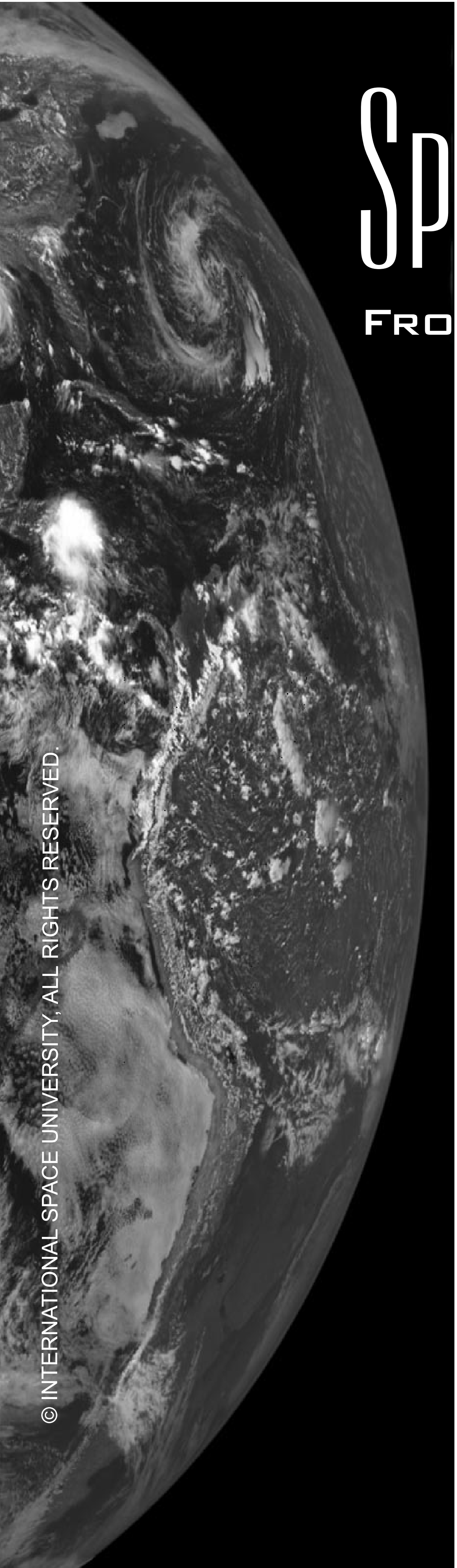
SPACE TOURISM

FROM DREAM TO REALITY



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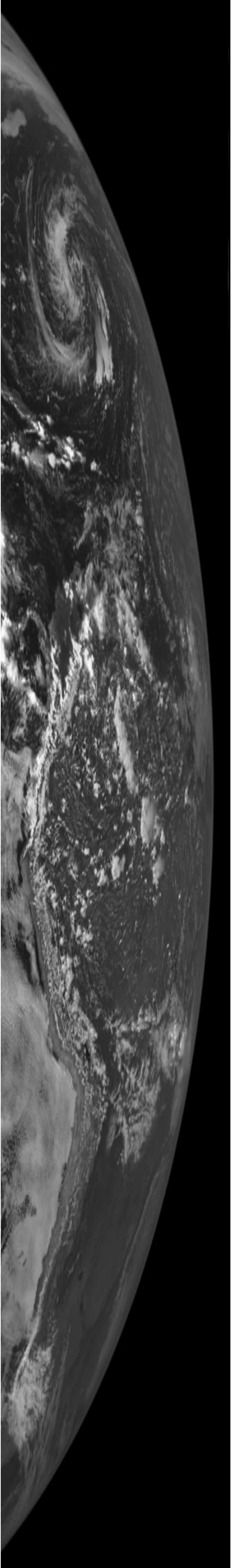
EXECUTIVE SUMMARY

INTERNATIONAL SPACE UNIVERSITY
Summer Session Program 2000
Valparaiso, Chile



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Nikolai Tolyarenko

Marleen Van Mierlo

Gudrun Weinwurm

And all the others who gave us their help and moral support.

Thank you all of the Faculty/TA's who helped and gave moral support.

The 2000 Summer Session of the International Space University was hosted by the Universidad Tecnica Federico Santa Maria in Valparaiso, Chile. This was ISU's first time in the southern hemisphere, and thus the first ISU Winter Session.

The cover depicts the Earth as seen from the eyes of the first space tourists. It is at once awe-inspiring, beautiful, and at least for now- it is our home. A student's spacecraft blueprint represents the dreams of tomorrow, the dreams we continually strive for. On the back cover, a painting depicts the elegance and romance of love with no bounds.

Shuxing Feng created the title, "From Dream to Reality." It is a reference to the dream in China of travelling to the Moon to visit the mystical princess who according to Chinese folk tales lives there.

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Cover Design by Patricia Garner.

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Additional copies of the Final Report or the Executive Summary for this project may be ordered from the International Space University (ISU) Headquarters. The Executive Summary also can be found on the ISU website.

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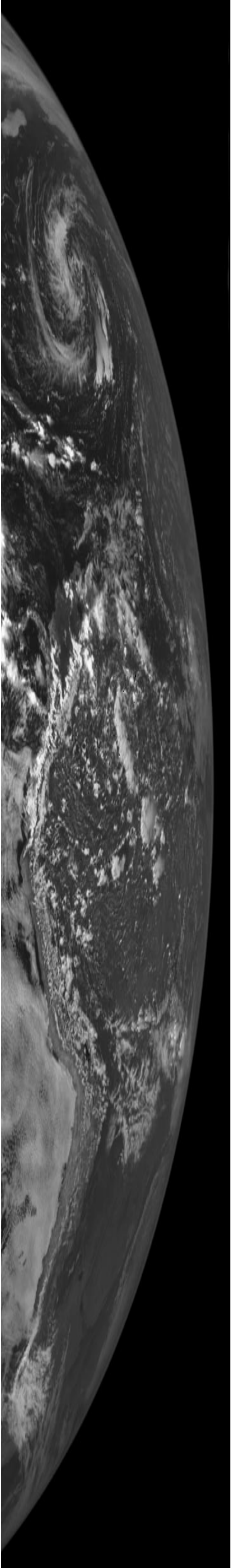
"Somewhere, something incredible is waiting to be known."

-Carl Sagan



World of Space Tourism

Turismo Espacial	*Rymdturism*
Space Tourism	Τουρισμός στο Διάστημα
Տիեզերական տուրիզմ	Uzay Turizmi
Tourisme Spatial	kosma spaco turismo
Ruimtetoerisme	अंतरिक्ष पर्यटन
Weltraumtourismus	Torism Spassial
宇宙旅行	תיירות חלל
Turisme i rummet	Turism spatial
Romturisme	Turasóireacht Spáis
우주 여행	***太空旅行***
Turismo spaziale	Vesoljski Turizem

Introduction

Over the course of human history there has always been a strong desire to travel and explore. During the recent decades people have ventured to the last remote areas on Earth. For the adventure tourist of tomorrow, space is the natural next step. For others, travelling into space is a dream in itself.

Our mission is to expand opportunities for humans to experience space by proposing a framework for tourism that is enduring, evolutionary and open to all.

Why is this important? Bringing a heightened sense of unity and environmental awareness to the general public, politicians and business leaders may help all create a better world back home. On an even more basic level, the beauty of space inspires us, as images from the moon, from space station MIR and the Shuttle already have. As more space farers share their experiences from the new frontier they will inspire a generation to reach for their dreams just as we were inspired to reach for ours.

The era of public space travel is approaching faster than most people think, driven by the human desire for adventure, travel and fun, and the economic motivation for creating a space tourism industry. Before this will happen, advancements in engineering, law and policy, and medicine must be made, as well as considering the issues involved in business and management. Public awareness of the possibility must be increased and worldwide excitement about space generated in order to make space tourism a reality .

This document summarises the main findings from the areas mentioned above that run through each evolutionary stage of space tourism:

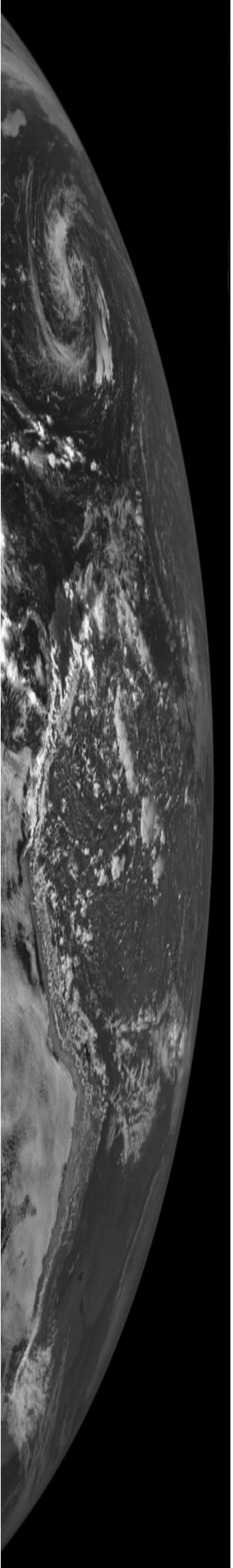
- Current space tourism activities
- Pre-orbital space tourism activities
- Low Earth Orbital (LEO) space tourism covering LEO flights and facilities - the focus of the project
- Future visions of space tourism

The beauty of the cosmos continually inspires wonder and curiosity. Throughout history, space has provided humanity with both practical benefits and fertile grounds for the imagination... Together with future generations, we will be the next explorers to unravel the mysteries of the universe

- United Nations

"The best way to predict the future is to invent it"

- Alan Kay



Client

What are the dreams and needs of future space travelers? Who will they be? Where will they go?

Current space related activities

Currently several possibilities exist for humans to start fulfilling their dreams about space. Only a few have enjoyed the ultimate thrill of being in space, yet there are ways to prepare people through simulations for this upcoming adventure.

Neutral Buoyancy Hydro Lab

A visit to a cosmonaut-training center or to a space camp gives the traveler the opportunity to experience many activities related to space and space exploration.

They can get the feeling of varying g-forces, similar to lift off and re-entry using huge centrifuges. In a *Neutral Buoyancy Hydro Lab* they can float in an environment similar to true weightlessness.

It is possible to fly up to Mach 2.5 and to reach altitudes of up to 25 km with Russian jet fighters. From this altitude the curvature of Earth can be seen. Flying a jet aircraft in a parabolic trajectory generates a microgravity environment that can be enjoyed by the passengers for up to 30 seconds per loop.

Zero g during a parabolic flight

Near term space tourism

Sub-orbital flights are expected in the near future. These flights will take people to the edge of space and offer the thrill of real space flight for the first time. They will provide the excitement of feeling weightless, the view of Earth below, and reaching the magic 100km mark.

High altitude balloons may also be a way to include a wider range of clients, offering a longer stay in the upper atmosphere.

Tourism in Earth Orbit

Going into space will be a memory that will last a lifetime.

To look at Earth from above is a wonderful dream and also one of the most impressive experiences cosmonauts/astronauts have on their spaceflights. During a stay in Earth orbit, travellers will enjoy views of the Earth, the stars and the Moon.

View from the Space Shuttle

Microgravity will provide a huge “playspace” for performing sports, games, weddings and experiments. Passengers will be able to conduct scientific studies, and thus become involved in the daily work of the cosmonauts and astronauts. This will raise their understanding and awareness of the usefulness of space.

According to surveys conducted on the needs and interests of travelers, the preferred duration time for a space flight ranges from 2 days to one week.

There should also be enough space inside the craft to satisfy the needs of the clients in terms of privacy and entertainment. This required volume strongly depends on the flight duration.

Well-equipped sleeping quarters as well as client-oriented hygienic facilities have to be provided for long duration flights.

To be able to provide all these different experiences and a comfortable environment for the travelers implies the need for an orbital entertainment and recreation facility.

Future Space Tourism

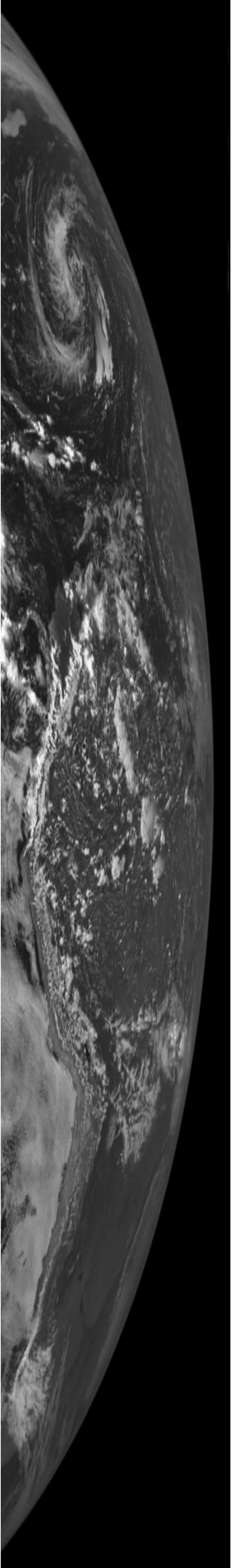
For the future space tourist Low Earth Orbit will not be a limit anymore. Space hotels with microgravity swimming pools and cruises to the Moon, Mars and other celestial bodies will be possible. Going into Outer Space will not be just a dream anymore: it will become reality.

Future holidays on Mars

The “pale blue dot” Earth looks so fragile and inspiring. The idea of “us” and “them” breaks down and only the overwhelming sense of “we” is left… a small planet united, floating in the cold harshness of space.

“Sure it is expensive… ...but what is the cost of an unfulfilled dream ?”

- Mike Saemisch



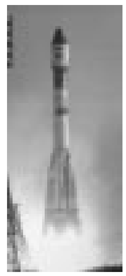
Engineering

The future possibility of space tourism is relatively promising, given the current state of technology for human spaceflight.

Current Space Technology

Currently, there are only two launch vehicles in operation that can carry humans into space: the Space Shuttle and the Soyuz, operated by NASA and Russian Space Agency, respectively. Both are mainly used for LEO missions.

Shuttle



Soyuz

The Space Shuttle consists of a reusable orbiter with two recoverable and reusable solid rocket boosters and an expendable external tank. It can carry a crew of eight people, but in case of an emergency it can carry two more. The current launch site is Kennedy Space Centre. The shuttle orbiter lands as an aeroplane, and can therefore be landed at airports.

Soyuz has three stages, and can carry up to three people into orbit. The current launch site is Baikonur. The Soyuz capsule descends with parachutes and lands on land.

There are also some other vehicles developed for transporting humans to space, but which are not used now:

Buran: Designed and built to carry two to four crew. Only five Buran Shuttles were built. It was cancelled due to lack of funds. (Russia)
Hermes: Designed to be launched on an expendable Ariane 5 booster, to carry three crew up to 800 km orbit, on missions of 30 to 90 days. Although much technology was developed, it was cancelled due to political and financial reasons. (ESA)
HOPE-X: Intended to be a small unmanned re-entry vehicle to be launched by H-IIA, the H-IIA Orbiting Plane Experimental (HOPE-X) failed twice in sequence. Development is currently on hold. (Japan)
Shenzhou: This is the unmanned test capsule in the development of a manned capsule under the name Project 921. It carried a dummy passenger and returned safely after completing 14 orbits. Currently, a manned flight is planned after a second unmanned flight. (China)

There are some other launch vehicles, such as Ariane 5, Titan, and Proton, which are not developed for manned flights but which may possibly be modified to accommodate humans.

Currently, liquid rocket propellant systems have an advantage over other types of chemical combustion, such that they have the highest achievable performance and can be operated during all phases of the flight. Solid rocket propellants are still used (mainly for lift-off) because of their high thrust. For space tourism, the use of solid propellant rockets will probably not be an option because of the fact that they cannot be turned off. The relatively high risk involved in the use of these systems is not acceptable.

Near-Term Technology Options

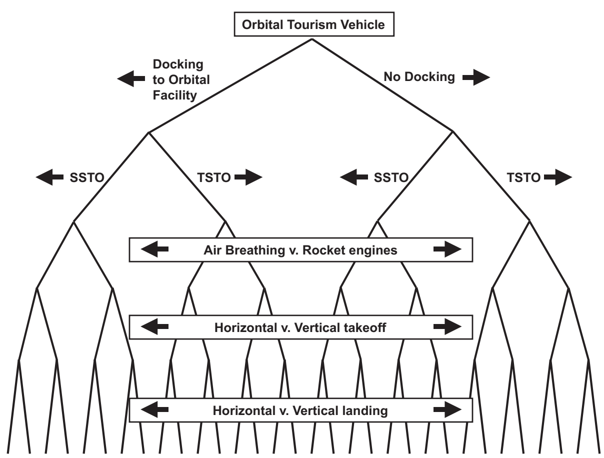
Two types of technologies, with further development, may be used to achieve space tourism in the Earth's outer atmosphere, within the coming five to ten years. These are:

1. High-altitude manned balloons
2. Sub-orbital flight technologies

The proposed concept for high-altitude passenger-carrying balloons is to use them to lift a pressurized capsule carrying three people to the stratosphere at about 40 to 50 km altitude. The air density at this level is 0.3% of the air density at sea level, which gives a view of a black sky together with the stars, even in daytime. Moreover, the Earth´s curvature is clearly visible underneath, with a field of view of about 1400 km diameter. The balloon would stay aloft for several hours. The navigation system would use GPS to position the craft. The descent would be performed by separation of the pressurized capsule from the balloon, at which time the capsule would start free-falling. During the initial phase of the descent, the capsule will fall through a region where the atmosphere is very thin, providing about 30 seconds of microgravity before atmospheric drag starts to decelerate the capsule significantly. The capsule should also have life support and descent-recovery systems as well as carrying a telescope for entertainment purposes.

The other option proposed for near-term space tourism is a two-hour duration sub-orbital flight, reaching altitudes of 80 to 100 km. This option would also provide the experience of weightlessness, Earth sightseeing from high up above, as well as a sense of being in space.

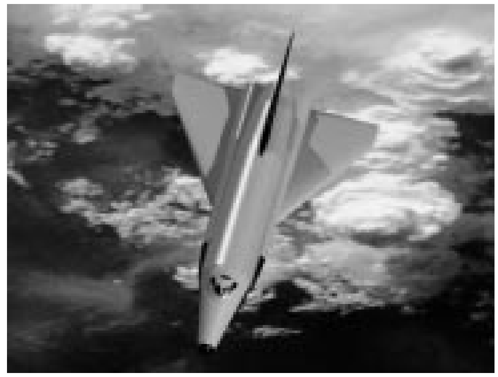
The vehicle to be used can be one that is built to meet the X-Prize requirements. The X-Prize is a privately funded competition that is encouraging the building of a vehicle capable of taking three passengers to an altitude of 100 km and repeating the trip within 2 weeks. One proposed vehicle is the Pathfinder rocket plane, which is a fighter-bomber-sized aircraft that can eject a payload in its upper stage to LEO. The payload system is suitable for development to carry a capsule of three passengers. As the flight is short (less than 2 hours), only a basic life support system needs to be designed to supply the manned capsule. Furthermore, the passengers will need to wear spacesuits. Pathfinder will take-off and land at an airport just like an aircraft. This means that the available ground infrastructure for air transport can be used with minor additions.



Configuration tree for an orbital tourism vehicle.

Orbital Space Tourism Technologies

There are a number of concepts to deliver tourists to orbit and return them safely to Earth. The first choice is whether to have a


Pathfinder

vehicle taking tourists to orbit and back or to have a transport flying passengers to an orbital facility and returning them after their stay ends. In the first case, the vehicle would need to be equipped with all necessary amenities for the passengers during the flight, whereas in the second case these could be located at the facility, making the transport a small and light vehicle.

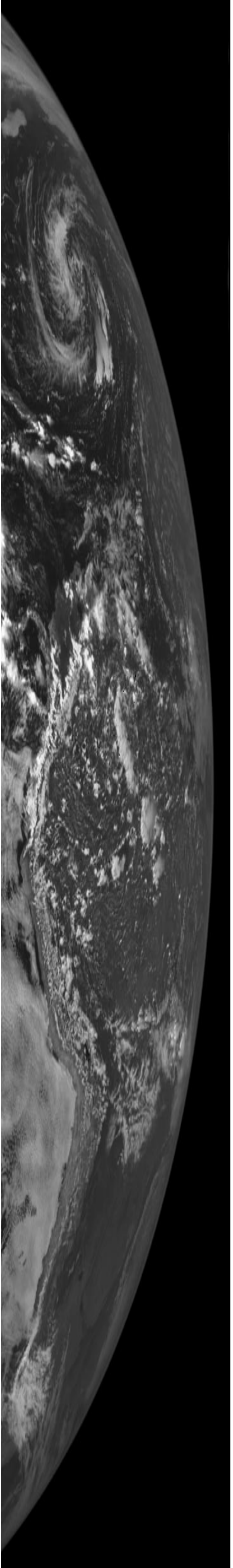
The trade-off is between saving on the recurrent launch costs by using a facility containing amenities against the higher initial launch costs to put the facility into orbit. The number of flights per year and the length of the stay in orbit are important drivers affecting this choice.

The second choice is the number of stages. Two Stages To Orbit (TSTO) vehicles would have a higher payload fraction but suffers from higher complexity from vehicle mating. Single Stage To Orbit (SSTO) vehicles would have simplified operations and logistics offering faster turnaround times and hence lower costs but would require the development of advanced materials.

The third choice is between air breathing engines and rocket engines. The former

"Problems…look mighty small from 150 miles up."

-Roger B Chaffee (US astronaut)



offers higher payload mass fractions but suffers from higher complexity. The latter offers higher thrust levels.

The last 2 choices concern the use of either horizontal or vertical orientation for both take-off and landing. Vertical launching will simplify the vehicle structure, as there is no lifting surface, adding to payload capacity. Horizontal launching will improve the safety as engine failures can be managed by gliding to an alternative landing site assuming a large cross-range capability. In addition, the vehicle will be able to fly in more varied weather conditions, reducing the number of cancelled flights, which will improve its market potential.

It is expected that many customers will want to view their home country. Since most of them will come from North America, Europe and Asia, it is necessary to choose a highly inclined orbit. However, high inclination orbits experience higher levels of space debris and radiation. The ISS has an inclination of 52 degrees. This gives a ground track that covers the USA, Japan, South America and Australia very well. Northern Europe and Canada are hardly covered, but this might have to be sacrificed for safety. At 50 degrees, the flux of space debris is much less, but the radiation in the South Atlantic Anomaly will still be a problem to deal with. The development of more accurate predictions to avoid solar particle events is preferred to the use of extensive shielding. However, risks to tourists may be minimised by only having trips during periods of low solar activity and avoiding travel through the radiation belts at an altitude of 200 km. The orbit altitude has to be optimised in terms of the V budget, considering atmospheric drag.

The probability of serious impact from space debris is estimated to be approximately 0.6 per million flight hours compared with aircraft all-causes accident probability of 0.3 per million flight hours. The Space Shuttle typically has to have four windows changed due to space debris damage. To satisfy customer requirements, there will be a larger window area on future passenger space vehicles than on the Space Shuttle. The need to replace damaged windows will increase turnaround times and maintenance costs.

There are 3 choices for the level of autonomy used on the space vehicle. A crewed vehicle would incur high costs due to the number of crews needed for frequent flights. Alternatively, a crewless vehicle would save money but would require preparation and / or selection of the passengers. The last alternative is an automated vehicle that has a trained professional who would be responsible for the safety and comfort of the passengers but would not control the vehicle.

A public space transport vehicle would need to meet safety requirements similar to those for commercial aircraft. In particular, the reliability of the engines must be improved compared with current crewed vehicles. It will be difficult but necessary to ensure a rate of 1 in-flight-shutdown (IFSD) per 20,000 hours flight time. The launch vehicle design must avoid the need for frequent unplanned long-duration maintenance periods which would make orbital trips less attractive.

Future launch facilities for reusable launch vehicles will require more optimal launch operations than current sites. A flight centre that services and launches the vehicle from the same location is preferable, as is planned for the X-33. Launch operations should be highly automated which will reduce costs. Future spaceports should have similar facilities to airports with infrastructure to handle take-off & landing, maintenance & parking, refuelling, traffic control, and handling of passengers, luggage & cargo.

An important issue for ground operations is whether a vehicle can be processed horizontally or has to be prepared vertically as with current expendable launchers. Horizontal processing is more convenient and less labour-intensive: an important factor when the flight rate is high and the turnaround time must be kept low.

The choice of propellant affects operations. There is experience of handling kerosene at airports whereas cryogenic propellants such as liquid oxygen require more specialised equipment for production and storage. Toxic propellants require special handling procedures and equipment.

A combined Air and Space Traffic Control (ASTC) system will need to be set up to prevent collisions between aircraft and spacecraft during launch, re-entry and landing phases. This could be done by extending the proposed new Air Traffic Control (ATC) system called the Automatic Dependant Surveillance Broadcast (ADS-B) system, enabling aircraft with GPS receivers to broadcast their position and velocity, to spacecraft as well as ground control.

Future space tourist vehicles will require aircraft-like operations to be profitable, needing advances in technology and a different design philosophy governed by maintainability and operations, rather than development and production optimisation.

Tourists will require greater habitable volume for comfort and recreation than astronauts have been allocated in the past. The Space Shuttle External Tank could be re-used to build a space facility. However, orbital maintenance of the external tanks is critical and out-gassing of the foam insulation is a concern. The TransHab inflatable module provides almost 3 times as much volume as conventional metal volumes after inflation. The multi-layer structure gives better protection than metal against space debris and provides good thermal insulation.

Noise levels inside a tourist facility should be below the level currently predicted for the International Space Station (ISS) and must be below the standard limit for occupational noise exposure (85 dB). Ventilation fans generate this noise. Hence, quieter fans must be developed. Permanent space facilities will require better personal hygiene capabilities for tourists than those available on the ISS. Sleeping quarters will require windows.

The ISS could be used for space tourism activities. Examples include communication with astronauts, flights to observe the ISS at distances of several kilometres to tens of kilometres and docking with the ISS with the possibility of stays at an additional habitat module.

Future Space Tourism Technologies

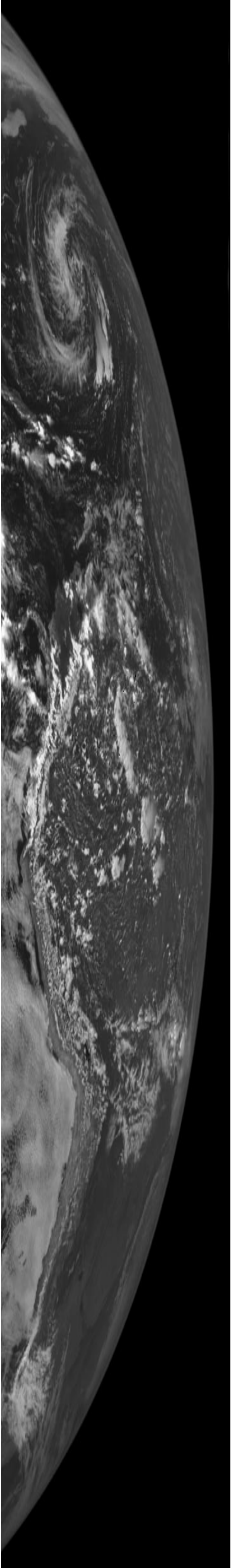
After we have accomplished orbital flights for tourists around the world and viewed our fragile planet from above, the demand from people is likely to force the market to grow from orbital flights to interplanetary flight, and to space hotels in orbit and on planet surfaces. Then, further into the future, we will be able to take lunar cruises and rest at a hotel on the Moon, enjoy cruises of Saturn´s rings, observe spectacular active volcanoes on Io, take advantage of package deals available for Mars, and eventually experience interstellar travel.

These futuristic ideas may presently be beyond our technological knowledge and ability. The crucial aspect of travel for these vast distances will always be speed. Numerous exotic ideas exist, which range from the more realistic to the more imaginative: ramjets using nuclear propulsion, electric (ion or plasma) propulsion systems, solar and laser sails, electromagnetic mass drivers, wormholes, antimatter energy, etc. There are also other issues to be overcome, such as minimizing the deteriorating effects of micro-gravity or zero-g on the human systems, and protection of both humans and spacecraft from the solar flares and cosmic radiation.

Space Tourism has been a dream up to now. However difficult, every achievement is a dream at first, and this is a project lighting the path from dream to reality.

"Circling the Earth in the orbital spaceship I marvelled at the beauty of our planet, 'People of the world! Let us safeguard and enhance this beauty, not destroy it!'"

-Yuri Gagarin, First Human in Space



Business & Management

The Market for Space Tourism

Tourism is the world's leading economic contributor, producing 10% of the world's gross national product, and is the sector generating the greatest amount of tax revenues at US$655 billion per year. Adventure tourism not directly related to space has been rapidly growing in popularity during the last 2 decades. Space-related tourism activities are very important for raising public awareness and interest in space tourism, thereby increasing the market potential for actual space tourism.

Few companies are currently planning to offer sub-orbital flights. Space Adventures is taking deposits for its $100,000 ticket-price sub-orbital flights anticipated for years 2002 or 2003. MirCorp is about to launch its first private " citizen explorer " for an 8-day stay on board the Mir Space Station. Several companies have concepts for orbital and lunar hotels.

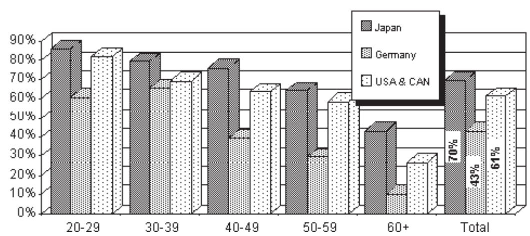
Once the near-term milestone of making publicly accessible orbital flights becomes a reality, many players from related service industries will enter this new market because the initial barrier of Reusable Launch Vehicle (RLV) development cost and its high associated risk will no longer exist. Examples of potential entrants include adventure tourism companies, travel agencies, airlines, ocean cruise line operators, hotel operators, resort companies and theme parks.

The economic rationale for the emergence of a space tourism industry is founded on two grounds - one is the stimulation of the space arena by opening a new market for RLVs, and the second is the establishment of a new global service industry. Estimates from market surveys suggest that a ticket price of the order of $50,000 or less is necessary for a space tourism industry to sustain itself. However, we estimate, that based on current technology, a future sub-orbital space trip, carrying two passengers would cost in the order of $550,000 per passenger. Hence, the estimated cost is approximately an order of magnitude greater than the price that a sustainable market will probably accept.

Although RLV development is the key to substantially reducing the cost of access to space, the high associated costs, significant political and technical risk, market uncertainty, and required long-term development timeframes provide major disincentives to potential private investment. Furthermore, subsequent to the costly development phase, a reduced ticket price, as a result of future profitability, is also dependent upon the achievement of low operational costs per flight. Uncertainties affecting the feasibility of eventual general public space travel and tourism business start-ups in the US include: market demand and elasticity; transport vehicle acquisition and operating costs; trip price; reliability and comfort; and insurance and regulatory burdens. Notional business models suggest that profitability of eventual large-scale service operations will depend on per orbital trip costs that do not exceed $1-2M.

Marketing

The market for transportation services is driven by customer demand, and innovation is similarly driven by potential new demand. The development phase of the project must start upon completion of the market analysis to specify the exact characteristics of the final product. At the beginning of operations, a space tourism business should have an incremental business plan, starting with niche markets. From market surveys, data indicate that many young people, from different cultures, are already prepared to go on very expensive "space adventure trips" at the present time, even though physical risk exists.



Percentage of respondents interested in taking a space trip. (Abitzsch, 1996)

Since expected initial high ticket prices will deter much of the general public, it is advisable for initial competitors in the space tourism industry to simultaneously target large corporations as customers as well as young, wealthy, adventurous individuals at the outset. Initially targeting the niche market of young adventure-seekers is of prime importance because of the higher inherent risk and the lower comfort levels early customers will be expected to accept in exchange for being among the first to explore this new frontier. By the time the orbital space flight industry becomes accessible to the rest of the general public, most people will have already been introduced to the product through secondary promotion by corporate customers offering sponsorships or tickets as prizes or rewards to their employees or client base.

Financing

Passenger travel services to and from space are not available today because government space agencies are not trying to develop them. Dramatic advances in propulsion systems and structures are needed to achieve the lowest unit cost vehicle that would lead to the development of a large service market. The probable costs to develop these systems will be high and government research and development co-investments are needed. Such technology developments or demonstrations are either too risky or too long-term for the private sector to undertake under normal market circumstances.

Several RLV ventures have stalled because of their inability to find investors to complete their development programs. Tax exemptions to support a broad range of innovation should be considered by governments so that all taxpayers will bear the risk as opposed to only the investors. The encouragement and enabling of space research for commercial purposes would generate a demand for using space, making a presence in space more attractive to industry. Auctioning access to space laboratories and transportation would indicate how much the market is willing to pay.

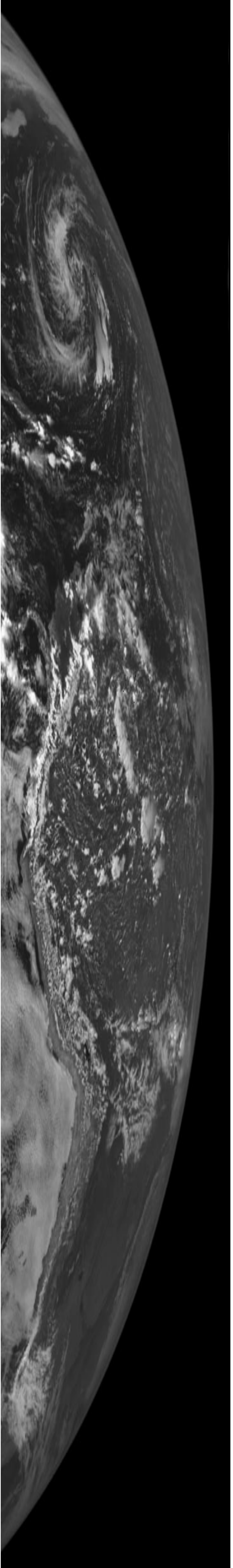
Once the viability of the industry is established, it is anticipated that the credit risk of initial competitors will follow that of current tourism or airline companies and shares in them will be publicly traded.

A stepwise approach is foreseen for X-Prize competitors, such that once the technology has been proved, further financing will be more easily secured to build the hardware that incorporates improvements for passenger transport certification. Investors will be interested in business plans that propose alliances between tour operators and aerospace companies as well as evidence of advanced booking from an adventurous and excited public. The rate of return demanded by investors for space projects ranges from 20-40% with investors usually preferring approximately 20% ownership. A payback period of 3 to 6 years is usually required. Nevertheless, regardless of the expected financial return, a well known and credible CEO(Chief Executive Officer) or key member on the board of directors with strong space industry recognition will be needed to convince investors to examine proposed business plans.

Future scenarios usually assume the world becomes wealthier, and it is expected there will be a larger market for space tourism with a wider and more exciting range of products. However, these products will have to be cost-effective in order to attract investors and costs musts be balanced by achievable revenues to ensure that these activities are self-sustaining.

"The future is not something we enter. The future is something we create."

- Leonard I. Sweet.



Medical

Space travel for civilian tourists poses medical challenges that are both similar to, and different from those faced by astronauts. The medical care provided by a space tourism venture must be tailored to passengers that are focused on leisure not on a mission. These passengers will not be as well prepared, both physically and psychologically, as current astronauts.

If an adequate customer base is to be maintained, selection standards for space tourists must be less stringent than for current astronauts. For very short duration sub-orbital flights, only guidelines similar to those for variable gravity rides (e.g. roller coasters) may be necessary. For orbital flights, the presence of active disease states (hypertension, heart disease, psychiatric illnesses and possibly pregnancy) may be necessary exclusion criteria in order to decrease the probability of expensive evacuation procedures. For the near-term, it is likely that space tourists will have to be physically able to perform emergency egress procedures to be accepted for space travel.

Prior to departure, space tourists should receive training in CPR (Cardio-Pulmonary Resuscitation) and first aid procedures. For safety reasons, pre-flight training should include coping strategies for feelings of isolation and claustrophobia. Personal hygiene has historically been a source of conflict on long-term missions. The pre-flight experience should bring all the tourists to similar standards before spending extended periods of time in the closed quarters of an orbiting space facility. Teamwork strategies and issues of multiculturalism should also be part of preflight training since the customer base for space tourism will likely be global.

As with current manned space missions, the space tourist should enjoy a pressurized cabin atmosphere with appropriate oxygen and carbon dioxide content, and a fail-safe system for toxic inhalant removal. As the duration of the space experience lengthens, life support systems should evolve from open-loop to closed-loop designs. Environmental noise, that has recently been a concern for the International Space Station, will need to be further decreased for customer satisfaction. The use of quieter fans and other onboard equipment should be considered for space tourism travel. For experiences of three to five days, tourists will require a habitable volume greater than the $10\ m^3$ per person offered currently by NASA´s Space Shuttle. To allow for recreational space, long-term missions will require volumes greater than the $175m^3$ per person predicted for the completed International Space Station.

Space motion sickness (SMS) includes nausea, headache and dizziness and can seriously preclude an enjoyable tourist experience if not counteracted. Two out of three astronauts experience SMS during the first hours in space, despite the use of pre-flight and in-flight anti-nausea medications such as scopolamine and promethazine. Preflight Adaptation Training devices are currently used to expose astronauts to the disjunctive visual and vestibular stimuli similar to those experienced in space. This device may give a head-start to the adaptation process and decrease the severity of SMS in orbit. Susceptibility to SMS is difficult to predict and appears to be independent of provocation during parabolic flights and ground-based training. It is reasonable to anticipate that SMS will be a concern for civilian space travel lasting longer than 2 hours. An improvement in the efficacy of SMS drugs would be a major advance in helping increase customer satisfaction.

The fluid redistribution that occurs during spaceflight causes facial puffiness, nasal congestion, and fluid loss. This fluid loss causes a low blood volume and orthostatic intolerance (fainting or lightheadedness caused by upright posture) upon returning from spaceflight. Orthostatic intolerance is currently counteracted by fluid loading prior to reentry and the use of anti-gravity suits. Future countermeasures to decrease the fluid redistribution may include lower body negative pressure suits worn during spaceflight and also simulated gravity.

A minimal reduction in total muscle mass can be expected after a space flight of three to five days. These losses occur primarily in the postural muscles of the lower extremities but are unlikely to impair the egress of tourists from the spacecraft in a 1-g environment. Countermeasures during a stay in space of that duration are not medically necessary, but are recommended to provide a full astronaut-type experience for the tourists and to accelerate full recovery after their return to Earth.

In missions of several months, lower extremity muscle atrophy of up to 30-40% has been documented. Bone calcium is lost at a rate of 1 to 3% per month. In the far future, very long-term microgravity exposure for tourists will require countermeasures for musculoskeletal degeneration. Current countermeasures include treadmill running with bungee cords, penguin suits (modified spacesuits) and other resistive exercises. The development of space facilities capable of providing artificial gravity using centrifugal forces will greatly improve the physical well-being of future space travellers.

Compared to the typical Space Shuttle orbit of 28.5 degrees, higher inclination orbits can traverse areas in which radiation hazards may be increased during periods of intense solar activity. Current countermeasures to decrease radiation risks are limited to predicting solar flares, setting exposure standards, and radiation monitoring. Some biologically-active antioxidant compounds are under investigation. For a mission beyond LEO, additional spacecraft shielding and onboard capabilities to monitor solar activity will be required.

Ground-based flight surgeons currently conduct private telemedicine conferences and assess crew health for the duration of space flight missions. Space tourists will require augmented support with additional access to ground-based physician specialists, possibly linked via a hospital network. The capability of transmitting various patient health parameters to the flight surgeon on Earth currently exists. Medical equipment to stabilize an ill or injured crew member is currently flown on spaceflights. The development of portable diagnostic imaging capabilities is recommended. Emergency vehicle should be docked with an orbiting facility to allow for a medical evacuation. In this way, a sick patient need not compromise the trip for the rest of the passengers. One of the staff members in orbit should also have medical training equivalent to a paramedic, in addition to fulfilling other duties for customer satisfaction.

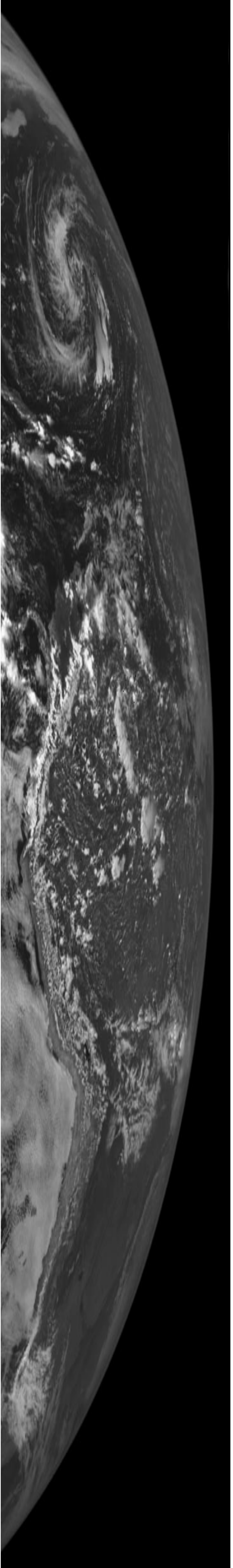
Finally, the day will come when space tourists will go beyond LEO. Issues related to radiation protection, long-term physiologic adaptations as well as self-sufficient life support systems will have to be resolved before that can become reality. Psychosocial dimensions of these activities include the birth of a new "space culture" that will set apart those who have experienced space travel from those who have not. Many ethical questions including those pertaining to medical care during interplanetary travel with limited capabilities will have to be raised.

In-orbit treadmill: a countermeasure to prevent bone demineralisation and muscle atrophy

"It's human nature to stretch, to go, to see, to understand.

Exploration is not a choice, really; it's an imperative."

-Michael Collins



Policy / Law

Space tourism development is not explicitly supported by governments. However, if there is a market for space tourism, it is the role of governments to fund the essential technology development that are too long-term and risky for private undertaking before the private sector is willing to invest. The challenge of a space tourism policy is to establish the technological and regulatory environment that will encourage private companies to invest in space tourism and allow commercial ventures to prosper. The expected result is the lowering of costs and the increase in reliability of access to space. In addition, it is beneficial to policymakers to support space tourism because of the potential economic benefits.

The first part to a space tourism policy is to confirm the market surveys about the public´s willingness to pay to travel to space and characterise people´s desire to travel into space. We suggest a discussion among public, political and space communities through various media and independent public surveys to raise the awareness of space tourism as a realistic activity.

A second part of a space tourism policy is to create a favourable scientific and technical environment. This policy includes life sciences research, development of low -cost technology, propulsion system improvements, fully reusable launch vehicle development and ground infrastructure studies for space transportation.

Finally, a favourable regulatory system will have to be created. One of the major regulatory barriers to space tourism is the Liability Convention (1971) of the United Nations Committee on Peaceful Uses of Outer Space. This treaty states that the launching country is liable to pay compensation for loss of life, injury, or damage to property, resulting from objects launched into space by that country. Therefore, the launching state is entitled to prohibit any private space launch activities. A possible solution would be to adopt a limited amount of compensation regulation, as defined by the Warsaw Convention (1929) for the aviation sector. This has been the main factor enabling the commercialisation of air transport.

However, limited liability is not sufficient and will never be accepted without guarantees of the safety of space tourism flights. For this purpose, detailed certification and licensing of the spacecraft will be necessary. Traffic regulations such as launch or re-entry authorisation will have to be defined as well.

All of the above will enable risk quantification and management for insurance purposes.

Furthermore, many additional regulations will be necessary including:

- Adaptation of aviation law to sub-orbital flight,
- Environmental law,
- Criminal law or tax law applying in outer space,
- Derogation of the Non-appropriation Principle of Outer Space, including orbits and planets.

Only after having solved these major political and regulatory challenges will space tourism be able to develop and expand as a self-sustaining undertaking.

Conclusions

Space tourism is currently at a very pivotal stage, with the potential to grow rapidly in the next three to four years. Governmental and public interest in space is increasing, as a result of millennial generated interest in the future. It is also reflected in the growing number of space related tourism activities. Additionally for some, going into space is no longer just a dream; it is starting to become a reality.

The gap between the current cost of launches and the cost needed to make space tourism a self-sustaining market must be closed. Today's launch technology is inefficient and complex to operate, and thus very expensive. The current commercial market for launchers is too small to promote the development of new technology. Space tourism has the potential to bring this cost down by creating a new and large market for reusable launch vehicles.

Governments and space agencies should invest in the research and development of reusable, safe and low cost launch vehicles. Private investors will also play a key role. Tourism is the largest existing industry worldwide, and space tourism would be worth the investment even over the long payback period typical for space projects. The development of such a robust industry would benefit space agencies, governments and businesses.

A favorable regulatory system will have to be created. Limiting the amount of compensation required by the Liability Convention of the United Nations may be an important step. Detailed certification, licensing, taxation, and air traffic control procedures for spacecraft will also be necessary.

From a medical perspective, there are no serious barriers for space tourism. The average civilian can safely go to space if she or he meets minimal medical selection criteria and receives adequate training and preparation.

Space tourism is the start of a new era of exploration and adventure. As we begin to experience space for ourselves, we will discover new insights into who we are and our place in the universe. In time, space will become accessible to all and humanity's vision of itself will evolve as we turn our dream into reality.

"May your future be limited only by your dreams."

-Christa McAuliffe