are fundamental to the establishment of any emerging industry. Without governmental support, an appropriate regulatory regime and organisational framework (i.e., regulatory body or authority), even the most innovative of ideas rarely develop to become commercially exploitable. This is even more pronounced when those ideas involve new technology or risky activity. This Chapter addresses the role to be played by the government in facilitating the starting up or in stimulating the development of the space tourism industry. In line with the specific theme of this Study Report, the Chapter focuses on what regulatory requirements will be needed to kick-start a new space travel venture in India.

5.1 REQUIREMENTS OF THE LAW

5.1.1 International Obligations

5.1.1.1 Passage of Objects during Ascent and Descent Trajectories

Under Article 1 of the *Convention on International Civil Aviation*, adopted in Chicago in *1944 (*Chicago Convention), to which India is a party, each State possesses complete and exclusive sovereignty over its territory, including the superjacent airspace. Therefore, all objects that venture into the territory or airspace of a State (including aircraft) must seek the prior permission of the State being over flown unless such permission has been previously granted under any relevant bilateral or multilateral international treaty to which the State of the object (aircraft) and State being overflown are parties.

In similar fashion, there is no existing rule of customary or conventional international law permitting free passage of space objects through the airspace over the territory of a foreign State during their ascent and descent trajectories. Therefore, it will be imperative for States interested in initiating and operating space tourism activities (including India) to seek the required permission of those other States through whose airspace their space objects may pass well in advance, preferably through bilateral means, a new international treaty or by appropriately amending the Chicago Convention.

5.1.1.2 Harmonizing Safety Standards at the International Level

Since vehicles involved in the conduct of space tourism, particularly those used in orbital flights, might 'fly' to and from the territories of foreign States, they would be required to comply with the safety requirements of all the States whose respective territories will be the place of departure, place of destination or will be overflown. As discussed below, the U.S. and some European countries have already started the process of drafting and adopting such harmonized safety standards. Since uniformity of technical standards and procedures for space travel vehicles and spaceports will be imperative for the success of the space tourism industry, it will be in the interest of all those countries, including India, to strive to achieve such uniformity through international bodies like the International Civil Aviation Organisation (ICAO), which has extensive expertise and experience in setting technical standards and procedures for civil aviation. This would require the broadening of ICAO's mandate to cover outer space which concerns of all mankind. In other words, the role of harmonizing safety standards at the international level in relation to space tourism should be assigned to ICAO.

5.1.1.3 International responsibility and liability for National Space Activities

Under the 1967 Outer Space Treaty, to which India is also a party, States are internationally responsible for the space activities of both their public and private entities. In addition, they are under obligation to ensure that the space activities of their non-governmental entities (i.e. private companies) are carried out in conformity with the provisions of the Outer Space Treaty. Therefore, various space-faring nations have enacted domestic (national) laws the most important object of which is to ensure that private companies conducting space activities within their territories respect the international obligations assumed by the State under those treaties. In general, these laws impose licensing requirements upon private companies engaged in or intending to engage in space activities. To ensure compliance with these requirements, such national laws typically impose heavy penalties and sanctions for violation of the licensing requirements prescribed therein.

Moreover, under the Outer Space Treaty and the 1972 Liability Convention both of which have been ratified by India, it is the State and not the public entity or private company conducting space activities that will be held internationally liable if injury or damage is caused by any spacecraft belonging to such an entity or company. Thus, there must be in place some sort of national legal framework under which the Government of India can recover any monies paid to third party States or entities on account of damage or injury caused by the space activities of a private company or other entity operating from within the territory of or under the jurisdiction and control of India.

5.1.2 National

In order to give effect to those international agreements that India has entered into in relation to space tourism and for the purpose of regulating space tourism in India, the enactment of a new special national law might be required as there is no special legislation addressing space activities in India at present. Since by its own terms, the *Indian Aircraft Act* of 1934 applies exclusively to aircraft, its provisions would not apply to the crafts that could be used in the conduct of space tourism. The Act could, however, be amended appropriately to govern the conduct of space activities such as space tourism (i.e., those space activities that involve space transportations systems akin to air transport).

Article 253 of the Indian Constitution empowers Parliament to make any law applicable to the whole or any part of the territory of India for implementing international treaties, agreements and conventions.[47] It enables the Government of India to domestically implement all of its international obligations and commitments. It should be noted that in 1950 when the Indian Constitution was adopted, its drafters did not have the benefit and/or foresight of the advanced technologies that we have today that enables people to explore and use outer space. Accordingly, there is no mention of phrase "outer space" in the Constitution of India. However, for the last five decades Indian Government through its Department of Space (including ISRO) has been carrying space activities without any constitutional challenge to its jurisdictional authority. Thus one can assume that the Constitution needs no amendment in order to operate, or regulate space related activities like space tourism by private entities, by any ministry or department of the Government. The Central Ministry of Aviation seems to be a logical body to undertake this responsibility but perhaps it should be renamed as Ministry of Aerospace.

The new laws to be enacted should deal with all the relevant aspects of space travel including: compulsory registration of spacecraft; nationality; marking; fitness of spacecraft; air worthiness/space worthiness; medical standards; licensing of space crew and safety precautions for launching; liability; and, technical standards.

5.1.3 Role of National Regulatory Bodies

National regulatory bodies of different countries would play a significant role in their respective jurisdictions to ensure the safe and efficient operation of space tourism, particularly by implementing and ensuring compliance with the relevant international and national legal requirements and safety standards that have been outlined above. To illustrate the proper role of a national regulatory body, we refer in the sections that follow to the examples of the Federal Aviation Administration in the U.S., (an agency within the Federal Department of Transportation which has been designated as the main regulatory body for space transportation, including space tourism) and the European Aviation Safety Agency (EASA).

5.1.3.1 The Federal Aviation Administration (FAA) in the U.S.

a. In order to promote the emerging space tourism industry, and to create a clear legal, regulatory, and safety regime, the United States Congress passed the Commercial Space Launch Amendment Act of 2004 (CSLAA thereby amending the Commercial Space Launch Act of 1984)[48] and mandated the FAA to regulate the space tourism industry. As a result, the FAA is authorized to oversee, license and regulate all aspects of commercial launch and re-entry activities and the operation of launch and re-entry sites (spaceports) carried out by U.S. citizens or by anybody else from within the territory of the United States. The FAA exercises this responsibility in line with public health and safety, safety of property, and the national security and foreign policy interests of the United States. The FAA is also responsible for encouraging, facilitating and promoting commercial space launches by the private sector.

b. During the deliberations that led to the enactment of the Commercial Space Launch Amendments Act of 2004, the U.S. Congress found that: space transportation is "inherently risky" and that the public interest would be served by creating a "clear legal, regulatory and safety regim e."[49] Congress also expressed the opinion that launch licensees/permittees (the operators) would have to obtain written "informed consent" from "spaceflight participants" (SFPs),[50] a new term invented to refer to space tourists or passengers who are interested in travelling to space during the experimental stage or aboard experimental vehicles. Section 460.45 of the FAA's final rule, which became effective on 13 February 2007, expressly states that:

"...before receiving compensation or agreeing to fly a space flight participant, an operator must inform each space flight participant in writing about the risks of the launch and re-entry, including the safety record of the launch or re-entry vehicle type. For each mission, an operator must inform a space flight participant, in writing, of the known hazards and risks that could result in serious injury, death, disability, or total or partial loss of physical and mental function. ... The operator also must disclose that participation in space flight may result in death, serious injury, or total or partial loss of physical or mental function. An operator must inform each space flight participant that the United States Government has not certified the launch vehicle and any re-entry vehicle as safe for carrying crew or space flight participants. If there is a separate operator for each vehicle, each operator must provide this statement for the space flight participants on its vehicle."[51]

According to these new FAA regulations, an operator is under obligation to inform an SFP of the risks related to launch, re-entry as well as known hazards and risks that could result in serious injury, death, disability or total or practical loss of physical and mental function. Operators are also required to disclose all hazards. Following disclosure, the SFP must sign an informed consent form. In the absence of strict and rigid regulations and certifications to ensure safety of the space travellers, the SFP is not fully protected and is deemed to be aware of and to have voluntarily assumed the risks inherent in space travel by having agreed to sign the form related to 'informed consent.' 'Informed consent' is "the legal doctrine that governs the risk involved in the space industry and which a SFP may face." [52]

c. Safety measures in the design and construction of experimental reusable Launch vehicles (RLV's): The FAA issued Guidelines for Experimental Permits for Reusable Suborbital Rockets (herein after referred to as the Guidelines) in May 2005. The Guidelines were consequently finalised in 2007.[53] Although not binding, the Guidelines address the various matters expected to be reviewed and evaluated by the FAA in an application for an experimental permit. The guidelines also identify the safety measures that the FAA would expect a permittee to comply with while conducting permitted activities.[54] In developing the Guidelines, the FAA designed its strategy to account for the unique needs of experimental flight testing of reusable suborbital rockets, while preserving the benefits of redundant safety approaches. The Guidelines include a variety of safety measures (hazard analysis) aimed at protecting the public.[55]

d. The U.S. Department of Defense, the National Aeronautics and Space Administration, and the aerospace industry have successfully used hazard analyses for decades to identify, characterize, and analyze hazards and reduce risks to acceptable levels. The Guidelines include the following criteria to determine the acceptability of risks: (i) the occurrence of any hazardous condition that may cause death or serious injury to the public should be extremely unlikely; and, (ii) the likelihood of an occurrence of any hazardous condition that may cause major property damage to the public, major safety-critical system damage or reduced capability, decreased safety margins, or increased workload should be remote. In developing qualitative criteria to assess risk, the FAA incorporated industry practice and existing government standards.

5.1.3.2 The European Aviation Safety Agency (EASA)

In 2008, EASA unveiled its proposed regulatory approach to suborbital vehicles, which have been classified or designated as aircraft[56] and not spacecraft. Under those proposals, designers and operators of such vehicles will have to be fully certified in respect of matters such as operations, flight crew and passenger licensing, and continued airworthiness even before commencement of their first commercial flight. Rules CS-23 and CS-25 are being put forward with special conditions as the certification route and any certifications issued could be type-limited. The U.S. Federal Aviation Administration rules, which have already attained the status of law, do not require vehicles to be certified before first use and that state of affairs is unlikely to change well into the next decade.

5.1.3.3 The Office of the Director General of Civil Aviation in India

Keeping in view the immense financial expenditure and logistical challenges involved in the setting up of new governmental institutions at the national level and the current state of the Indian economy, it is preferable that the regulatory duties associated with space tourism be assigned to the existing regulatory body which has been dealing with, and is thus conversant with such matters in the aviation sector. In line with the foregoing, we recommend that the regulation of space tourism in India should be assigned to the Office of the Director General of Civil Aviation (DGCA). Due to its strategic position in civil aviation, and its immense expertise in promulgating rules and regulations governing civil aviation in India, the DGCA can play a vital role in the encouragement and regulation of the space tourism industry in India. As a model worthy of emulation, the U.S. approach to the regulation of commercial space launches and all other aspects of space tourism could provide good examples for the DGCA. This will not only minimize the expenditure but also provide a sound basis for the development of the space tourism industry in India.

In addition, India should make concerted efforts in the international forum to expand the mandate and jurisdiction of ICAO to cover space tourism, (at the very least over such space tourism activities that have a direct impact on the safety of civil aviation). It is interesting to note that on a proposal by Dr. Sanat Kaul, in his capacity as India's Representative to the ICAO Council, a preliminary study was carried out by ICAO in 2005 on the Concept of Sub-Orbital Flights.[57] The Study concluded that "Vehicles which would effect earth-to-earth connections through sub-orbital space could incorporate the constitutive elements of aircraft and fly as such at least during descending phase while gliding ... The Chicago Convention applies to international air navigation but current commercial activities envisage sub-orbital flights departing from and landing at the same place, which may not entail the crossing of foreign airspaces. Should, however foreign airspace(s) be traversed, and should it be eventually determined that sub-orbital flights would be subject to international air law, pertinent Annexes to the Chicago Convention would in principle be amenable to their regulation." Therefore, ICAO could be expected eventually to get involved in the international regulation of some aspects of space transportation.

CHAPTER

6 Present and Future Challenges

At this point in time, it is still too early to paint a comprehensive picture of the state of the space tourism industry in India. In practice, any effort to put together a business plan for the conduct of space tourism in India will be faced with a variety of roadblocks. This Chapter identifies and discusses existing and future impediments militating against the viability of a space tourism industry in India.

6.1 AVAILABILITY OF APPROPRIATE SPACE VEHICLES

By definition, a vehicle that can be used in the conduct of space tourism is one that can safely transport passengers to an altitude higher than 100 km above the surface of the Earth. This is believed to the altitude at which space begins, meaning that the passengers can experience weightlessness. Currently, the global space tourism industry is at the preliminary stage of developing different kinds of vehicles capable of transporting human passengers into sub-orbit. There is not in existence a fully developed, confidently safe and dedicated spacecraft capable of being used to offer space travel to human passengers on a commercial basis. This factor alone creates a lot of uncertainty when one attempts to assess the viability of the space tourism sector.

6.2 LACK OF PUBLIC INTEREST

For purposes of determining the level of "space enthusiasm" of respondents and to ascertain any possible relationship between the demand for public space travel and the general interest in space, our survey questionnaire asked respondents about their past participation in terrestrial space-related activities. Respondents were asked if they had ever visited a space launch site or a planetarium, and whether they had ever attended at a space shuttle launch or participated in space camp. The total number of such activities that each respondent indicated having participated in previously was used to gauge the level of his or her interest in space.

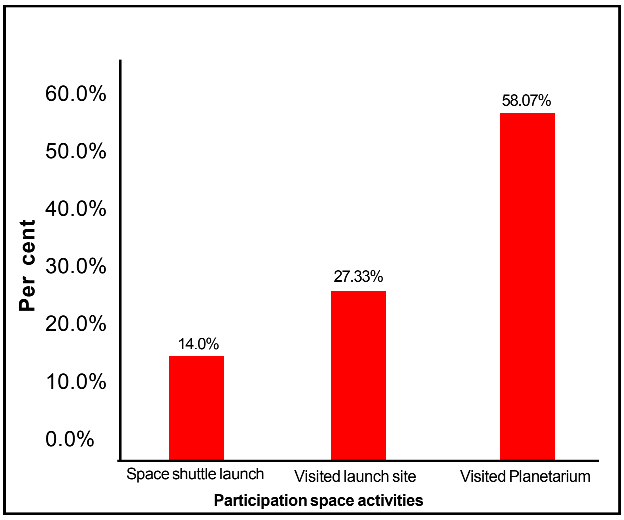

Figure 10: Interest in Space Activities

Of all the space-related activity options presented, the greatest percentage of respondents (59%) indicated that they had visited a planetarium; about 27 % had visited a launch site and about only 14 % had participated in a space shuttle launch. Taken together, these responses show that only a fraction of the population has an active interest in, and inclination towards space activities. (see Figure 10)

To some extent, however, the lack of public interest in space activities can be ascribed to the absence of awareness about commercial space activities in the context of leisure and travel/tourism. Lately, the great majority of Indians only think about 'space' in connection with 'cyberspace' since that is the perspective from which space activities are most visible.

Moreover, people's interest in space activities can be stimulated with the help of media. Things like reality shows in which the winner gets a free ticket for suborbital travel could further enhance the interest of the public in space. Besides those, things like awarding frequent flyer points redeemable for free space travel could also attract space tourists. Already, Virgin Galactic is offering such promotions.

6.3 THE GREEN FACTOR

The vehicles to be used for space tourism will produce a variety of green houses gases, the most important of which will be carbon dioxide (CO_2) and we will address only these emissions. Space tourism operators need to document the CO_2 emissions resulting from their flights and supporting operations in a holistic way. Initial calculations show that a typical suborbital flight using technology similar to that of the Bristol Spaceplanes Ascender will produce three tonnes of carbon dioxide per flight per passenger and Bristol Spaceplanes suborbital flights will produce CO_2 emissions equivalent to a London to New York.[58] It is interesting to look at the effects of scaling up the suborbital space tourism industry. A recent study published by Futron predicts that there will be up to 852 flights a year out of the New Mexico spaceport. If on a global basis, we assume that there would be 3,000 flights a year with 6 passengers on each flight and 3 tonnes of emissions per passenger, the total emissions per annum will be 54,000 tonnes. By way of comparison, this is equivalent to the emissions produced from 5 days of continuous operation of a 500MW gas-fired power station, or from 3 days of electricity consumption if UK consumers leave their electrical items such as TVs on standby. In contrast, British Airways produced 16,132,000 tonnes of emissions in 2005 mainly from its flight operations.

The carbon dioxide emissions from an orbital trip to the ISS on a Soyuz launcher have been estimated to be 143 tonnes per passenger.[59] Clearly, any scaling up of orbital tourism will not use Soyuz technology. It is interesting to note that the global space tourism industry has already recognized the environmental impact of its operations and is taking steps to mitigate them. Virgin Galactic for instance has stated that its spaceplane will use renewable energy and may even be a net energy producer, a feature which could make it "carbon negative".

6.4 ESTIMATING THE COST OF SUBORBITAL FLIGHTS AND FINANCIAL PLANNING

As shown in Table 5 below, the design, development, testing, evaluation and production of five spaceships and two mother ships is estimated to cost around US$ 350 million.[60] Virgin Galactic has signed a production agreement with Mojave Aerospace Ventures to use the Mojave spaceport for twenty years at a total cost of US$ 27.5 million.[61] According to rules proposed in the U.S. a company offering suborbital travel services would incur costs of about US$ 2,384,676 for 10 years,[62] therefore in the span of twenty years it would incur costs of US$ 4,769,352. The operating cost for such type of space vehicle would be about US$ 600,000 per launch[63] and each launch would have six suborbital tourists. Therefore the estimated head cost per passenger per flight would be US$ 0.12 million. However it has been assumed that due to future technological advancements, this head cost would be reduced to US$ 0.09 million per passenger. Presently, the marketing costs being incurred by Virgin Galactic is assumed to be US$1,800,000 per year. We have assumed that by 2013, this marketing cost would also decline by 25% to US$ 1.35 million. Based on the foregoing estimates, we have computed the expected cash flow for a company which would launch 104 spaceflights to meet the demand of 624 tourists per annum between 2010 and 2020.

Table 5: Cost Structure of a Company Operating Suborbital Trips

Nature	Cost Items	Amount in million US$
Fixed Cost	Design, Development, Testing, Evaluation & Production (5 SS2+2 WK2)	350
	Spaceport Lease charge (20 yrs)	27.5
	Regulatory Cost(20Yrs)	4.769352
Variable Cost	Operating Cost/pax	0.09
	Marketing Cost/year	1.35

For this computation, in Table-6 below we have assumed that the company would disburse an amount of US$ 132,269,352 in the year 2010; as payment for research and development, spaceport lease and regulatory charges. It will also incur other costs of US$ 250 million till 2012. In 2013 when the price of such travel has declined to US$ 150,000 it is expected that the demand for suborbital travel in India will increase. If this company is able to meet the hypothetical demand of 624 Indian suborbital passengers per year then the expected cash flow would be US$ 93.6 million.

By the year 2020, it is expected that the company would lower its operating and marketing costs by a further 25% from US$ 0.09 million to US$0.06 million/launch and US$ 1.35 million to US$0.09 million/year by 2030.This cost reduction due primarily to technological advancements would in turn lead to price reductions. If competition in this sector increases, it is assumed that the company will lower the ticket price to US$ 100,000 per passenger.

Table 6: Expected Cash Flows for Suborbital Trip

	Expected Cash Flows	
Year	Expected Revenue (Inflow)	Expected Cost (outflow)
2010		-132.269352
2011		-100
2012		-150
2013	93.6	-57.51
2014	93.6	-57.51
2015	93.6	-57.51
2016	93.6	-57.51
2017	93.6	-57.51
2018	93.6	-57.51
2019	93.6	-57.51
2020	93.6	-57.51
2021	62.4	-38.34
2022	62.4	-38.34
2023	62.4	-38.34
2024	62.4	-38.34
2025	62.4	-38.34
2026	62.4	-38.34
2027	62.4	-38.34
2028	62.4	-38.34
2029	62.4	-38.34
2030	62.4	-38.34

On this expected cash flow we find that Net Present Value would be US$ -168.28 million for operations up until 2030 assuming the rate of interest to be constant at 10%. Therefore we can conclude at this stage that it might not be advisable to invest in this venture as the company would incur a loss of US$ -168.28 million. If we calculate the Internal Rate of Return (IRR) for this expected cash flow we find that it comes out at 2 %. Therefore it can be said that, at present, it is not profitable to operate suborbital flights in India for tourism given the cost structure.

6.5 ESTIMATING THE COST OF ORBITAL FLIGHTS AND FINANCIAL PLANNING

Our cost structure is based on the inferences of an economic model known as the "Cost and business analysis module" (CABAM) and "Launch marketing for normal ordinary people" (LMNOP) developed at Space System Design Laboratories at the School of Aerospace Engineering of the Georgia Institute of Technology and published in September 2006 by the American Institute of Aeronautics and Astronautics.

According to this Study, a hypothetical company operating under certain assumptions would have the cost structure shown in Table 7 below:

Table 7: Cost Structure of Company Operating Orbital Flights

	Optimistic	Most Likely	Pessimistic
DDTE (Design development testing and evaluation)	100	225	300
TFU(Theoretical first unit cost)	52	66.5	84
Fixed Operating Cost /year	5	5.75	6.8
Variable Operating cost/flight	5.5	49.6	76
Facilities Development cost	30	50	100
Number of Flights	5	12.5	30

The following assumptions are made for purposes of financial planning based on the cost structure of the company:

a. The company is vertically integrated and is developing the vehicle, acquiring the fleet and operating the ground and operating activities to provide the experience of orbital travel to the consumer.

b. This model has analyzed only the cost of the transport operator. Any space destination/ hotel operator in space is not factored in the analysis.

c. The initial operating capability of the project is assumed to be 2013 with DDTE starting from 2010; fleet acquisition and ground handling occurring from 2011-12 and 13 years of flight operations (i.e., till 2025).

From the foregoing, we obtain three scenarios of expected cash flows for the company: Optimistic; Most likely; and, Pessimistic. Taking the analysis further, we have incorporated several relevant factors in our financial estimates in order to arrive at the Net Present Value (NPV) and Internal Rate of Return (IRR) for the three scenarios. See Table 8 below:

Table 8: Sensitivity Analysis of Cost Structure of Company Offering Orbital Trips

Sensitivity Analysis

	Optimistic	Most likely	Pessimistic
NPV@10%	US$ 472.93 million	US$ ($519.46) million	US$ ($3,560.44) million
IRR	45%	Negative	Negative

For the optimistic situation we see that NPV and IRR are US$ 472 million and 45% respectively. A positive NPV signifies that investment in the venture is quite good. NPV at 10% shows a profitable venture and IRR at 45% shows that market fluctuations cannot have much effect on the profit margin of the company engaged in this business.

In the "most likely" scenario, the estimates show a negative NPV (i.e. US$ -$519 million and IRR is also negative. This is because variable costs would have increased by 150% thus making the venture a loss-making one. It is advisable not to set up a business in this venture unless there is a dramatic reduction in the cost.

With regard to the "pessimistic" scenario, the estimates show a negative NPV (i.e., US$ -$3,560 million) and IRR is also negative. Negative NPV suggests that it would not be profitable to do business under this scenario whereas the negative IRR suggests that it is not at all viable to finance this project. As the variable cost in our model is assumed to increase by about 600% from US$ 200 million (optimistic) to US$ 1200 million (pessimistic), this in turn changes NPV values from positive to negative. Thus, feasibility analysis of this business is much dependent on what will be the variable cost of providing this service.

To conclude, it can be safely said that orbital space tourism will be a really good venture to invest in if the variable costs of providing this service falls within the range of optimistic estimates as shown in Table 8 above. However, if the variable cost falls within the "most likely" or "pessimistic" scenarios, then the viability of providing orbital flight service would become questionable.

6.6 LACK OF ENTREPRENEURIAL INTEREST

So far, the financial analysis demonstrates that NPV for suborbital travel at 10% rate of interest is negative and IRR is merely 2% which shows that no prudent entrepreneur would like to venture into such a project. However, various secondary sources of revenue such as theme and virtual reality space parks; space camps; training, production and launch recovery facilities parks; trip training facilities etc have not been considered.

While in the case of orbital travel it has been found that under the optimistic scenario, cost estimates show a very promising return, a slight variation in the type of vehicle used could result in high fuel costs which will immensely affect the feasibility of the project. Thus, the viability of space tourism is primarily dependent on the type of vehicle which will be available to transport passengers.

Therefore to boost entrepreneurial interest in this sector, it is imperative for the government to waive or reduce the tax burden in the initial years and to provide subsidies for research and development in the space tourism sector.

Although there are at present significant roadblocks which are hindering the growth of space tourism in India, it is believed that in the coming decade, demand for space tourism will become established and grow in India. The growth will most likely be attributed to the grovelling Indian economy. The Indian economy is going to add millionaires at the fastest rate in the world. This statement provides optimism for the commencement of the space tourism industry at least from demand side. All that is required is to address the supply-side challenges.

CHAPTER

7 Findings and Recommendations

7.1 NUMBER OF TOURISTS

This preliminary pilot Study has established that demand for suborbital travel in India could dramatically increase from a projected figure of approximately 4000 suborbital tourists in 2013 to approximately 50,000 tourists in 2025. If the industry is able to meet all of this projected demand for suborbital travel in India, expected revenue would amount to an estimated US$ 629 million in 2013, and this is further expected to increase exponentially to US$ 4,975 million by 2025.

With regard to orbital travel, supply side constraints need to be taken into consideration since at present it is only the Russian Soyuz technology that can be used to provide such travel. Accordingly, the estimated demand for orbital travel in India involving the use of Soyuz capsules is estimated to be 2 tourists in 2010, increasing to a maximum of 8 tourists by 2025. Consequently, the expected revenue from orbital travel in India is estimated at US$ 40 million in 2010, increasing to US$ 160 million by 2025.

The foregoing revenue forecasts are based exclusively on the hardcore operations of spaceflight. Various ancillary revenue sources like theme and virtual reality space parks, space camps, training, production and launch recovery facilities parks, trip training facilities, and other such public quasi-entertainment facilities have not been included in the revenue forecasts. In the civil aviation industry, such ancillary sources of revenue are extremely important for the sustenance of operators. In similar fashion, if such ancillary sources are included in the estimation of revenues to be derived from space travel the resulting picture would look very promising.

Besides, in order to attract private investments in the space tourism industry, the government should provide tax benefits, subsidies for research and development during the initial phases of the industry's establishment. This will allow the industry to create new jobs and as well enhance India's global credibility as a high-tech, fast developing nation.

7.2 COST

In order to start up a business venture to cater to the demands of the suborbital travel market in India, it is estimated that an organization would incur the following costs: US$ 350 million for design, development, testing, evaluation and production of five spaceships; US$ 32.2 million for regulatory and lease charges; US$ 90,000 per passenger for operating costs; and US$ 1.35 million for marketing costs. It is therefore possible for a business venture to successfully operate in this sector. However, the estimated IRR of 2% indicates that the return on investment in the sector is very low.

With regard to cost estimates for orbital travel, three scenarios were identified, namely: "optimistic", "most likely" and "pessimistic". A hypothetical company offering orbital travel under the optimistic scenario would have IRR of 45% which indicates that the orbital travel sector under that scenario is a very attractive sector to invest in. On the contrary, if the company or organization operates under the "most likely" or "pessimistic" cost scenarios, it will have negative IRR. To conclude, it can safely be said that on the whole, it is risky to invest in the orbital travel sector in India at this stage.

7.3 TARGET MARKET

Presently, space travel is affordable only to the affluent segment of society. Only people with discretionary net-worths greater than US$ 1 million can afford to participate in such type of travel. Therefore, as part of this Study, a survey was conducted to determine, among other things, the level of interest in space activities that each of these eligible individuals constituting the target market has. The raw data obtained from the survey was analyzed and it was determined that males are more likely to have an interest in space travel than females. Therefore, any effort to kick start a space tourism business venture in India must first target high net-worth male individuals as potential customers. Also, since nearly two-thirds of the sample used in conducting the survey fall within the 50-70 age group, it is recommended that this age group should form the initial target customer group. In addition, it is important to target young professionals in the 25-35 age group who are not yet HNIs, but are nevertheless eagerly looking for new and exciting things to do.

The Study finds that demand for orbital travel is present in India – the survey responses indicated that at least two tourists could be expected to participate in orbital travel using Soyuz capsules, and marketing for such type of travel can be done in India. Meanwhile, we also found that if more flights for orbital travel were to be operated by private ventures they would be of more interest to our target respondents.

For suborbital travel, the study determined that the respondents who expressed interest in such type of travel were extremely sensitive to changes in the price. Hence, our demand forecast for suborbital travel increases in 2013 when it is envisaged that the price will be reduced to US$ 150,000. Thus, we can find that, at present, orbital travel is more attractive than suborbital travel to high net-worth Indians. However, extensive advertising may improve the demand scenario for suborbital travel.

7.4 TYPE OF VEHICLE AND LOCATION PLANNING

We infer from our technical analysis report that horizontal take-off and horizontal landing (HTHL) vehicles are the most appropriately suited for suborbital travel; it has been established for instance that a vehicle such as Virgin Galactic's SpaceShipTwo is feasible both technically and commercially. Currently, there are 335 unused or underused airports in India some of which can be converted into spaceports. Ideally the expansion or transformation of Mumbai airport into an airport/ spaceport would be the most desirable option for the purpose of facilitating the establishment of the space tourism industry in India.

For orbital travel, however, vertical take-off and landing (VTVL) vehicles may be the most appropriate, at least during the initial stages. In India, the Sriharikota launch centre can be developed into a state-of-the-art launch facility to enable vertical take-off and landing of such types of travel.

In order to offer space travel services from India, there are three options available: (a) Provision of service by a foreign operator; (b) Provision of service by an Indian company using foreign built vehicles; and, (c) Possibility of developing a vehicle in India by independent means or through a joint venture. Each of these options may be executed only when the existing regulatory impediments are removed.

For this purpose, a strong lobby must be created to convince Indian policymakers that the space tourism industry would be economically, socially and internationally beneficial to the country. It is interesting to note that in its *Annual Report 2008-09*, ISRO has indicated plans to realize "a Two Stage To Orbit (TSTO) fully re-usable launch vehicle," for which "a series of technology demonstration missions have been conceived [and] a Winged Reusable Launch Vehicle technology Demonstrator (RLV-TD) has been configured. The RLV-TD will act as a flying test bed to evaluate various technologies viz., hypersonic flight, autonomous landing, powered cruise flight and hypersonic flight using air breathing propulsion. First in the series of demonstration trials is the hypersonic flight experiment (HEX)."

7.5 SAFETY, LIABILITY AND INSURANCE

Liability rules are among the most fundamental concerns with respect to commercial activity because all parties must be aware of what their obligations, rights and remedies are before engaging in any activity. The quantum of liability can be classified as limited or unlimited and this would reflect the existence or otherwise of a cap on the amount of damages that can be paid. Under the current regime of international space law, State liability is the rule. This means that a launching State is internationally liable to pay compensation for death, injury, damage or destruction of property suffered by third parties as a result of the space activities of the launching State's private entities which are in breach of its international obligations. An ideal liability regime for injury and damage applicable to spaceflight transportation vehicles carrying passengers and cargo ought to make provision for different situations; (i.e. damage caused by collisions, damages to third parties on the surface of the Earth and damage caused to passengers).

The manufacturer of the vehicle and manufacturers of its component parts are obliged to design and manufacture safe products, and also to warn against the dangers of using of the product. If these obligations are not fulfilled, they could be exposed to product liability claims; claims in which it is alleged that the manufacturer of a product is in breach of his duty of ensuring that he delivers a reasonably safe product. It is therefore imperative that appropriate regulatory procedures are put in place (including the mandatory requirement of sufficient insurance coverage) in order to minimise liability risks and to encourage new ventures in the space tourism industry in India.

7.6 PRIVATE PARTIES UNDERTAKING SPACE TOURISM ACTIVITIES

Private companies and other entities can be entrusted with different activities in connection with space tourism. The price per ticket of trips to space would largely be dependent on the efficiencies of the private sector and continued progress with technological development. The role of the Government in the establishment of any new industry is to help the private sector develop and also to encourage the growth of domestic economies through progressive authorization, supervision and regulatory incentives aimed at facilitating the commercial growth of the industry.

It is significant to note that the aviation sector in India is maturing quite rapidly following the deregulation of the industry and the entry of private airlines. With the exception of Jet Airways and Go-Air, all the other private players (i.e., Kingfisher, Spice Jet, and Indigo) are typically owned by businessmen who have only recently diversified into aviation from other core businesses. Therefore, there is immense potential in selling the idea of space tourism to cash-rich business groups, especially entrepreneurs like Vijay Mallaya, Ajay Singh, Jeh Wadia and Rahul Bhatia, who have already demonstrated possession of cutting edge business acumen in venturing into hitherto new and unfamiliar business terrain.

7.7 INSURANCE FOR SPACE TRAVELLERS

The risks associated with commercial spaceflight are only likely to be covered by the commercial insurance industry once space vehicle designs are finalized, made safe, and operationally reliable. Unless expressly prescribed by law, space tourists or passengers (altogether referred to as spaceflight participants in the U.S.) may not be inclined to waive their rights to sue the spaceflight operator in the event of an accident causing death or injury. The spaceflight operator may insist that the spaceflight participant agree to a waiver of liability as part of the spaceflight agreement. However, the legal validity of such waivers may be challenged particularly in the aftermath of an accident in which a spaceflight participant who suffers death or injury is left without redress.

7.8 GOVERNMENT'S INCENTIVE TO FACILITATE THE DEVELOPMENT OF SPACE TOURISM IN INDIA

India has become one of the major space powers in the world particularly in the period since the successful launch of the Chandrayaan – I. The Indian space sector is being opened up for private participants and the nation has begun commercializing certain technologies and services internationally. The privatization and commercialization of space technologies in India make it imperative for the Government of India to adopt progressive public policies; to enact appropriate national space laws and regulations; and, to mandate and enable the Director General of Civil Aviation to encourage and regulate space tourism.

More importantly, the Government of India ought to show leadership in this field. In practical terms, this would require that the Department of Space/ Planning Commission/Ministry of Finance/ Ministry of Tourism/Ministry of Civil Aviation and the Prime Minister's Office will all have to come to terms with reality and agree to facilitate the establishment of such a futuristic and innovative industry. Equally, some identified State governments will also have to be part of the process since ground facilities will be located within their respective territories. Particularly, in order to attract private investments into the sector, the government should provide tax benefits and subsidies for research and development at least during the initial stages. This would enable the sector to generate employment and enhance India's global credibility as a high-tech, fast developing nation in the long run.

The Indian Institute of Space Technology, Thiruvananthapuram in Kerala inaugurated in 2007 should be encouraged and sufficiently supported in its effort to assist in the development of the appropriate human resources and critical space technologies for the future.

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End Notes

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[23] Convention on International Liability for Damage Caused by Space Objects (the "Liability Convention"); 961 UNTS 187; (opened for signature on 29 March 1972, entered into force for India on 09 July 1979).

[24] The term "launching State" means (i) a state which launches or procures the launching of a space object; and (ii) a State from whose territory or facility a space object is launched.

[25] 'Damage' is defined to mean loss of life, personal injury or other impairment of health, loss of or damage to property of States or of persons (natural or juridical) or property of international intergovernmental organization.

[26] Convention on Registration of Objects Launched into Outer Space (the "Registration Convention"); 1023 UNTS 15 (opened for signature on 14 January 1974, entered into force for India on 18 January 1982).

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on 22 April 1968, entered into force for India on 09 July 1979); and The Agreement Governing the Activities of States on the Moon and Other Celestial Bodies (the "Moon Agreement"); 1363 UNTS 3; has entered into force on 11 July 1984. India signed the Agreement on 18 January 1982 but has not yet ratified it.

[28] To summarize them: The first international instrument was the 'Convention on offences and certain other acts committed on board aircraft' signed at Tokyo (commonly known as Tokyo Convention,1963), followed by the 'Convention for the suppression of unlawful seizure of aircraft' signed in Hague (commonly known as Hague Convention,1970), 'Convention for the suppression of unlawful acts against the safety of civil aviation' signed in Montreal (commonly known as Montreal Convention,1971), 'Protocol for the suppression of Unlawful Acts of Violence at Airports Serving International Civil Aviation, Supplementary to the Convention for the suppression of unlawful acts against the safety of civil aviation done at Montreal' signed in Montreal (commonly known as Montreal Protocol,1988) and 'Convention on the marking of Plastic Explosives for the purpose of Detection' done in Montreal (commonly known as Montreal Convention, 1991).

[29] Agreement among the Government of Canada, Governments of Member States of the European Space Agency, the Government of Japan, the Government of the Russian Federation, and the Government of the United States of America concerning cooperation on the Civil International Space Station, 20 January 1998. (hereafter referred to as the 1998 IGA)

[30] Article 22(1) of the 1998 IGA.

[31] Mainly based on Pamela L. Meredith, "Commercial Space Transportation: Risk, Liability and Insurance," Abu Dhabi, April 16, 2009, available at http://www.mcgill.ca/files/iasl/Session_7_Meredith.pdf And: Michael C. Mineiro, "U.S. Federal Licensing and Regulation of Commercial Human Space Flight", downloadable from http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1368226

[32] Available at : http://www.faa.gov/about/office_org/headquarters_offices/ast/media/PL108-492.pdf

[33] 49 UNITED STATES CODE § 70112(a)(1).

[34] 49 UNITED STATES CODE § 70112(a)(4).

[35] 49 UNITED STATES CODE § 70102(21) excludes spaceflight participants from the definition of "third party."

[36] Commercial Space Launch Amendments Act, P.L. 108-492 (Dec. 23, 2004), available at : http://www.faa.gov/about/office_org/headquarters_offices/ast/media/PL108-492.pdf

[37] 49 UNITED STATES CODE § 70102(17) defines spaceflight participant as "an individual, who is not crew, carried within a launch vehicle or reentry vehicle."

[38] New York Laws: General Obligations: (5-226) *Certain Prohibited Contracts and Provisions Of Contracts; New York Agreements Exempting Pools, Gymnasiums, Places Of Public Amusement or Recreation and Similar Establishments From Liability for Negligence Void And unenforceable.* This provision declares void and unenforceable any agreements exempting recreation and similar establishments from liability for negligence : http://law.justia.com/newyork/codes/general-obligations/gob05-326_5-326.html

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[44] Daniel Peden, "Commercial Insurance for Private Space Travel A Serious Concern", http://www.urinfo.co.uk/commercial-insurance-for-private-space-travel-a-serious-concern/

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[46] Pamela L. Meredith, "Commercial Space Transportation: Risk, Liability and Insurance" at http://www.mcgill.ca/files/iasl/Session_7_Meredith.pdf

[47] Article 253 states: Notwithstanding anything in the foregoing provisions of this Chapter, Parliament has power to make any law for the whole or any part of the territory of India for implementing any treaty, agreement or convention with any other country or countries or any decision made at any international conference, association or other body.

[48] Commercial Space Launch Act of 1984, as codified and amended, 49 UNITED STATES CODE, Subtitle IX, Chapter 701.

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Participants; Final Rule, (2006) 14 CFR Parts 401, 415, 431, 435, 440 and, 460; U.S. Department of Transportation, Federal Aviation Administration. (emphasis added)

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[53] U.S., Department of Transportation, Federal Aviation Administration, 14 CFR Parts 401-437, *Final Rule: Experimental Permits for Reusable Suborbital Rockets*, available at http://www.faa.gov/about/office_org/headquarters_offices/ast/licenses_permits/sub_orbital_rockets/newregs/media/EP_FR.pdf

[54] To develop the guidelines, the FAA examined, for purposes of streamlining, the regulatory strategy currently used to license the launch of reusable launch vehicles (RLVs). This strategy combines three safety approaches:

(i) A licensee must demonstrate that the risk from a launch falls below specified quantitative collective and individual risk criteria,

(ii)A licensee must have a comprehensive system safety program consisting of both system safety management and system safety engineering, to identify hazards and reduce risks to the public, and

(iii) A licensee must comply with several operating requirements, developed by the FAA from lessons learned in the launch vehicle industry.

[55] Hazard Analysis: Under the guidelines, an applicant performs a hazard analysis and provides the results to the FAA. Typical elements of a hazard analysis include:

(i) Identifying and describing hazards

(ii)Assessing risk using qualitative severity and likelihood levels,

(iii) Identifying and describing risk elimination and mitigation measures to reduce the risk to acceptable levels, and

(iv) Demonstrating that the risk elimination and mitigation measures are correct, complete, and achieve an acceptable reduction in risk.

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