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General Public Space Travel and Tourism— Volume 2 Workshop Proceedings

D. O'Neil, Compiler

Marshall Space Flight Center, Marshall Space Flight Center, Alabama

J. Mankins, and I. Bekey, Editors

NASA Headquarters, Washington, DC

T. Rogers and E. Stallmer, Editors

Space Transportation Association, Arlington, Virginia

W. Piland, Editor

Langley Research Center, Hampton, Virginia

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PREFACE

This document is the second of two volumes that present the results of the Space Act Cooperative Space Travel and Tourism study conducted by the National Aeronautics and Space Administration and the Space Transportation Association during the past 3 yr.

Volume 1 contains the study's fundamental findings from the beginning of the study until the publication was released, and volume 2 the detailed findings of the multiday workshop conducted at Georgetown University, Washington, DC. Please note that the members of each of the workshop sections conducted their studies independent of each other.

In the nature of things, there is some overlap in interest between some of the sections. Because the general public space travel and tourism area is so broad and novel, a decision was made not to eliminate any redundancies—the full range of section-by-section findings and recommendations is presented. Because of the differing backgrounds of the members of each section and their different study approaches, the form of each section's report differs somewhat from that of the others.

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LIST OF ABBREVIATIONS

AAS	American Astronautical Society
AFTE	Autogenic Feedback Training Exercise
ASTP	Advanced Space Transportation Program
DOC	Department of Commerce
DOD	Department of Defense
DOT	Department of Transportation
EEL	Evolved Expendable Launch Vehicle
ECLSS	Environmental Control and Life Support System
FAA	Federal Aviation Administration
G	force of gravity
GPS	Global Positioning System
HRST	highly reusable space transportation
<i>ISS</i>	<i>International Space Station</i>
ISU	International Space University
LEO	low-Earth orbit
LH ₂	liquid hydrogen
lox	liquid oxygen
<i>MIR</i>	Russian Space Station
NASA	National Aeronautics and Space Administration
OSHA	Occupational Safety and Health Administration
PST	public space travel
R&D	research and development
RLV	reusable launch vehicle
SSTO	single stage to orbit
STA	Space Transportation Association
STAIF	Space Technology and Applications International Forum
STS	Space Transportation System (such as the Space Shuttle)
TRE	Torso Rotation Experiment
USAF	United States Air Force
VR	virtual reality

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**GENERAL PUBLIC SPACE TRAVEL AND TOURISM—
VOLUME 2 WORKSHOP PROCEEDINGS**

I. SPACE TRANSPORTATION AND DESTINATION FACILITIES

David Smitherman

NASA Marshall Space Flight Center
Marshall Space Flight Center, AL 35812

Wallace McClure

Boeing North American

A. Introduction

The Space Transportation and Destination Facilities section focused on space transportation vehicles—from use of existing vehicles to development of specialized transports—and on space stations, space business parks, space hotels, and other facilities in space of the kind that eventually would provide services for general public space travel (PST) and tourism. For both transportation and destination facilities, the emphasis was on the identification of various strategies to enable a realistic incremental progression in the development and acquisition of such facilities, and the identification of issues that need resolution to enable formation of viable businesses.

The approach was to determine the best (1) strategies for general PST and tourism development through the description and analysis of a wide range of possible future scenarios. With these scenarios in mind the section then identified (2) key issues to be explored, (3) opportunities to eliminate barriers, (4) recommendations for future actions, and (5) top-level requirements and characteristics for general PST and tourism systems and services that would guide the development of transportation and destination facilities.

B. Strategies for General PST and Tourism Development

In order to understand the full range of strategies that should be pursued, five scenarios, or possible futures, were developed that might lead to general PST and tourism system/services development. These scenarios represent the range of ideas that could lead to sound businesses. It was agreed that no single approach was right, but a combination of events would likely take place that would eventually lead to the creation of these businesses. Each scenario was then analyzed to determine the basic enablers, barriers, strengths, and weaknesses. The five scenarios are as follows:

1. Scenario 1—Government Investment Bootstrapping (Shuttle → X-33 → RLV → Orbital Passenger Transport → *International Space Station* → Destination Facility)

This scenario builds upon Government investments in technology and vehicle developments. As illustrated by the parenthetical items above, the Shuttle development and technology investments in the X-33 would lead to a reusable launch vehicle (RLV). This in turn would lead to the development of one or more orbital passenger transports needed for large-scale general PST and tourism. Likewise, the Government's development of the *International Space Station (ISS)* would precede the design of the basic building blocks for a public destination facility; i.e., a "hotel," either by utilizing part of the *ISS*, by refurbishing the *ISS* at the end of its program life, or by building a new facility based on *ISS* technology as illustrated by the Space Business Park presentations made in the workshop.

a. Enablers. The enablers to this scenario are seen to be the National Aeronautics and Space Administration's (NASA's) investment in the X-33, *ISS*, and advanced propulsion systems, and Department of Defense's (DOD) investment in a military space plane. The need for a robust highly reusable rocket engine and air-breathing rockets was also identified.

b. Barriers. The Government's control of these technology investments is seen as a barrier to general PST and tourism business creation because the Government seems primarily interested in lowering the cost of existing launch services to meet present needs, and not in opening new markets such as general PST and tourism. A good example of this problem is the current X-33 development, where it is noted that the X-33 industry partner is not considering the market potential for space travel and tourism, based upon publicly released information, but is focusing only on the existing launch service markets.

c. Strengths. The ability of industry to leverage these Government technology developments to create an orbital passenger transport is identified as a strength and, also, as potentially the fastest way to allow large-scale general PST and tourism businesses to be created because of the large technology development and demonstration costs involved in acquiring this new type of vehicle.

d. Weaknesses. Unfortunately, it is difficult for commercial businesses to depend on consistency in Government technology investments. The Government is bound by a year-to-year budget appropriation process* that hinders long-term planning and coordination of investments by our private sector. Also, historically the Government's focus has been on Government missions that are significantly different from new market considerations that could open space to the general public.

2. Scenario 2—Orbital Low-Earth Orbit Vehicle (Small to Medium Low-Earth Orbit Vehicle → Upgraded for Passengers → Destination Facility)

This scenario assumes that a small-medium reusable launcher will be developed that can be successfully upgraded for passenger transportation, and a destination facility will be put in place later. An approach that illustrates this is the Kistler Co. rocket that is expected to begin tests next year. Planned upgrades to this system include a reusable two-stage system building on the initial surface

*The NASA budget is now being authorized for 2 yr, FY 1998 and 1999; the appropriations will continue to be made yearly.

low-Earth orbit (LEO) vehicle. Also, some of the X-Prize Foundation candidate concepts under development appear to fit this scenario.

a. Enablers. There is a growing market for small LEO launchers because of the growth of interest in using LEO communications satellite constellations by the communications industry. A reusable vehicle could have a significant market advantage and force the development of similar type vehicles for other markets, including upgrades for passenger carrying.

b. Barriers. The expansion of the satellite communications market is already in progress, so there is concern as to whether a new small LEO vehicle may be acquired too late to capture the bulk of the initial market. If a higher production rate of expendable launch vehicles is attained, it will lower their cost and thus perhaps become a barrier to a new reusable vehicle development. Upgrades of a new or existing system for passengers may find Government-sponsored competitors that will try to deter their access to space through market barriers and regulatory and policy entanglements. Basically, anything that can carry people to/from space at a lower cost than the Shuttle or Soyuz could be viewed by some as a threat to those multibillion-dollar Government programs.

c. Strengths. The fact that this scenario depends on no Government investment is considered a major strength. As illustrated by the Kistler concept, several X-Prize Foundation candidates, and others, the vehicle development would be driven by market considerations instead of Government missions. This in itself makes the development and operations of the small LEO vehicle more cost efficient, and permits quick response to market demands for passenger transports.

d. Weaknesses. The development of a small LEO vehicle system would be expensive and complex—perhaps more so than their developers appreciate—as illustrated by the problems encountered by the X-33 and X-34 program Government and industry partners. It may also be difficult for the developer to find sufficient private financial backing to construct a system that can be upgraded to meet the needs of multiple markets, while capturing enough initial market to justify the investment needed.

3. Scenario 3—Suborbital Fast Express Package (Fast Express Package (Cargo) → Human Suborbital → Small Orbital Vehicle → Human Orbital Vehicle → Destination Facility)

This scenario assumes that a small reusable suborbital vehicle is designed to provide fast express package delivery services around the world for military and/or commercial purposes. It would likely be upgraded to a human suborbital vehicle for executive travel and tourism. The DOD is now studying the use and character of military space planes. This, in turn, would lead to the development of orbital capabilities for cargo and human transportation and, eventually, the development of destination facilities.

a. Enablers. Aerospace technology development for small, highly reusable vehicles is a key enabler for this market since fast turnaround and a high trip rate is required. There should be early market acceptance of this service inasmuch as there is already an established package delivery service worldwide. Regulatory clearance for initial operations should be similar to those used for today's commercial aircraft and could take advantage of the X-33 regulatory issues being addressed now. Growth to a passenger point-to-point transportation system would enable services to be provided for general PST and tourism, and the addition of small stages for LEO insertion of payloads would address the market growth expected for small LEO communications satellite constellations.

b. Barriers. The fact that space package delivery services are a totally new concept to the aerospace industry is an early barrier in itself. Also, new kind of transports may find Government-sponsored competitors that would see them as a threat to the traditional launch systems now in use.

c. Strengths. The potential for very high trip rates—higher than any now in existence—is very attractive. Also, the fact that the market is an entirely commercial market that does not require Government support in meeting it adds to the strength of this approach.

d. Weaknesses. The primary weaknesses in this scenario could be the upgrade to a passenger system if the initial vehicle is designed as an automated system without a pilot. Such an upgrade would require justification in pursuit of other markets in addition to the package delivery service one. Also, this market does not require an orbital vehicle. So, again, other markets will be required to prompt upgrading the vehicle to provide LEO delivery capabilities.

4. Scenario 4—“Leap of Faith” Investment (\$\$\$ → Tourism-Capable Vehicle → Orbital Destination Facility)

This scenario assumes that an investor service has access to great wealth to finance a tourist-class space transportation system (STS) service upfront without any need for incremental vehicle developments. A good example of this can be seen, conceptually, through some of the proposals put forward in Japan. Also, some of the X-Prize Foundation participants fit this category because their vehicles are designed for human space flight with plans for direct upgrade to passenger-carrying if their endeavors are successful.

a. Enablers. The enablers in this scenario could result from market surveys that many believe show sufficient justification for the large upfront investments required. Also, the availability of investment funds from interested parties with the prospect of high returns from the market or, in the case of the X-Prize, some payback in the prize itself along with a lot of prestige for the winning party may also enable this development path.

b. Barriers. Concern about the technology base, regulatory circumstances, and operating experience are seen as primary barriers to the large investor approach. There are still many technologies that need further development to achieve the high operability needed to bring the cost per trip down and to ensure acceptably safe, reliable, and comfortable operations. Also, many of the regulatory issues for general PST and tourism have yet to be addressed, which could result in costly delays to the first operational flights if all the safety concerns are not worked out properly. Also, a great deal of operating experience is required to build up credibility and confidence.

c. Strengths. The strengths of this scenario are that it is purely commercial, very focused, does not need incremental developments, and uses nontraditional approaches—a committed, large “leap of faith” investment would support the vehicle development. With enough money, this could be the fastest way to create a large-scale general PST and tourism business; and once one company proves the market, others will follow.

d. Weaknesses. The major weakness to this approach is that it is hard to justify such a large investment with the apparent lack of a convincingly large market in this area. Large investors usually look for more secure markets for such substantial investments, ones where the return on investment is to be associated with a proven track record.

5. Scenario 5—Synergistic Hotel—Theme Park (Ground-Based Hotel / Theme Park → Suborbital “Hook” for Increased Revenues → Small Orbital Vehicle → In-Space Destination Facility)

This scenario starts with a ground-based hotel and theme park where visitors enjoy space simulations. As an added commercial draw, the market for use of the hotel and theme park would then grow through the use of parabolic flights in aircraft that provide some 20 sec of zero gravity, as is done now in the training of astronauts and the development of zero-gravity equipment. As interest in this adventure vacation experience grows, investments would be made to develop suborbital vehicles for short sightseeing rides to space. Orbital vehicles and space theme-park destinations would follow as the market grows.

a. Enablers. Hotels and resorts with the appropriate space theme ties would be the primary enablers for this market. These could include space camps, Disney’s Epcot, and the entertainment business theme parks that include space adventure rides and simulators. These space-related theme parks could have sufficient draws to create package deals that could finance the operations and provide the entertainment and training needed.

b. Barriers. This approach is heavily dependent on the development of a market large enough to justify the vehicle investments. Several steps are required before reaching the orbital vehicle goal, which means this approach may prove to be very slow in development.

c. Strengths. If the adventure ride into space is sufficiently tied to the ground-based theme park experience, then the investment for the initial suborbital vehicle does not have to be justified as a stand-alone business. The ride itself becomes a draw to all the other attractions, products, and services that in turn finance the entire operation. Users of the suborbital vehicle would also provide revenue for food, lodging, and other services at the hotel/theme park. The terrestrial destination might also avoid the need for an orbital destination in early years if the total experience is sufficiently entertaining, even though the space ride itself is very short. Also, since this approach follows through a full range of parabolic and suborbital rides first, there will be greater opportunity to build an experience base for space tourist operations, so the orbital adventure will be a more assured and successful investment.

d. Weaknesses. This approach is also a weakness in that there are multiple steps and upgrades along the way to the development of an orbital vehicle. This highly synergistic approach would require multiple justifications for the developer to go through to reach the next step.

Note: It must be appreciated that incidents causing serious injury or death could shut down the market indefinitely through increased regulation or faltering customer trust. This fundamental consideration applies to all of the scenarios.

C. Strategy Summary

The actual path taken to realize the servicing of a general PST and tourism market could easily encompass any or all of the five scenarios described above. One approach cannot be selected today above another, around which to develop a primary strategy. Much more careful analysis and imaginative thinking will have to be done in the private sector over the next few years to narrow down the opportunities.

D. Key Issues to be Explored

Given the range of development scenarios that could occur, the key issues associated with the development of transportation and destination facilities for general PST and tourism were identified. These issues are grouped into four areas—technical, market, regulatory and legal, and venture or organizational management.

1. Technical

The STS must achieve high safety and reliability, reasonable comfort, and low price. It is commonly assumed that this will happen by bootstrapping onto the developments from industry/ Government technology programs such as the X-33. Unfortunately, high safety for Government programs may involve doing only a little better than current safety factors for the Shuttle and the expendable vehicles now in operation, which are not nearly as high as the aircraft level of safety needed for the general public. Also, the cost reductions targeted for the X-33 are good enough for Government programs, but are still a long way from allowing trip prices that approach those charged for airline tickets and tours. Commercial alternatives or appropriate modifications of the Government programs are needed to develop the right propulsion and vehicle technologies and to address all the design issues and complex systems engineering tasks related to high safety and low price.

The *ISS* development is the state of the art in destination facilities development. That technology will likely provide a basis for the initial on-orbit facility infrastructure. Technical issues not being addressed include the need for large volume facilities that would require on-orbit construction, and variable gravity facilities, and eventually 1-G (Earth gravity) facilities. The cost for the initial destination experience will be high, and the size of *ISS* accommodations may not be sufficient. Technologies for a hotel specifically optimized for tourism must also be considered. These technologies would be quite different than those required for the *ISS*. As an example, the tourism-optimized design may call for modifications to more traditional technologies such as partial-G toilets, showers, washers, dryers, food preparation devices, and emergency medical care (see app. A).

A combination of both the vehicle and accommodations into one system could be an approach that would eliminate the need for early development of destination facilities. However, this approach would be constrained by the volume.

2. Market

Detailed market analysis will lay the basis for the type and size of initial services to be provided. Although there were several market surveys cited during the workshop, there was a consensus that more detailed market surveys were needed before major investors would be willing to advance the large sums. Also, there needs to be a way to validate or test the market before commitment to a large system. This is where the features of the parabolic and suborbital ventures look attractive for initial transportation systems, as is the use of the Shuttle fleet. Initial destination facilities utilizing existing space assets or constructed from existing *ISS* technologies were cited as a first step toward testing the destination facility market.

3. Regulatory and Legal

In most cases, regulatory and legal issues can be resolved by using a common sense application of existing codes and regulations that are now in use in analogous surface businesses. This will likely be the approach taken initially, with specific regulations put in place as needed. There is a concern that too much regulation initially may stifle the development of this novel business, whereas too little could hinder investment because of the uncertainty of the regulatory environment.

Physical/medical screening will be somewhat dependent on the vehicle system. If it is operated as an airliner, then the physical requirements will be minimal. However, if the launch environment is more strenuous, and the time for emergency return is not flexible, then physicals and liability waivers will be required to protect the passengers, crew, and investors.

Liability and indemnification will be similar to other activities of similar risk. Regulations will be needed to define the limits of liability for the operators.

Regulations that govern the operating “rules of the road” will be needed and are currently being explored through the X-33 and X-34 development programs and other private sector programs. The Federal Aviation Administration (FAA), Department of Transportation (DOT), Department of State, Department of Commerce (DOC), DOD, and NASA all have concerns about vehicles passing through the atmosphere, into space, and over international territories.

Current Government control of human access to space is also an issue. Any new system will need to consider the general public, specifically. When the general public thinks about space today, they think about NASA. A human system including NASA, or having NASA’s blessing, would be viewed positively by the public. On the other hand, any commercial system may be viewed as a competitor to the Shuttle system and might be viewed as a threat to a very large and well-established Government and Government-contractor infrastructure. These issues must be worked out as public space trip systems-services come closer to fruition.

Standards, codes, and certification need to be modeled after existing Earth- and space-based facilities and transportation systems. In general, these are not Government-driven, but are recognized business standards that have been promoted by the private sector as a means to promote safety and provide bases for arriving at acceptable insurance liability. A similar approach needs to be taken for the

establishment of safety codes for space transportation and destination facilities. For transportation, the aviation industry may serve as the initial model, but for destination facilities, surface building codes would be applicable, as well as the codes that govern the development of passenger ships at sea. For example, any space vessel should have a captain with the same authority as a sea captain. It is debatable as to whether escape provisions for large space structures should be the same as for sea vessels where there is life boat capacity for every person, or whether it should be like building construction where there is a safe haven or fire wall that divides the facility up internally to provide for safety. These issues are being explored in the *ISS* program.

4. Venture or Organizational Management

The venture or organizational management structures will likely be as varied as the scenarios described earlier. They will develop funding sources and venture paths that inevitably look to minimum cost and risk wherever possible, including the use of Government assets, tax incentives, and anchor tenancy from the Government or a large private investor. The establishment of a firm fixed price for the use of Government assets, the establishment of broad tax incentives, and the imaginative use of the large Government civil and defense space transportation markets were identified as major contributions that the Government could make to the establishment of a general PST and tourism business.

The credibility of the management and technical team will also be key to the success of the space venture. Do they have credible space technology and management experience? Are they using proven space technology? Do they have operating experience? A positive response to these questions will help provide reassurance to the investors and the respective insurance backers.

E. Opportunities to Eliminate Barriers

Opportunities to eliminate the barriers to the PST and tourism business were identified.

1. Technical

In the space transportation area it was noted that NASA's and our space industry's current emphasis on the development of new propulsion systems, new engines, prototypes, demonstrations, and X-vehicles, with focus on integrated systems engineering approaches, provides a major opportunity to eliminate barriers to general PST and tourism. More emphasis is needed on general public space transportation issues to focus Government and private technology developments into areas of high economic leverage.

In the destination facilities area, the completion of the *ISS* provides a major opportunity to eliminate perceived barriers to space construction and habitation. Further expansion of this effort is needed to develop and demonstrate low-cost technology and to focus systems engineering on hygiene issues, closed-loop life support systems, power, safety, and emergency medical care, as well as large-volume and low-gravity facilities.

2. Market

Simulations of space travel at the space centers, space camps, theme parks, and in the entertainment industry have already gone a long way towards eliminating some of the barriers to space development. This momentum needs to be continued but is not enough to open the in-space market. Obtaining better market data, and then validating the data, would be major steps towards helping to eliminate barriers to general PST and tourism.

3. Regulatory and Legal

The Government needs to take a proactive position to promote general PST and tourism. This can be achieved through proper policy and regulatory actions. A change to the administration's space policy that would identify general PST and tourism as a national goal would go a long way toward eliminating barriers. In addition, providing public access to Government-controlled technology, systems, and facilities for market validation (STS/*Mir*/*ISS*) is needed. The establishment of initial suborbital flight regulations and the establishment of the rules of the road, standards, and regulations that industry needs to follow, are also required.

4. Venture or Organizational Management

Continuing with this need for a proactive Government position, financial incentives for the venture investors need to be established. This could include tax incentives, use of independent research and development funds, and encouragement to form company consortia with investments from the financial community.

F. Recommendations for Future Actions

Specific recommendations for future actions by Government and/or industry are as follows.

1. Technical

Space Transportation:

- Explore the near-term development of more robust, reusable rocket engines for Government and commercial use.
- Support the long-term Integrated High Payoff Propulsion Technology program to develop the next generation robust propulsion systems to meet Government and commercial space transportation needs.

Destination Facilities:

- Explore the use of *ISS* capabilities and its technology for public use.
- Develop technologies for low-cost, large-volume, artificial-gravity habitat systems.
- Organize a workshop to focus on the definition of relationships, systems engineering, and integration between *ISS* and early destination facilities for general PST and tourism.

2. Market

- Develop high-fidelity market data as tools and aids to understanding the market potential and the risks in development of a general PST and tourism business.
- Conduct more indepth analyses of potential space travel markets, especially those of particular interest to the investment community.
- Initiate a nationwide public awareness campaign on the potential for PST and tourism.
- Use the Shuttle fleet and the *ISS* to explore and stimulate the space tourism market.

3. Regulatory and Legal

- Develop policies for private use of Government space transportation and destination systems; i.e., the Shuttle and the United States (U.S.) portion of the *ISS*, to allow testing of the market.
- Form a Washington, DC-based coalition "Interest Group" to promote general PST and tourist interests.
- Work with Congress and the Administration to form policies which encourage and permit proactive support from all Government agencies for the development of a large, general PST and tourism business.
- Work for regulatory, tax, and legislative policies which will encourage this new business by better defining the playing field for commercial investments.

4. Venture or Organizational Management

- Promote legislation to provide tax incentives for commercial investments to stimulate a large general PST and tourism business.
- Better define accounting and tax implications for all space systems/services.
- Form partnerships to conduct systems engineering studies to define space transportation vehicles and destination facilities concepts that will serve to guide technology, marketing, and financial planning for the commercial investors.

G. Top-Level Requirements for General PST Systems and Services

This is an accumulation of ideas that express the general requirements and characteristics of general PST and tourism systems and services. These ideas relate to quasi-"ultimate" large-scale, surface LEO trips rather than to early niche market adventure trips.

1. Space Transportation

Several characteristics of STS's are driven by the particular needs of general PST and tourism. Too, the development of the market is heavily influenced by these characteristics. These characteristics include price, safety, reliability, comfort of the provided services, and schedule availability.

Initial space trips have been suggested purely for sightseeing purposes, where passengers do not disembark from the vehicle, and the vehicle provides all of their sustenance for the duration of the adventure. Terrestrial analogies to this include sightseeing flights which travel to and transit Antarctica

and the North Pole, as well as sightseeing flights over natural wonders, such as the Grand Canyon. Discussions of the viability of these flights and their related STS/services are driven by the perception that the market for such flights is a limited one, compared to the travel to a destination for a stay of some days or weeks. A terrestrial analogy is that of a hypothetical market for a sightseeing flight from San Francisco to the Hawaiian islands that would circle the islands from the air and return to San Francisco, versus the market for a flight to these islands with hands-on sightseeing and a stay in a resort there. Obviously, the market for a destination resort is more substantial if the costs are roughly equivalent. Thus, the obvious conclusion that the market for space transportation services is closely tied to the destination for the tourist.

However, there is also a sidelight to the market. There is a substantial terrestrial market in "cruises," where the vehicle/transportation system are the destination itself. Here the vehicle acts as a mobile resort, including substantial amenities for the passengers. In the cruise transportation trade the vehicle itself must position itself as a luxury resort, and the passenger must see the vehicle itself as equivalent to the destination resort. For STS services, this may be a more difficult situation to accommodate, because of the conflicting requirements of low-price transportation and sophisticated tourist services. The dollars and technical capability required to provide a trip which offers low-price transportation and resort level accommodations will be difficult to achieve. Such a space trip eventually might become more feasible using in-space transportation where less rigorous constraints of system mass fraction and a simpler in-space operating environment might be encountered.

2. Ground Infrastructure

Ground infrastructure requirements depend greatly on the vehicle design and operational requirements. For instance, the ideal vehicle might be much like an aircraft that is single stage to orbit (SSTO), with horizontal launch and horizontal landing profiles. This type of vehicle could be integrated into the world-wide network of existing airports and would therefore require only modification of some existing facilities and operational procedures to absorb the new vehicle fleet. If the vehicle is designed to be launched vertically, then new or modified existing ground facilities will be required. The implications that a space transportation vehicle design can impose on the ground infrastructure follow.

a. Access. First- and second-generation passenger-carrying STS's would probably build upon existing launch-recovery sites associated with orbital destinations. There are about a dozen sites in the world today that could accommodate orbital trips without undue worries about overflight of populated areas. If, as expected, fully reusable systems are the STS's of the future, and a suitable safety and reliability database is established, then these sites may be expanded greatly. However, there would be some restrictions upon the development of these sites, driven by both economic and physical constraints. The first of these is access—both to markets from which the passengers will come and to any orbital destination desired. Access to the site should be moderately simple and low cost and should not involve major inconveniences or hardships for a passenger or cargo to reach the space trip site. This will be important both for attractiveness to the passenger and for logistics operations. As an example, the Orlando, FL area can be seen as an attractive location given its proximity to both terrestrial attractions and destinations and its ability to draw upon other major transportation hubs. In comparison, a site located on an atoll in the mid-Pacific would be more difficult to reach, offer fewer amenities for passengers in transit, and be more difficult to stage supplies through, both for the transportation system and the orbital resort destination.

Similarly, it is desirable that the launch site be located at a latitude lower than that of the orbital destination because of orbital mechanics considerations; i.e., because of launch energy requirements, it is more difficult for a space transportation vehicle to rendezvous with a destination whose orbital inclination is more or less than the latitude of the launch site. Similarly, the location of the trip sites would be influenced by the orbital destination, the duration of stay there, and the transportation system cross range required. If a vehicle has only a very small cross range capability, then it may have to wait on orbit for some period of time until it can reach a recovery site. This calculation is dependent upon the specific geographic distribution of sites, the cross range capability of the vehicle, and the inclination and altitude of the orbital destination. Given a reasonable global distribution of flight departure and landing sites and a moderate cross range of a thousand miles or so, assured access to a landing site can be achieved in a short duration orbital flight.

b. Ground Support Systems. If you look at a modern airport or cruise ship terminal facility, there is a substantial amount of ground infrastructure which supports the transportation system. This is one of the primary reasons why space transportation vehicles that could be integrated into air transportation sites are desirable. The ground support infrastructure could include the following:

- Passenger transit facilities, such as lobbies, waiting rooms, amenities, lodging, parking, transit facilities, intermodal transportation facilities, and lounges
- Cargo/luggage collection, sorting, handling, packaging (into cargo containers), on-site transportation, shipping/receiving, distribution, and disbursement facilities
- Office/sales activities, including ticketing, reception, sales, reservations, and communications
- Vehicle processing, including on-site transportation (tow bar vehicles and tugs), positioning, repair and maintenance shops and facilities
- Vehicle servicing, including cosmetic maintenance (window washing, deicing, etc.), fueling, cleaning, and amenities/catering/servicing (lavatory/waste water servicing, food and drink catering, rubbish removal, etc.)
- Passenger embarkation/disembarkation, including passenger marshaling and disbursement, and gangway/flight way access
- Site logistics and facilities, including propellant storage and distribution systems, warehouses, hangers, utilities' distribution (water, power, sewage, gas, etc.), and transportation.

Many of these support systems are "behind the scenes" for routine ocean cruise or air transportation operations to the point that it is a sign of a well-run and efficient operation if the passengers are not aware of these operations and considerations. Such ground support operations and facilities will also be needed for routine and efficient space travel operations. They can be provided at virtually any site, but at a price. As a point of departure, new major terrestrial airports can easily cost several billions of dollars. The new Chek Lap Kok airport in Hong Kong is projected to cost \$9 billion by the time that it opens in 1998,¹ and the new Denver International Airport is carrying \$3.7 billion in debt from its acquisition.² If such a facility is needed for space passenger service, then the cost of this facility must be recovered against the commercial traffic through the facility, and the costs of operating the facility recovered as well. For commercial aircraft this is done through landing and transit fees. The ability to share facilities with other transportation nodes, or to build off of existing facilities, may drive such space trip facilities to co-locate with other transportation nodes as part of a global transportation infrastructure.

c. Noise. Among other environmental considerations, noise is one consideration for transportation node selection. Terrestrial airport operations may be constrained by local noise ordinances and in the U.S. by FAA noise-abatement regulations. STS's capable of orbital flight are expected to expend substantial energies in a short duration of time, which typically produces high noise levels. For rockets, the rocket exhaust produces a very high characteristic noise level, and for high-speed flight in departure or return, the impact of supersonic shock waves must be considered. Routine general PST and tourism operations from a trip site which may involve frequent departures, potentially at a higher than daily frequency, must deal with these noise considerations. This may mean increasing the clearance zone around such a flight landing site, and controlling departure and return corridors to minimize the impact of noise upon the environment. Some analysis indicates that a 15-km zone around such facilities³ should be sufficient, but further study is necessary. Other more configuration-dependent and technically driven considerations include shaping the vehicle ascent or descent trajectory to minimize impact upon specific areas, or operating in some form of mixed mode to minimize such impacts. For example, using turbofans to lift the vehicle off the ground and cruise to an orbital ascent location over a remote area may allow space transportation vehicle operations to operate much closer to populated regions without major noise impacts.

d. Propulsion/Propellants Safety. Transportation systems for general PST and tourism will, by their nature, carry a concentrated load of propellants, potentially including volatile hazardous materials. If a high level of reliability and safety in the use of these systems is established, then current standards may be relaxed. But until enough of an operational database is established that is adequate to provide confidence in safe operations, STS's must comply with current space vehicle launch regulations.

Explosions, caused by the uncontrolled combustion of propellants, may produce a blast wave with the potential of causing damage by crushing forces and winds. Debris, made up of vehicle fragments that may land upon structures or populated areas, and fires, where the uncontrolled combustion of the propellants results in heat, or thermal radiation, must be controlled. Toxic vapors can be eliminated through eliminating specific hazardous materials from the propellant systems of the vehicle (such as toxic hypergolic propellants). But, in the aftermath of an accident where a vehicle's composite structure or its cargo may be consumed by fire, a toxic vapor hazard may still occur.

Current operating procedures require specified trajectory clearances away from inhabited areas. This includes consideration of the potential blast wave, and the quantity/distance of debris from a potential problem. This safety zone from the launch/recovery site to inhabited areas, such as passenger terminals, may be as much as 13,000 ft or more, depending upon the specific design of the vehicle and the results of detailed technical hazard analyses. However, it should be noted that a typical commercial jetport has a runway of about 10,000 ft. So locating the site at the opposite end of the runway from the terminal may provide sufficient clearance for routine operation, if a sufficient cleared area exists there. Flight paths to/from the site should also be designed to minimize the impact of any potential problems, at least until enough experience is gained to demonstrate high levels of reliability.

Similar considerations should be employed for the storage and transport of propellants. There are existing commercial standards for STS's. A comparison between a typical jet port and a space trip site is informative. If the jet port accommodates 300 flights per day of MD-80's or Boeing 737's, with each

plane potentially carrying 60,000 lb of fuel, the jetport may have to accommodate 18 million lb of fuel per day. A 2-day storage would be equivalent to 36 million lb of fuel, or about 654,000 ft³ of storage volume. If a space trip site accommodates 1 daily trip of a liquid oxygen/liquid hydrogen (lox/LH₂) system, each carrying 1.8 million lb of propellant (typical for an SSTO-type vehicle), then a 2-day storage capability would be equivalent to 43,400 ft³ of lox and about 115,600 ft³ of LH₂. While these are cryogenic fuels with their attendant issues of boil-off and insulation, an advanced trip site capable of over 300 trips per year would not require substantially larger propellant storage acreage than is already provided by commercial airports.

e. Traffic Control. With the increase in space trip traffic, space traffic control issues must also be resolved. This includes establishing clearance for travel to or from orbit, assuring clear orbital paths from collision with other space objects, warning of space debris, and scheduling vehicles out of/into a general PST and tourism facility.

3. On-Orbit Infrastructure

On-orbit infrastructure requirements include the orbital requirements for the Earth-to/from-orbit transportation vehicle, the destination facility(s), be it a space station-laboratory, hotel, or space business park, and an in-space orbital transfer vehicle to transport cargo and personnel between destination points in orbit.

a. Space Transportation Vehicle On-Orbit Requirements. The basic requirements should include a transportation system to/from LEO destinations at high inclination to include access to the *ISS* and the *Mir*. This does not necessarily mean the vehicle has to go to the *ISS* orbit. That would be a preferred capability, but for initial tourism needs a destination facility at a lower inclination may be more economical with an orbital transfer vehicle added later to complete the transportation system to all possible destinations. Once on orbit, the vehicle will require orbital maneuvering and docking capabilities comparable to the Space Shuttle and the Soyuz vehicles.

Space transportation vehicle on-orbit requirements will also depend on the basic vehicle design and destination trajectory. If the launch to the destination timeframe is only a few hours, then minimum commercial aircraft type accommodations can be provided. However, if the designed trajectory requires a day or more to reach the orbital inclination, passenger accommodations will tend to become more like private compartments on overnight passenger railway systems. These two comparisons represent the lower and upper range of demand for passenger accommodations.

The transportation cost will probably be the most expensive part of the entire price to a passenger (including costs for their in-flight amenities, as well as themselves), which suggests the need for a quick trip to an on-orbit destination with minimum facilities in the vehicle for passengers, and more plush facilities on-orbit at the destination facility.

Passenger accommodations should include an open cabin with individual recliner-type seating similar to a commercial aircraft, but it should be adjustable to a more erect position for better body support during ascent and descent accelerations, and on-orbit zero-gravity body posture. The passenger cabin should include side and/or overhead view ports and individual video monitors for communications

and entertainment. Personal safety and hygiene requirements may include a half-mask respirator combination bag for all passengers to wear early in the trip until it can be confirmed that space sickness medications have been effective. A body tether may also be needed for attachment to an overhead rail for zero-gravity movement about the cabin and to/from public toilet facilities. Early flights with small passenger loads will determine if these features are really required, as well as to uncover other unforeseen problems.

Crew requirements for the space transportation vehicle on-orbit would be similar to those of a commercial passenger airline. Even though the vehicle will probably be nearly autonomous, it will be necessary to have a pilot and copilot who can provide a leadership role, communicate vehicle performance to the passengers, provide an understanding of the vehicle systems and anomalies, perform manual orbital maneuvering and landing when needed, and communicate with the surface and any orbital destination. Flight attendants would likewise serve the passengers as on a commercial aircraft.

b. On-Orbit Transfer Vehicle Requirements. Passenger safety and flexibility in transportation operations must be assured as the on-orbit infrastructure matures. A vehicle system designed to service the tourist market would include a passenger module capable of making passenger transfers between all human destinations in space. Initially this would mean the ability to transfer humans and cargo between the on-orbit tourist facility, the *Mir*, and the *ISS*. Such a vehicle transfer system has broad market appeal today. Possible services could include astronaut, passenger, and supply transfers between stations; satellite servicing and satellite orbital transfer; space rescue operations; orbital debris collection; and space station reboost operations.

Passenger transfer vehicle accommodations would vary according to the length of time required for the orbital transfer. If the transfer vehicle makes only short trips between the vehicles and several destinations in close proximity to each other, then minimum accommodations would be sufficient as described above for the space transportation vehicle. If the transfer vehicle is used to make transfers from low inclination orbits to high inclination orbits that take a day or more, then more spacious cabin-type accommodations would be required. Since the transfer vehicle is maintained on orbit, this option may prove more economical than including cabin-type accommodations in the surface-space vehicle.

4. Market Drivers

a. Cost/Price. One of the most important drivers in the general PST and tourism market is the cost of space transportation. This directly drives the ticket price per passenger and secondarily drives the cost of installing any orbital destination facility and supporting the passenger with food, drink, air, and amenities.

Several prior studies⁴⁻⁷ have directly linked the price of space transportation to expected demand for space tourism. Typically, the challenge has been to provide a ticket for space transportation at a very low price to a potential customer, while still ensuring sufficient revenue stream to justify the development of the advanced STS that would allow this lower cost. In this consideration, the price/demand elasticity between the ticket price and service demand is of great importance. But, as of this time, the price-demand elasticity for this new market is not known with sufficient confidence (see app. A in Vol. I).

It is important to note also that the prices charged for space tourism trips are by necessity higher than just the recurring cost of the transportation. A transportation system operator or developer must recover sufficient returns from the operation of their system to pay back their creditors, sustain recurring operations (including the replacement of vehicles), and earn a profit for their investors. Since the market demand for general PST and tourism is not well established as yet, this also has an effect upon the viability of STS's developed to service this new market. High risk requires high returns in a business investment and, therefore, the required returns for a significant investment may impose additional investment risks and initially force up the required price for the use of the system to obtain these returns. This is a "chicken or the egg" problem. If this market is to be realized, additional emphasis must be placed on conducting detailed market surveys and in-space market-related studies which address the types of services that are actually expected to be made available and the price that passengers/tourists are willing to pay.

b. Safety and Reliability. Besides a low price, a transportation system for space tourism must also provide a relatively safe service on a reasonably consistent schedule. To achieve this, it must demonstrate operations that are at least two orders of magnitude safer and more reliable than current systems. In analogy, aircraft transportation systems have demonstrated a sustained growth in safety over the past 70+ yr of commercial passenger operations. This safety record has been the result of a persistent focus upon identifying problem areas in airline safety, applying well thought out, technically, operationally, and economically sound design approaches, and establishing a regulatory and operations process to control these characteristics.

The aircraft business has developed an extensive database on how to maintain safe, reliable, and efficient operations. In 1960, major U.S. airlines carried 58 million passengers on board 3.8 million flights and suffered 67 accidents, 12 with fatalities. In 1995, they carried 550 million passengers on 8.2 million flights, suffering 33 accidents, two of them with fatalities. That is, over 35 yr, we have seen the market grow by an order of magnitude, while the probability of a fatal accident has dropped from one in 300,000 departures to one in a million.⁸ Commercial space transportation operations have a long way to go in order to approach those of airline operations of 35 yr ago. Current space operations run about 35 trips per year, and lose one vehicle in every 20–30. Our passenger-carrying vehicle, the Shuttle, does much better. It is now approaching one fatal accident in 100 trips, but this is lower than commercial airline operations by four orders of magnitude.

Passenger-carrying STS's should be designed and tested to high reliability. Approaching the same safety levels as commercial aircraft may be difficult until an equivalent database has been developed for sustained safe operations, but, initially, at least two orders of magnitude increase over current levels should be pursued. Establishing a much higher operational trip rate for space systems would aid in this effort.

c. Services. Current STS's are not designed to provide general PST and tourism services. The process to integrate and carry a payload on a space vehicle typically takes from 12–18 mo or more and may involve unique consideration of the interactions of the payload with the vehicle.

General PST and tourism will require a totally different approach to accommodate passengers as paying customers. There will have to be a standard set of services available, with the capability of a

mixed payload of passengers and cargo (luggage and/or supplies). Unique interfaces between the payload and the vehicle will be replaced by standard interfaces. Also, to accommodate people, the STS must be able to provide an appropriate Environmental Control and Life Support System (ECLSS), as well as appropriate access and habitability considerations. This can perhaps be accommodated through a modular passenger module, which would provide aircraft-like services and stand-alone ECLSS capabilities. But the interface between the passenger module and the vehicle must provide appropriate access and suitable services for the passengers.

d. Schedule/Availability. An STS for general PST and tourism should also provide scheduled services. There are two paths to follow for tourism-driven vehicle operations. The first is similar to charter aircraft operations and is similar to existing launch system operations: trips are not launched on predetermined schedules, but only when a sufficient cargo has been accumulated. Services for passengers, as well as the flight departure and return times, may be more catered to meet individual needs. Early trips may follow this model until sufficient traffic builds up to allow scheduled services.

Scheduled services are the long-term goal for the general PST and tourism market. Then, a transportation system is expected to provide a standard set of services with departures and returns on an established schedule. However, this service paradigm assumes the services provided are highly standardized, that the space transportation service "route" (including to and from a destination) is standardized, and there is enough traffic along this route to allow the system to operate economically.

5. Passenger Vehicle Accommodations

a. Windows. Obviously, one the biggest draws for a passenger on a space liner will be the ability to look out the window. Most conceptualizations of space passenger-carrying vehicles include windows at least similar to those of current commercial passenger aircraft. However, structural considerations during ascent and reentry may preclude having large banks of windows along the sides of the vehicle. This has been an ongoing issue between the designers of spacecraft and their passengers, and resolution of this issue will probably not take place until plans for the first routine passenger operations are formalized in detail.

However, there are valid psychological and market needs which drive the system to provide some form of external view to each passenger. Some passenger aircraft are currently experimenting with the delivery of video from the cockpit, and it may be found that such a direct video link to each seat from an external camera may be a sufficient substitute for a window. Similarly, windows in a passenger module contained in a vehicle may be covered until on orbit, thereby avoiding the issues of having to design windows capable of accommodating the harsher environments of ascent and/or reentry.

b. Volume. The immediate physical environment around the passengers should be conducive to their psychological and physical well being, as well as to establishing the proper environment for a quality trip experience. This includes the design and location of seats, walls, floors, and the selection of materials, colors and textures as is done for commercial aircraft. Based upon the experience of U.S. and Russian astronauts on *Skylab*, *Mir*, and the Shuttle, some persons may be very uncomfortable without a local vertical reference, and subtle clues could be maintained in the passenger accommodations areas to ease this physiological circumstance.

A passenger vehicle may be cramped, particularly if the vehicle is just acting as a transport to/ from an orbital destination. Anyone who has flown across country in coach class on a modern jet is aware of the tight volume constraints. However, some volume should be utilized to allow the passengers to experience weightlessness and to play with small objects in the new environment. Certainly, if this is not planned for, then passengers will play with whatever is at hand—pens, glasses, watches, etc., to see them “float.” As this may also involve playing with food or liquids, care must be taken to ensure that they do not interfere with the vehicle’s safe operations or the health and safety of other passengers. To capture and control small objects located near the passengers during flight, some personal stowage space near each passenger must be provided.

c. Lighting and ECLSS. Some lighting and ECLSS should also be associated with each passenger’s volume. Lighting for each passenger should be controlled at each individual seat, and area lighting made available throughout the passenger area. Local airflow should be conditioned, with some ability of different passengers to adjust the level for personal comfort. Furthermore, the air flow should be designed to move floating debris and objects out of the way. This will aid in continuously minimizing debris and capturing small objects which have not been properly stowed.

d. Ingress/Egress. Depending upon the specific design of the passenger vehicle, the passengers should have simple, nonphysically demanding access to their positions for the trip. This may be done as on commercial airliners with aisles and doors, but the consideration of when and how the passengers are loaded for vertical takeoff may impose some different access problems.

Once in space the full volume of the vehicle will be available, but access to and from the seats should be maintained to allow services and attendants to reach the passengers, or to allow the passengers to move about to reach the lavatory or other facilities. The design of the passenger volume should include appropriate handholds and rails. Wherever possible, the design should avoid sharp protrusions so as to minimize the possibility of bruises or painful collisions between a passenger and the vehicle’s internal structure.

Consideration of passenger ingress and egress should include dealing with emergency situations where the passengers may have to exit the vehicle rapidly. Similar criteria as required by the FAA for airliner passenger egress may be required. This means emergency doors, slides, or other capabilities may be needed.

e. Entertainment and Communications. It is reasonable to expect services similar to those available in commercial airline operations including music, video, and communications devices. With modern aircraft-like systems, it is possible to provide data communications, giving the trip status of the vehicle with its position in orbit, camera views from around the craft during the trip, and space-surface communications links for individual passengers.

f. Timetable. The duration of time the passenger spends on board the vehicle should be considered. Current Shuttle operations have the crew entering the vehicle some hours before liftoff, but such delays should be minimized for general public passenger-carrying vehicles. The specific timeline between start of passenger loading and launch may be dependent upon specific considerations for vehicle

processing and preparation, as well as safety considerations (loading time for cryogenic propellants), but experience and proper design should minimize this concern. Similarly, the habitability volume per passenger should be greater for longer trips.

g. Training/Guidance. The amount of specialized training required for passengers should be minimized. However, some familiarization and training probably will be needed. At a minimum, as with commercial airlines, some familiarization and guidance in emergency procedures should be provided.

h. Galley Services. The whole issue of food and drink in space is worthy of an extensive document. However, for an orbital trip with a duration of more than an hour or so, some type of galley services to provide liquids and solid food refreshments to passengers should be provided. While extensive meal services would be difficult to provide—and the potential inexperience of passengers with the techniques of zero-gravity eating may make meals a particularly difficult matter—there are methods of providing refreshment and sustenance to passengers during flight, and, of course, this service in itself will provide some entertainment.

i. Lavatory Services. Comfortable facilities for the elimination of bodily wastes in orbit must also be considered. Current Shuttle and proposed *ISS* systems are nonintuitive to persons used to being in a gravity field during the conduct of this common bodily function.

6. Destination Facility Accommodations

a. Crew On-Orbit Requirements. The on-orbit facility has to be piloted and will have orbital maneuvering and reboost capabilities to maintain on orbit. Crew capabilities must be designed to service the facility and the tourist population. A surface cruise ship is a good analogy to consider. The numerous systems on board the facility will have to be monitored and controlled by a capable captain and an engineering staff. Stewards will serve the passengers in the same way as on a ship at sea. Quarters for the crew with passenger-restricted access to the control of all vehicle systems is preferable. Complete crew rotations should occur every few months at first, with longer crew duration permitted as experience permits. It should be noted here that the zero-gravity environment will provide unique employment opportunities for many people with physical disabilities that are inhibited by the 1-G environment on Earth; some may actually prefer a permanent residence in space.

b. Passenger On-Orbit Requirements. The first space tourism facility will probably be the transportation vehicle itself. Like the Shuttle now, the accommodations will be limited to an open cabin area, windows, simple personal experiment activities, public-available lavatory, and a sleeping bag on the wall or bunk-sized locker. Tourists will expect better accommodations as the on-orbit time increases and dedicated permanent facilities become available.

The first permanent on-orbit facilities will probably be similar to those planned for the *ISS*. The *ISS* provides a good baseline design for safety and reliability and should help establish a precedent that the insurance industry can base risk estimates upon. Production and installed cost can also be derived from *ISS* experience, but operating costs are not as well defined at this time. Certainly, they must become much less costly.

Another approach for an early tourism facility could be a rotating hotel designed to provide a partial gravity environment. This would permit the use of existing terrestrial equipment and systems (e.g., toilet facilities, food preparation equipment, mechanical and plumbing systems, etc.) with proven terrestrial safety and reliability. *ISS* habitation experience should be carefully analyzed and the partial-gravity approach experimented with in order to understand the performance, estimate the cost, and help to focus upon the preferred technology and systems development.

By analogy to cruise vessels, medical facilities would include a staff physician or nurse with emergency medical equipment and a quick-return vehicle capability similar to those to be provided on the *ISS*. Medical facilities would expand as the facility expands. A side-line benefit to this is that some treatments such as those for severe burns and certain orthopedic procedures could benefit from a zero-gravity environment.⁹ This type of activity could be expected to expand the demand for on-orbit medical research facilities.

A second-generation hotel could provide cruise ship-like accommodations. More experience will be needed with on-orbit construction methods and large vehicle operations in the space environment. A need that is not being addressed by the *ISS* or *Mir* programs is the on-orbit construction of large pressurized volumes and low-gravity facilities. Three near-term options appear to be viable for the construction of large, low-cost, habitable volumes on orbit: (a) The conversion of Shuttle external tanks on orbit to habitable facilities, (2) the launch of a converted or partially converted external tank for habitation, and (3) the development of new rigid and/or inflatable structures that can be made habitable on orbit. Such a facility could be multipurpose—it could be used to accommodate televised sports events, tourist recreation, and film production.¹⁰

H. Summary

The need for a continuing dialogue between Government and travel and tourism interests must be emphasized as plans are developed for providing an STS-service for the general public. The promise of this capability has been recognized since humans first went to space in the 1960's, but it has not been realized, in part, because of the lack of critical technologies and the lack of proper Government policy. The initial critical technologies are within reach, and a proactive Government policy initiative for general PST and tourism can open up this new business opportunity. The recommendations listed in section F of this chapter (Recommendations for Future Actions) express these needs more concisely and should be implemented as soon as possible.

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II. PASSENGERS, CREW, LIFE SUPPORT, AND INSURANCE CONSIDERATIONS

Daniel A. O'Neil
NASA Marshall Space Flight Center
Marshall Space Flight Center, AL 35812

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Dr. Lawrence R. Young
Massachusetts Institute of Technology

A. Introduction

This section describes the key issues, barriers, opportunities, and potential trip packages related to the needs and expectations of initial space adventure travelers. A variety of ideas to overcome barriers is presented that address financial, psychological, and sociological problems expected to be encountered in establishing a general PST and tourism business. Tour package descriptions range from near-term surface training facilities to far-term lunar ones. Recommendations include requirements pertaining to human factors in design and needed technology.

B. Human Factors

Human needs and expectations will evolve as general PST and tourism services expand. Near-term adventure travel does not have to provide the amenities that later orbital tourist facilities will have to provide. Design consideration must be based upon customer expectations. There are key issues that technologists and designers must resolve, and there are barriers to be overcome.

1. Design Requirements

Human factors requirements will evolve from sparse accommodations to luxurious amenities as the general public business matures. Early space adventurers will tolerate cramped living quarters and zero-gravity toilets similar in design to the ones on the Shuttle and in the *ISS*. Later space travelers will increasingly expect more comfortable lodging, entertainment, and improved personal hygiene facilities.

In general, vehicles and operations should not subject passengers to more than 3 G during the launch phase and, during reentry, no more than 1.3 G; but higher levels can be permitted for short intervals. Space travelers should not spend more than about a week in a zero-gravity environment. Orbital facility personnel may spend longer periods in space, provided they adhere to a strict exercise regimen and proper diet. Early space travel will not be for everyone; perhaps space adventurers should meet standards analogous to the NASA Class IV Medical Standards for traveling into space. Orbital facility personnel should meet higher medical standards.

The trips should incorporate some entertainment infrastructure. Entertainment on early space adventure trips may consist primarily of breathtaking views and acrobatics. Later space tours should include specialized facilities for sports. Eventually, orbital resorts should include theaters for variety shows.

Travel agencies and universities should start developing curricula related to commercial space travel and tourism. Students who learn about potential opportunities for commercial space travel will become proponents, advocates, and champions for future space programs. Travel agents with an understanding of future space adventure travel opportunities can encourage people to visit space training facilities and/or space travel simulators. As space adventure travel packages become available, travel agencies and launch-recovery facilities should develop orientation programs that inspire people, alleviate their fears, and educate them about procedures. A well-established general PST and tourism business will require guide books, maps, and trained personnel who can assist travelers in maximizing their opportunities in space.

Near-term life support systems in space adventure travel will leverage the work done for the *ISS*. Large-scale space resorts and business parks will require more than today's closed-loop water and air reclamation system. Far-term life support systems will be like city sewage treatment centers or perhaps distributed personal life support systems. Orbital facility builders will need building codes and standards, and should be able to use commercial off-the-shelf equipment to minimize development costs.

Future orbital facilities will present opportunities for the exercise equipment industry. Exercise equipment manufacturers can use the results from ongoing research to begin designing future space exercise equipment. Space training facilities can demonstrate the prototype equipment to participants.

Presently, the medical community is developing telemedicine systems that allow doctors to get vital diagnostic information about patients while the ambulance is en route to the hospital. This equipment will serve an important role in the sickbays on future space travel vehicles. A potential scenario is a commercial space travel crew member relaying information about a sick passenger to doctors on Earth. The doctors can view the passenger through video, read diagnostic telemetry, and provide medical directions to the crew member. The emerging telemedicine equipment community should work with system designers and component manufacturers to develop systems appropriate for space use. Also, the aerospace community should determine the telemetry requirements of the telemedicine service (see app. A).

2. Key Issues

There are several barriers to establishing a general PST and tourism business that must be eliminated. The barriers are financial, political, and sociological in nature. Barriers that concern passengers on a personal level constitute key issues because, if they are not handled properly, space travelers will not enjoy their experience. Miserable vacation stories can hurt a young space travel and tourism business. These issues include space sickness, passenger preparation, personal hygiene, and privacy. Both aerospace and travel and tourism interests must understand key space travel issues. Some issues require technical solutions, others operational procedures; some require political imagination and others a thorough understanding of human psychology.

3. Opportunities to Eliminate Barriers

The aerospace community can overcome the technical barriers through focused research and development. Financial barriers can be eliminated through innovative investment strategies and partnerships. To break through political barriers, space advocacy groups must identify and inculcate champions. Overcoming psychological barriers requires education, marketing, and demonstrations. The following paragraphs identify specific barriers and potential approaches to eliminating them.

a. Financial. Creating a commercial space travel business will be expensive. Corporations will need to form consortia, obtain venture capital, issue bonds, and develop near-term sources of revenue for investment in long-term infrastructure. A series of space-related prizes could provide incentives to private companies to develop commercial space travel vehicles. Consortia could allocate profits from theme parks and new space training facilities to invest in the development and operation of space transportation vehicles. Banks could begin offering Space Accounts to future space travelers. Travel agencies or others could organize lotteries and/or auctions for tickets. Use of Government transportation markets would be helpful.

b. Political. General PST and tourism advocacy groups must find political champions that will seize the issues related to PST. Champions must work with the appropriate Congressional committees and Federal departments and agencies to establish sensible policies at the outset. Congress can learn from the development of regulations and policies for the airline business.

c. Ignorance and Fear. Many people will be afraid to travel into space, and the public will have misconceptions about space travel. Through education, advertising, and public relations demonstrations, general PST and tourism interests could put space travel into proper perspective as has been done previously for land, air, and water trips.

d. Physical Stress. Launch vehicle developers must design systems for low-G launches and reentry. In orbit, some facilities may provide full or partial gravity. Passengers should have appropriate physical training so that they will be fit for space trips.

e. Medical Care. Near-term adventure space travel must include contingency plans for passengers needing medical attention. In the far term, orbital resorts should include medical facilities with the telemedicine capability to remotely diagnose illness and injury and to direct medical procedures.

f. Quality of Life. Early space adventurers will accept uncomfortable accommodations. As commercial space travel matures, so will the demand for quality of life. Examples include prepackaged foods in the near term and food preparation systems in the far term, hopefully including hydroponic food production that would allow fresh vegetables to be provided at lower logistical cost. In the near term, entertainment may be nothing more than playing in a padded chamber and looking out the window. Far-term entertainment may include swimming pools, variety shows, and sporting events.

g. Crews with People Skills. Today, space travel involves technicians, engineers, and astronauts. Space travel of tomorrow should involve space flight attendants, tour guides, and concierges. Passengers will expect personable and competent crews that will make them feel at ease. Spacecraft

developers should automate most procedures to eliminate the need for people with technical backgrounds. Schools should create curricula for space trip attendants. Crew members should meet higher physical standards than the passengers so they can stay in space longer.

h. Crew/Passenger Ratios. Telepresence and robotic control systems can reduce the need for large crews. These systems must be demonstrated over long periods of time to build public confidence in them. General PST and tourism interests can work with the media to educate the public on how telepresence works. Even with highly reliable robotic control systems, passengers will feel more comfortable with company representatives aboard. Operations research and psychological studies can determine the minimum acceptable crew/passenger ratios.

i. Hygiene. Passenger expectations for personal hygiene will increase along with demands for higher “quality of life” trips. Early adventurers will accept the Space Shuttle or *ISS* zero-gravity toilets. Later orbital resorts that offer full or partial gravity should have much nicer lavatories. Commercial space travel may present opportunities to invent new hygiene products.

j. Privacy. Psychological studies can provide specific minimal requirements for passenger privacy. In near-term adventure travel, such as a suborbital flight, the need for privacy will not be as important as longer stay times in space.

k. Time Management. Travel agencies should develop detailed itineraries for near-term adventure travel. (One road map for space tours is provided below.) In the near term, trips will be short and entertainment will focus on the freedom of zero-gravity and the magnificent views. Itineraries for these short trips will resemble timelines that explain available opportunities to passengers. As trip times become longer and the number of opportunities increase, itineraries will be less rigid and allow passengers more time to determine their own activities. Tour guides can assist passengers in deciding how they want to spend their time.

l. Traveler Baggage. Minimizing luggage allowance will enable space transportation vehicles to carry more passengers. Early space adventurers may not carry any luggage; for longer trips, passengers will want to take some. Vehicle service companies may charge customers by the pound, or have strict requirements on luggage weight. Luggage companies may market “space qualified” suitcases. Orbital resorts could offer a complete wardrobe including even formals and wedding dresses. Onboard cameras or photographers would eliminate the need to bring personal equipment.

m. Sickness. Space motion sickness affects approximately 50 percent of the people who go into space.¹ Drugs, such as promethazine, offer relief from space sickness, but have side effects such as drowsiness. Changing maneuvers can eliminate some of the physiological causes. For example, in parabolic flights, pilots can provide rest periods and climb or dive more gradually. Interior designs of spacecraft and orbital resorts should eliminate visual cues that can cause space sickness. Focused research and development may result in new drugs, meditation training programs, vehicle maneuvers, and design guidelines. Learning new ways to move and control your body can mitigate space motion sickness. Examples of retraining the body to adapt to microgravity include Autogenic Feedback Training Exercise (AFTE) and the Torso Rotation Experiment (TRE).

Dr. Patricia Cowings at the NASA Ames Research Center and Dr. William Toscano at the University of California in Los Angeles studied over 200 people in preparation for tests of AFTE in space. A combination of biofeedback and autogenic therapy, AFTE is a patented 6-hr preflight training program which could benefit both passengers and crew through greater physiological self-regulation. During a typical training session, subjects are instructed to control a pattern of physiological responses and are given many different feedback displays (visual and auditory) simultaneously. Two groups of subjects, an AFTE treatment group and a no-treatment control group, were given three types of motion sickness-inducing tests: a rotating chair test, the combination of optokinetic stimulation with rotation in a chair, and a vertical acceleration test. Results showed that subjects given AFTE significantly improved their tolerance to the different types of motion sickness tests, whereas the control subjects exhibited little or no improvement. For example, subjects who were moderately susceptible to motion sickness increased their tolerance from 200 rotations in the rotating chair to nearly 1,000 rotations.¹

Dr. Douglas Watt, the Director of the Aerospace Medical Research Unit at McGill University in Montreal, Canada, attributes space sickness to jerky and stiff movements astronauts tend to make in microgravity. In space, astronauts tend to turn their head and torso together, as if wearing a neck brace, rather than moving them independently. This unusual act, even on Earth provokes the dizziness, headaches, and nausea of motion sickness. During the STS-78 mission, Canadian Space Agency astronaut Bob Thirsk carried out the TRE. In this experiment, astronauts wore a device on their heads attached to a backpack holding a computer. The equipment monitored eye, head, and torso movement. After studying the data, Dr. Watt hopes to train astronauts to avoid certain movements and behavior that seem to trigger space sickness.²

n. Regulation. Over-regulation can make it difficult for companies to make a profit. Industry should take the lead in developing standards, policies, and regulations that ensure the safety of passengers without crushing the profit potential. The Government should work closely with travel and tourism interests to define the roles and missions of agencies pertaining to monitoring and enforcing regulations. Contemporary commercial airline regulations in the airline industry can serve both as a positive and negative model for the nascent general PST and tourism business.

C. Tour Package Roadmap

A roadmap of tour packages provides a reference for expected levels of service for near-term space adventures and far-term off-world destinations. Adventure tours include high-risk outdoor programs with a certain amount of physical activity, experience with the unknown, and discovery. Grand vistas often engender a sense of the sublime, a feeling that you are part of something greater than you are. The following paragraphs describe potential tour packages, customer expectations, and technological and design requirements.

1. Space Training

Near-term space adventure travel may begin using a variety of space training facilities, ranging from camps to resorts. In recent years, people have become more interested in vacations that involve physical activities. Activities may include a physical fitness program similar to the one used in the

official astronaut candidate program. Training courses could teach valuable skills that would enrich a person's life even if they never travel into space.

Universities and space training facilities could offer a curriculum wherein people become certified for certain kinds and levels of space travel. Potential space adventurers would take a series of tests that certify their qualifications for simulations, suborbital flights, three-orbit tours, and 3-day tours. Along the way, participants could acquire certification in other adventurous activities such as scuba diving or piloting small aircraft.

a. Physical Education. Perhaps potential space adventurers should meet medical standards analogous to those of NASA Class IV. The physical education program could offer classes in nutrition, weightlifting, aerobics, and stretching. Medical examinations and physical tests would qualify participants for various kinds of specific space trips.

b. Space History Courses. An education in space history can enhance a space traveler's experience by providing a context and understanding of their place in history. Course material may include an overview of rockets, satellites, historical space events, etc. Basics of orbital mechanics could be referenced as well as the studies of Copernicus, Brahe, Galileo, Kepler, and Newton, all of which formed the bases for modern space flight. Space adventurers will appreciate their history class when they look through a telescope on their spacecraft and recognize different satellites.

c. Flight Training. Some space adventurers may want a deeper understanding of rocketry and space flight. One course may conclude with an FAA examination for small aircraft. Another class may explain the physics of rocketry and include launching model rockets. When the general PST and hotel business has established a number of orbital resorts, flight training may address piloting small orbital transfer vehicles in moving between one facility and another.

d. Autogenic Feedback Training Exercise. AFTE is an operant conditioning process used to enable an individual to regulate his/her body. Operant conditioning is a trial and error process in which the response learned and performed must be followed by either a reward or punishment. When a novice basketball player practices shooting fouls, he or she sees the ball going through the hoop (success) as a reward, or missing the hoop (failure) as a punishment. If the novice were blindfolded, he or she would not learn. The same rules that apply to improving athletic skills also apply to gaining voluntary control of one's own heart rate. Autogenic exercises provide specific instructions and methods of concentration that are likely to produce a desired response. For example, self-suggestion of warmth in the hands and feet is associated with measurable vasodilatation in the hands and feet. Classes in AFTE and other self-regulation techniques would benefit participants, not only in space, but in any situation that could cause motion sickness.

e. General PST and Tourism Agency Training. Agents in this business should understand most aspects of space tour packages. Courses in this area would provide students with an overview of launch/recovery facilities, an understanding of spacecraft accommodations, amenities, medical standards, entertainment, education opportunities, sites, timelines, etc. As longer space tour packages become available, courses will certify tour guides, space flight attendants, and space resort concierges.

f. Medical Training. Crewmembers must know emergency medical procedures in the event that a passenger becomes injured or seriously ill. As new medical diagnostic or telemedicine capabilities become available, personnel would be taught how to operate this equipment. Eventually, crew members will specialize as paramedics, nurses, doctors, etc.

g. Photography Classes. Space photography classes would go beyond composition, lighting, and shutter speed. Tourists would learn how to use onboard camera equipment, how to manipulate telerobotic camera systems, and about available subject matter such as satellites, orbital debris, Earth, the stars, etc.

h. Earth Observation Training. Space adventure travelers will have a greater appreciation of the Earth after they have taken an Earth observation class. They would learn how to operate the onboard Earth observation equipment and how to interpret the data.

i. Emergency Procedures. Early space adventure travelers will need to understand emergency procedures. Travelers would experience simulated emergencies to test their understanding of the procedures. As the general PST and tourism business matures, orbital resort guests will not need extensive training in emergency procedures, but the resort personnel will need a thorough understanding of evacuation procedures. Through simulation, future crew personnel would evacuate numbers of guests to space "life boats."

2. Simulations

People who want a more visceral space travel experience could experience a variety of simulations. Some simulations could create the sensation of weightlessness while others could use virtual reality (VR) for walk-throughs of future orbital facilities. Space training facilities might include some simulations or people might graduate from a course and proceed to other facilities that specialize in space travel simulations.

a. Neutral Buoyancy Tanks. Using a large tank of water and props, space training facilities can simulate a zero-gravity environment. Participants wear a weighted space suit that prevents them from floating to the top of the tank. Through interaction with props and other people, participants could perform a simulated extravehicular activity such as servicing a satellite.

b. Centrifuge Rooms. In a centrifuge room participants could experience the increased level of gravity they will feel during reentry. The room spins, which causes a centrifugal force to push participants against the walls of the circular room.

c. Parabolic Flights. Today, potential space adventurers can experience zero gravity on a parabolic aircraft flight. A large plane, such as a KC-135, carries several passengers in the cargo area without seats or other obstructions. The plane flies up and down in a series of parabolas. At the peak, participants experience weightlessness. At the trough, passengers feel somewhere between 1 and 2 G. The plane may fly as many as 40 parabolas. Often, people get sick because of the repetitive transition between 0 and 2 G. The pilot can minimize the sickness by providing sufficient rest periods between parabolas and gradual climbs and descents.

d. Virtual Space Tours. Theme parks and space training facilities could provide virtual space tours through such technologies as VR and telepresence. People can immerse themselves in a three-dimensional computer generated environment using powerful computers, stereo audio/visual headgear, and special gloves for controlling the system. VR environments may include future orbital space resorts, spacecraft, and off-world settlements. Telepresence applies VR user interfaces, remote control systems, and cameras to direct robotic systems to look at something or pick up an object. (The Luna Corp. has developed a concept for a teleoperated lunar rover that people can drive. A variety of teleoperated vehicles could provide people with spectacular views of Earth or even allow them to capture a piece of space debris.)

3. Suborbital Trips

Suborbital trips present a near-term opportunity for adventure travel. Participants could experience the thrill of a Mercury-style space flight. Using modern technologies such as the Global Positioning System and teleoperated control systems, a company could launch an adventurer traveler and maneuver the capsule to splash down in a specific location. An alternative is a small highly reusable space transportation (HRST) vehicle with a pilot and multiple passengers landing at a standard airport. This tour package would offer an incredible view of Earth and 5 min of weightlessness. Travel agencies could wrap vacation packages around the flight so the splashdowns or airport landings could be made at an exotic locale. A small HRST vehicle could also reduce 16-hr cargo and passenger trips to 90 min.

4. Three-Orbit Tour

A three-orbit tour could provide passengers the photo opportunity of a lifetime, time to play in zero gravity, and time to think about their world. A passenger spacecraft could include a padded room for acrobatics and windows or perhaps even an observation cupola. After enjoying the magnificent view of the Earth, perhaps passengers might be able to orbit near the *ISS*, *Mir*, and a variety of commercial satellites. Robotic camera systems on the outside of the ship would enable passengers to take many photographs. In addition, passengers could have hands on experience with several types of remote-sensing equipment.

This tour may not be for everyone, because early space adventure travelers cannot expect the amenities found on a pleasure cruise. An analogous activity on Earth may be a trip on a deep-sea fishing boat. The spacecraft may include a zero-gravity bathroom and a small sickbay. The crew may consist of two people who monitor automated control systems and tend to sick passengers. On such a short trip, they would not prepare food, but they could provide prepackaged snacks.

5. Three-Day Trip

A 3-day trip offers more personal time and may call for more structured activities. This tour package may be analogous to a trip on a large sailing ship where passengers do some of the work. Passengers could perform some tasks that provide the experience of being an astronaut. For example, the trip could include some onboard experiments that require some human interaction. Like the three-orbit tour, passengers would have access to robotic cameras, remote sensors, an acrobatic chamber, and

perhaps an observation cupola. Additional activities could include teleoperation of orbital debris collection systems. The telerobotic system could deposit the debris in the back of the ship for return to Earth or forced reentry. (Imagine the excitement of bringing home a piece of space debris as a souvenir!)

Wedding ceremonies have transpired in cyberspace, on roller coasters, on top of flag poles, under water, and at other offbeat locations. A matrimony package trip could take wedding parties into space for a unique ceremony. The package could offer time for in-space acclimation, wedding vows in the cupola, a reception, and a private room for the newlyweds.

As the general PST and tourism business grows in sophistication, the 3-day tour could offer stops along the way at special orbital facilities. These orbital facilities could later grow into orbital hotels for longer vacations. Examples of specialized orbital facilities include a swimming pool, gymnasium, and observatories. A swimming pool in zero gravity is more like a large blob of water—swimmers could enter at one end and swim through to the other. A gymnasium could provide more room than an acrobatic chamber with a greater variety of equipment and games. Tourists could play a game of soccer or fly through a three-dimensional obstacle course. A visit to a space-based observatory would give tourists a greater appreciation of the universe and let them see advanced space science hardware up close.

Again, the 3-day tour would offer minimal amenities. Artificial gravity would not be required, so the ship would have a zero-gravity toilet similar to the *ISS*. Scheduled activities should include sleep periods scheduled around circadian rhythms. Passengers would eat prepackaged meals. A potential architecture for the ship includes a private room for two people, a larger room with several sleeping bags, and a larger sickbay than on the three-orbit tour ship.

6. Orbital Resorts

Eventually, the specialized orbital facilities will evolve into space resorts. Competition will provide a variety of places for passengers to visit via orbital transfer vehicles. Entertainment will probably be a primary consideration of such early resorts. Professional sporting events could take place in orbital “stadiums” (perhaps constructed around large—70,000 ft³—Shuttle vehicle external tanks that would be placed in orbit). Some resorts could include casinos and variety shows with incredible zero-gravity choreography, and other resorts could serve as retreats for religious and business organizations.

Passengers could have a choice of gravity levels among the various resorts. Some resorts may offer 1 G or partial G, while others have zero gravity. Amenities at orbital resorts would far exceed the modest accommodations of the early adventure tours. Travelers would expect more personal space, better bathrooms, and fine cuisine. Room design should eliminate undesired visual cues and consider circadian rhythms.

Resorts would also include physical training facilities and medical facilities. For resort personnel and travelers who spend a longer time in space, physical training facilities would offer a variety of exercise equipment and artificial-gravity environments to maintain muscles and bones. Inevitably, as the number of people in space increases, there will be a need for medical facilities with a staff capable of performing minor surgery. Other societal problems will eventually arise, requiring the need for security systems and personnel. Design requirements would include orbital debris shielding and radiation protection.

Resorts, like any other business, require offices and a communications infrastructure. Eventually, travelers will expect shops and theaters. These features will drive the requirements for communication, electricity, plumbing, etc. As the resorts in LEO expand, so will the infrastructure and investment capital. In time, resorts and transportation systems will move out towards geostationary orbit and, eventually, to the Moon.

7. Lunar Settlements

Eventually, it can be expected that Government agencies and corporations will establish outposts on the Moon. The Moon offers partial gravity of $1/6$ G which will reduce incidents of space sickness and provide people the feeling of superhuman strength. Tourists could wear a pair of wings and fly under their own power within a dome. Tourists could visit the original Apollo landing sites or enjoy viewing a splendid Earth-rise.

D. Recommendations

- Identify detailed human factors requirements for space infrastructure elements, the commercial travel and tourism business, and technology developers.
- Define guidelines and boundaries for developing policies, building codes, standards, and regulations pertaining to the future general PST and tourism business.
- Outline basic “road maps” that businesses, universities, and Government agencies can use to develop projects, goals, and objects.
- Determine minimum gravity requirements for long-term sojourns in space.

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III. CERTIFICATION, REGULATION, LEGISLATION, POLICIES, AND ENVIRONMENTAL ISSUES

Keith Calhoun-Senghor

DOC/Office of Air & Space Commercialization

Carl S. Rappaport

DOT/Office of Commercial Space Transportation

Scott Pace

RAND/Critical Technologies Institute

A. Introduction

Critical regulatory issues affect general PST and tourism. These regulatory issues concern the nature and extent of regulation to protect public health and safety, safety of property, and U.S. foreign policy and national security interests. Statutory objectives must be considered in the context of international obligations requiring Governmental authorization, and supervision of commercial space activities. Optimal types and levels of regulation of the emerging business should:

- Assure Congress, the media, the financial community, and the public that the business is safe
- Reduce uncertainty and risk by providing a more stable business environment
- Minimize Government burden on industry and commerce
- Promote uniform performance-based industry standards.

This section examines the regulatory and policy issues affecting the viability of public access to space. After a series of presentations, followed by questions and discussions, this issue was divided into three sections:

- Near-term regulatory issues
- Near-term policy issues
- "Beyond the near term" issues.

B. Near-Term Regulatory Issues

Four major regulatory issues need to be addressed in the near term.

1. Space Prize Participant Damage Waiver (X-Prize, etc.)

Throughout history, prizes have been offered as incentives to solve difficult technical or scientific problems. Currently, an X-Prize Foundation has been established that seeks to award a \$10 million

prize to the first party to develop a feasible method of launching a payload into orbit and returning it to Earth on a reusable vehicle, ready to be launched again within a fixed period.

However, for the award of such a prize to be financially acceptable, there must be some legally binding way for a participant in the contest to waive his or her claim to damages against the organizers of the prize if they should be harmed, or harm others, in pursuit of the prize. Such relief could take the form of legislation, or some other type of legally enforceable mechanism.

General PST and tourism liability regulations should draw upon those used regarding liability for aviation operations. On average, the U.S. loses 23–28 aircraft per year. In 1994, losses totaled \$2.2 billion (35 percent for hull loss, 40 percent for liability). Passenger liability factors include the degree of airline negligence, passenger pain and suffering, passenger future earning power, and crash location. Average costs were \$2 million per life lost in domestic flights. Between 80 and 90 percent of airline liability cost is for litigation. A cap established at the Warsaw convention is \$75,000 for overseas flights. Presently, there is discussion of raising the cap to lower legal costs arising from lawsuits that typically challenge this cap.

2. Experimental Flight Regulations

It is also necessary to develop a standard set of regulations to govern the safety and other aspects of experimental flights. This would protect those engaged in high-risk experiments by giving regulatory protection in the event of liability claims resulting from these tests. It would also give the public and entrepreneurs some minimum assurance of the acceptable level of risk involved in these ventures. A potential change in regulations may allow the use of Bureau of Land Management land areas for experimental space flight. Safety regulations should address experimental human space flight. These regulations can use experimental aircraft as a model.

3. Uniform Spaceport Regulations

General PST and tourism would be greatly beneficial to U.S. space capabilities. However, opposition would arise to direct Government subsidies. Therefore, a business model is crucial. Typical business risks include technical risk, market risks, financial risk, and policy/regulatory risks. Analogous aviation regulations include FAA/ICAO regulation, safety surveillance, airport ownership, air traffic management fees, liability/litigation costs, and media coverage of accidents.

The Commercial Space Launch Act, as amended, requires licensing of commercial space launches and commercial operation of launch sites in order to protect:

- Public health and safety
- Safety of property
- Foreign policy and national security interests.

Commercial spaceports will play an important role in making space travel for the general public a routine and affordable matter. However, in order to protect the public and offer uniformity to the launch providers using spaceports, it will be necessary to develop a standard set of regulations to govern

their operation and use. Spaceport regulations can derive benchmarks from consideration of international practices. Currently, the DOT is drafting spaceport regulations. However, any regulations will need to be refined over time to accommodate evolving uses of spaceports as alternative launch and recovery sites.

4. Space Traffic Management

To avoid risks of inappropriate or hostile regulations, business representatives must cooperate while competing with one another. Current National Space Policy (September 1996) is silent on tourism.¹ There are different policy concerns at different stages such as: research and development (R&D), testing, and evaluation. Presently, Government supports operations, traffic control and clearances, and infrastructure construction. Extrapolating present Government support, one can imagine space tourism infrastructure such as spaceports, space business parks, even hotels.

As the use of space becomes a more common and commercial endeavor, a framework will be needed within which the increasing amount and types of space traffic will be managed. This will require some means of tracking and controlling the number of vehicles that will reach and operate in orbit and of assuring rights of way, priority orbits, etc. Such a system could be based on current international air traffic control regimes, or it could grow along with the evolution of this particular market.

Near-term thought will need to be given to this issue before the volume of traffic overcomes the capacity to manage it. The current legal framework includes:

- Space Law—the 1967 Outer Space Treaty
- Trade—the 1944 Chicago Convention (Aviation)
- Liability—the 1929 Warsaw Convention (Aviation) and the 1972 Liability Convention (Space).

An important point regarding current regulations is that international law is permissive. Chicago Freedom Conventions identified a number of privileges, not rights, for airlines. The first five freedoms are (1) the right to fly across another country without landing, (2) the right to land in another country for purposes other than carrying passengers; e.g., refueling and maintenance, (3) and (4) the right to load or unload passengers, mail, and cargo in another country, and (5) the right to enable airlines to carry passengers to one country and then fly on to another country, a.k.a., “beyond rights.” Informal freedoms include a state’s right to carry traffic between two other countries via an airport in its own territory, the right to operate stand-alone services between two other countries, and carriage of passengers and cargo within the borders of another country, a.k.a., “cabotage.”²

C. Near-Term Policy Issues

Three different paths can lead to general PST and tourism: Government-driven, privately-driven, and a mix of public and private activities. Government-driven programs include support to the *ISS* and other Government-funded human space flight projects. Privately funded efforts include the evolution through parabolic aircraft flights, suborbital trips, and orbital trips to space hotels. Future private ventures include the transfer of passengers and cargo. An example of a public/private mix is the support of space

business parks with mixtures of cargo and passengers from all sources. Several policy issues also need to be debated and resolved in the near term to allow general public access to space to develop to its full potential.

1. Determining the Availability and Use of Excess Government Launch Assets

There are significant and predictable consequences to allowing, or not allowing, the widespread commercial use of excess Government launch vehicles. The arguments on both sides are substantial. However, thus far the policy of the U.S. Government has been to restrict the use of excess Government launch assets to limited educational purposes and DOD use only.

If this continues to be the policy, it will impact the cost, timing, and technology used for commercial ventures in the future. Rather than relying on surplus assets currently in existence, newer technologies will need to be brought to the market.

2. Government Procurement Policies

Financial concerns of a general PST and tourism policy agenda include clarification of tax treatment for RLV's and space infrastructure; i.e., depreciation. Private competition should supply ISS logistics. The circumstances under which the United Space Alliance, organized to operate the Shuttle fleet, would be allowed to compete must be considered.

Regulatory and policy measures which benefit commercial space activities (in general) are preferable to those which benefit general PST and tourism (in particular). A policy and regulatory agenda should include support for R&D, not only for the RLV, but for subsystem technologies as well. R&D should also improve the understanding of space debris risk and develop mitigation strategies.

Space transportation policies should be considered in future Government space transportation acquisition decisions. Should the United Space Alliance be allowed to carry passengers and commercial cargo? Should evolved expendable launch vehicles have a "Dyna-Soar" addition? The Government must consider the ramifications of using RLV's only, and two stage to orbit (TSTO) versus SSTO. These policies can derive from a comparison of DOD, NASA, and DOT-FAA Commercial Space Transportation practices.

As in the case of excess Government launch assets, Federal procurement policies can have a great impact on which space transportation technologies are developed and what markets are pursued by private companies. Government procurement policies should be consistent within the broader framework of U.S. policy goals and work to promote the development of simpler, less costly, and more safe and reliable space transportation technologies.

3. Explicit DOT Authority to License Reentry Vehicles

The DOT is currently seeking explicit legislative authority to license reentry vehicles to remove any ambiguity about its authority in this regard. Legislation is being developed in Congress which would grant such authority. Therefore, this issue may be resolved in the near future.*

4. Privatization of Zero-Gravity Aircraft Flights

One important step in bringing affordable space flight to the public would be the privatization of zero-gravity aircraft flights. This would allow members of the public to experience simulated weightlessness in a manner, and at a price, that could serve to establish and stimulate the market for actual suborbital and orbital flights. Such parabolic flights are conducted privately in Russia. The policy decision is whether such private flights, properly licensed, should be allowed in this country.

5. Limitations on Second-Party (Passenger, Cargo) Damages

A general PST and tourism capability implies the ability to carry cargo and/or passengers. Demand for this capability will induce competition for time-urgent shipments. Today's subsonic air cargo; e.g., FedEx, could lead to tomorrow's high-speed commercial transports in the Mach 3–5 range. As a matter of policy, any limitations on the amount of damage allowable against carriers because of damage to cargo or passengers would significantly affect the financial viability of such ventures. However, the policy implications are also significant for those affected by such loss. The value of such an unprecedented decision would be significant for other businesses.

D. "Beyond the Near-Term" Issues

Eventually, regulations and policies must address the infrastructure, environment, and rights associated with PST. Many of the certification procedures and regulations can derive from analogous systems such as aerospace construction standards and maritime law. The following paragraphs describe these categories of issues.

1. Property Rights and Individual Rights

Potential tourist attractions in space may include captured asteroids or salvaged satellites. Today's regulations pertaining to international waters may provide a model for developing space-based salvage and mining laws. A legal framework should be in place before property rights' issues arise. Topics for discussion in this area include:

- A claims registry for property rights in space
- The development of rules governing rights to noninterference of space-based property
- A potential registry of "deeds" and liens for orbiting assets both man made and natural
- Definition of judicial jurisdiction for the application of criminal and civil laws in orbit.

* This issue was addressed by the Congress in 1998 in H.R. 1702, an Act "to encourage the development of a commercial space industry in the United States...."

Given the closed and controlled environment in which space travelers will live, individual rights must be carefully considered. Examples include personal behavior, gambling, and drinking. A clear command of authority can derive from today's maritime law. Regulations followed by the cruise line industry may serve as a model for gambling and drinking in space hotels. The legal framework should provide enough flexibility for "House Rules" pertaining to drinking, smoking, and dress code.

2. Launch/Recovery Facility and Space Environment

Today the space around Earth is littered with debris traveling in various orbits at rates up to 18,000 mph. Orbital debris endangers orbital facilities and drives requirements for expensive tracking systems. Regulations must address the in-space environment as well as the Earth environment surrounding launch and recovery facilities. Environmental issues relate to:

- Regulation of noise around such facilities and space debris in the near-Earth and space environments
- Rules governing overland supersonic flights for experimental and reentry vehicles
- Procedures and other rules relating to the operational impacts of space systems
- Regulations for cleaning the space environment to ensure the safety of orbital facilities.

3. Certification of Commercial STS's and Operations

General PST must have safety standards, building codes, and certification procedures to ensure the safety of passengers and crew. Many of the launch vehicle and facility construction regulations can derive from existing standards, or transition from Government standards to industry developed standards. Space transportation facility construction involves issues such as:

- Development of a regulatory fee structure, if necessary to sustain the oversight of launch and recovery facilities
- Oversight of orbital facilities
- Tax treatment of orbital facilities and the appropriate role of tax incentives, tax holidays, etc.

The "rule book" for space destination systems has not been written. Building codes and safety regulations need definition and refinement. Some example building codes include emergency egress for large numbers of people, medical facilities, galleys for food preparation and heating, venting, and air conditioning. The aerospace industry may lead the development of building and operating codes. *ISS* systems can serve as a baseline. Cleanliness standards may derive from regulations set forth by the Occupational Safety and Health Administration (OSHA). The passengers themselves should be required to pass any physical standards identified by the FAA and NASA.

E. Recommendations for Future Action

- Begin debate and work on regulatory and policy near-term issues.
- Engage in a public policy debate on the longer-term issues.
- Increase the visibility of the potential for general PST and tourism as a viable economic market through:
 - Small, exciting ventures to start
 - Serious study of this market to increase financial credibility.
- Directly engage the public's excitement—bypass the "experts."

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IV. FINANCIAL, ECONOMIC, BUSINESS PLANNING, AND MARKET REQUIREMENTS TO START A VIABLE SPACE TOURISM BUSINESS

Dr. Neville Marzwell
California Institute of Technology

Abstract

Technology, markets, business, and financial surveys suggest that a general PST and tourism business will be created if a vehicle is developed and demonstrated to be adequately safe for a fast turnaround time at an acceptable price. Various issues are identified that could be "show stoppers." The major single requirement for the creation of a solid business is the design from scratch of a very highly reliable system that is uniquely built for general public passenger transport. This vehicle must be designed to be operated like an airline. It should have fully autonomous flight control and navigation systems. It is critical for this vehicle to have onboard health monitoring systems and real-time launch-abort savability. Other issues that could impact business success are space sickness and Government regulations that, if combined, could break the spirit of the public and the entrepreneurs. The major factors affecting the economics of a viable general PST and tourism business are identified. An ultrahigh flight rate and high safety and reliability are crucial. Figures of merit similar to those used to evaluate the economic viability of conventional commercial aircraft are developed. Items, such as payload/vehicle dry weight, number of passengers, turnaround time, propellant cost per passenger, insurance, and depreciation costs, are discussed in detail, and indications are that an infrastructure can be developed for a viable business. Reference space vehicle designs optimized for general PST and tourism are used to assess the business opportunity. Subsystem allocations for safety and reliability, operability, and cost are discussed, and a route to developing and implementing such capabilities has been judged to be realizable and financially promising.

A. Introduction

A large-scale general PST and tourism business will require an infrastructure made up of launch and landing sites, vehicles, training and medical diagnostics, and facilities to support hundreds of trips per year. Until now the commercialization of space has been heavily handicapped by the high cost of space transportation. It should be possible, with today's technology, to reduce the recurring launch cost to \$2,000–\$4,000 per kg. This would present a significant improvement over today's cost. The proposed reusable systems should strive to achieve safeties of 99.99 percent, which is a significant (two orders of magnitude) improvement compared to today's systems at 95–98 percent.*

*Shuttle operations now approach 99 percent.

The conventional wisdom is that once such low-cost access to space is available, market demand will nucleate, chiefly by allowing and prompting large numbers of commercial business opportunities. But it may well be a slow process. The growth potentials will only be limited by safety and reliability first and foremost, and cost to a much lesser extent. However, present costs are still too high to attract major traffic from such uses as low-priced passenger transport to and from space, space manufacturing, rapid worldwide package delivery via suborbital flight, and possibly extensive levels of mass delivered via military-like vehicles.

1. Commercial Ventures

The economics of starting viable space businesses, in general, are sobering. Financial planning for the enterprises, capital needs, acquisition procedures and sources, size and elasticity of markets, growth from initial demand, and the criteria for financially viable ventures—all must be considered. However, if a vehicle is developed and demonstrated to be adequately safe and reliable, and trips are offered at an acceptable price, then financially viable general PST and tourism businesses will begin to be created.

2. Possible Foundations for General PST and Tourism

Traditional space transportation approaches are limiting and different approaches are now needed. A general PST and tourism service requires that a transportation system and infrastructure be made available that is specifically conceived and built for general public use. This STS will need excess capacity that can be used for cargo needs. It must be designed at a price that the initial small market will bear. Capacity could then expand at lower prices as business expands.

As a straw man, a price of \$12,000 a ticket in 1997 dollars is suggested. This price represents a discussion point only and is not intended as a goal but more as what might be possible in today's market where tourists are spending comparable sums on an annual basis to take adventure tours. It was noted that even the \$12,000 ticket would not make an orbital vehicle a viable entry with transportation costs of \$2,000–\$4,000 per kg, but it could certainly be an incentive for shorter suborbital adventure trips.

The next step in building the business would be to build a few space tour vehicles and then use them as test vehicles for cargo transport to get customer acceptability, establish the viability of the industry for insurance purposes, bring in initial revenues, and be certified for passenger carrying by Government authority. This was the same approach (albeit unsuccessful) that the Russians used for their supersonic transport, the TU-144, when it appeared that, in its initial production models, it would not be suitable for passengers.

After the space tour vehicles, the next goal would be to develop a capability for an in-space stay that would leave a positive feeling of a worthwhile "fulfilling experience." In essence, what this service would be selling would be not only transportation or exotic thrills but also a basic life "experience," a rite of passage. It is important to understand that, in the beginning of this business, it is not so much the destination but the way and thrill of getting there that would be important. As its passengers used to say about the *Graf Zeppelin*, "You did not fly, you voyaged."

3. General PST and Tourism Issues

There is a definite need for a major shift/change of perception when it comes to general PST and tourism. Access to space cannot be limited to highly trained and closely selected individuals, nor can it be regarded as the exclusive province of governments. The importance of establishing a business that will be supported by the business community under the same degree of scrutiny now accorded all large business deals cannot be underestimated. Management know-how is extremely important; the ability to determine market characteristics in detail and forecast demand will be at a premium, especially in the early years.

One of the interesting aspects of space travel which have already shown up in space is motion sickness. This is not a new phenomenon for international travelers. The old pictures with the travelers at the rail of an ocean liner is a cliché, but motion sickness in space seems to be almost endemic, and there is no recourse to larger ships and fresh sea air. Even astronauts with demonstrated resistance to motion sickness have had trouble in the Space Shuttle environment. Ongoing research needs to establish the degree, time, and duration associated with space sickness to open up this business to a greater market than just the adventuresome rich who are ready to put up with considerable discomfort.

Another area of concern is the important one of insurance and the viability of coverage. The business must depend on a commercial market that plays by generally accepted principles for underwriting. Along the same lines, but involving governments, are the regulations and licensing matrix that the business will be subject to. At the current time, it is unknown how the regulations and the licensing will be done or even how many governments or locally administered centers would be involved in an undertaking of this magnitude. This must be known to reduce the business risk of the entire enterprise. The business must know the planned roles of governments both national and local as well as the international community to be able to successfully operate in space.* Governments at any level can function as supporters or creators of barriers.

Operational maintenance and servicing costs are another serious business concern. Overall vehicle design and operating safety, reliability, robustness, reusability, durability, and cost are the keys for a successful routine operation. Close attention must be paid to the technologies involved, the development pace of those technologies, and the time required to see their successful utilization. This new business must be able to demonstrate credible low-risk and best-engineering practices in space transportation. For this reason alone, it must show that it can successfully operate with an optimized general public passenger-carrying vehicle that takes low-risk and best-engineering practices into account. All of this helps to develop and achieve a perception of safety in a business that will most likely rise or fall on its safety record regardless of its financial viability.

4. Major Factors Affecting Successful Business Initiation

It is obvious that to succeed in the general PST and tourism business rigorous business plans are necessary. These plans must be able to detail end-to-end space vehicle and infrastructure cost. Vehicle

* The recent announcement that an agreement has been reached among NASA, the Air Force, and the FAA regarding the latter's licensing of all U.S. spaceports is encouraging.

reliability, robustness, serviceability, lifecycle, reusability, and safety are all items which must be addressed. Operations logistics and architecture must be carefully thought out. The tour pricing strategy from initiation through the growth phase must be clear, carefully thought out, and articulated. Market size and market segments must be accurately forecast. Marketing development, maintenance, and growth costs must be carefully laid out. Load factors and turnaround time must be delineated and the cost to operate each tour known exactly. The business plans must have a comprehensive capital investment strategy. Financing mechanisms must be in place and accessible to the companies who seek to develop this market. The entire system must address the level of comfort for the traveler that is required, as was done in the age of the great ocean liners; and insurance and licensing protocols must be accurately forecasted and priced.

5. Business Risk and Uncertainties

Every business plan that will be developed in this new business must address the uncertainty of market demand, affordable seat prices, revenues per trip, and trips per year to evaluate net profitability. Business plans must recognize the limitations of existing space rocket vehicle designs and technologies as alternatives. They must base their analysis on a strong case for demonstrated safe and reliable vehicles that will protect the general public and have the economic viability to support a large business. The current history of the high cost of current Government-financed and developed space vehicles, rocket engines, and space operations needs to be addressed as well as the processes and technologies that will reduce these costs. An explicit process to initiate insurance coverage and determine its costs will have to be worked out prior to any strong investment in this system. One thing that must be determined is the impact of destination location(s) for tours which, in this context, includes options such as in-continent trips, suborbital trips, intercontinental trips, orbital trips, short visits to a space station, lunar orbits, etc. This will heavily influence industry demand forecasting, marketing, and early investment. Other factors will be the number, location, and cost of the spaceports that will support any of the options and yet offer the best return on its investment.

6. General PST and Tourism Vehicle Design Goals

The family of vehicles should be designed from the outset as a general public space transport system. In this system the traveling public will be looking for very high safety and reliability. One of the challenges facing the designers will be finding an optimal vehicle size for market needs. This is a problem facing airlines and airline manufacturers on a nearly annual basis. The vehicles must have a safe life support design and operational architecture. The vehicles themselves must demonstrate great durability with the capability of frequent trips to and from space. In essence, what the public will want to see is airline-style operations with rapid turnaround. Vehicles must be equipped with fully autonomous flight control and navigation systems. There should be an onboard health monitoring system. Unlike current vehicles, there is a requirement for launch abort with full vehicle savability at any time. On the ground, the family of vehicles must show simplified ground handling and maintenance compared to current systems. Again, the goal here is airline-type maintainability and operability. To be economically viable, in contrast to today's circumstances, there is a strong need for small numbers of launch and recovery personnel, for this would lead to a very low operating cost.

The design approach for the entire family of vehicles needs to be based on the philosophy that high safety and reliability, operability, and low operations costs are more critical than performance. In the same vein, high margins and robustness of the vehicles are more important than size. The designer needs to keep in mind that these vehicles need to operate with rapid turnaround and a long life, inasmuch as this equates to many trips with few interruptions. There must be a real-time, full abort capability with an engine out. The designer must eliminate as many catastrophic failure modes as possible. This is expected to be accomplished through following a program of rigorous design margins with an ongoing probabilistic analysis. The vehicles must have a real-time health monitoring system. Scheduled maintenance must be routine and rapidly accomplished. The vehicles are expected to be developed through incremental flight testing with extensive system and subsystem testing and certification. Of importance to the designer will be fuel selection with emphasis on safe and low cost.

7. Potential Sources of Capital

The sources of capital for investment in these enterprises include private investors, venture capital, international capital markets, strategic capital markets, the space transportation vehicle manufacturers (who in some cases will have a history of financing aerospace vehicles), spaceport construction companies, debt financing, the initial public offerings of any space venture companies, or any combination of the above. Possible new mechanisms should be explored which might take the form of temporary tax reductions.

The potential strategic partners who could potentially profit from a general PST and tourism business include:

- Major cruise ship companies (who have a long track record of financing large state-of-the-art vehicles)
- Major international hotel chains (bear in mind that the cost of the average casino currently built in Las Vegas today exceeds \$1 billion.)
- Major international airlines
- Major theme park operators, major international media organizations (the first purchased stay at the *Mir* space station came from a Japanese news organization)
- The entertainment industry whose current products, on average, exceed \$70 million a venture.

The initial market segments are believed to revolve around ground-based opportunities, rather than space flight itself. Opportunities in this area, in ascending order of difficulty and technology requirement, include:

- Receiving centers such as the Kennedy Space Center in Florida for tourists, private vehicle launch, and recovery sites
- Simulation and training centers, teleoperation centers, telepresence centers, medical diagnostics centers, interactive centers, on-site hotels/restaurant chains, parks and shopping centers, physical enhancement through low-gravity exercise, museums and cameras on the Moon accessible from Earth locations
- Rovers on the Moon and Mars, the command of which would be made available to the public.

Once the first stage is underway, the second stage of space travel and tourism would start with an introduction to zero gravity, to include suborbital trips. The person or persons who would make this flight might be "X" prize winners. The contest approach might have a niche for the right time at the right price. Suborbital trips could use a modified military space plane design if one is developed. The suborbital period would be followed with an orbit program of 3–16 orbits (analogous to those of the Mercury program) in which the tourist(s) would live in a transport vehicle for 5 to 24 hr. This venture would be the first of the orbital space tours. The small vehicle involved in this phase would be sustained by other ventures such as cargo transport, satellite transport, etc. to gain proven reliability for larger follow-on vehicles.

The next major goal in this incremental approach would be 1 wk in a transport vehicle for a total of 100 orbits. This would later be combined with 1 wk or more at an orbital resort hotel. These steps are believed to represent easily achieved incremental results and a reasonable evolution in the market.

B. Cost Drivers

The model for identifying the cost per trip is the sum of fixed, plus variable, costs. The major fixed costs are called out as R&D costs. The production costs of the vehicle plus the infrastructure costs are divided by the total number of trips. This total is then added to the variable operations costs, plus the failure costs, plus the propellant costs, in deciding upon the price per trip. The price per trip will relate to many other business considerations and would include profit.

Given this model, a major goal is a large total number of trips with an emphasis on rapid turn-around for each vehicle. Operations costs would be controlled by large design margins, regular planned maintenance on easily maintainable platforms, and the old standby of testing, testing, and more testing. This means an incremental flight test plan. One major goal is in the area of low-failure costs; i.e., both high reliability and a safe abort capability, with the vehicle design potential of surviving a single catastrophic failure in the flight systems. Propellant costs should be held in line through the use of conventional propellants such as lox rather than the more exotic LH_2/lox . Low infrastructure costs for the spaceports and the replacement systems and components are also very important, since recurring costs will probably determine the continued viability of any general PST and tourism business ventures.

C. Recommendations

The main recommendation is to stimulate a rising tide of interest by using present assets to create a market pull. This includes creating market demand and interest to enhance expectation. This could be stimulated through the efforts of one or more association(s) that would deal with public relations, entertainment, media support, etc. Also stimulating the rising tide would be the process of building a financial and credit infrastructure utilizing potential space voyaging slots, credit cards, certificates, awards, and competitions. Movies would be a tremendous aid here with the Discovery Channel, educational television, education, and entertainment providing a means of communicating with the public. Health and manufacturing benefits would be emphasized as part of this approach. The overall object is to support a diverse set of businesses which could function at different price ranges.

On the space trip front, the recommendation for designing for reliability and robustness is made using an aircraft-airline mentality. An example is Southwest Airlines which not only encompasses the vehicle but the entire support infrastructure.

To achieve acceptability, the industry should initially promote limited trips for highly specialized groups at their own risk.

D. Conclusions

- “Raise the tide” incrementally.
- A safe, reliable, and low-cost transport vehicle is needed if general PST and tourism is to become a big business.
- Financial, market, and technology readiness appears reasonable.
- Project leadership, commitment, and expert vision are critical for success, to obtain financing, and gain credibility.
- A change in the public’s basic perception of space travel is necessary at an early stage in business development.
- Reliability, operability, cost, margins, safety, and efficiency through optimal size are more critical than performance.
- A start is necessary at various levels for various niche markets.
- The Government role should focus on the development of key technologies, licensing through a clear regulatory procedure, and using its mission transportation needs to assist in private sector market creation.
- One or more general PST and tourism associations should be created to help gain political, social, and financial acceptability.
- Business already exists today to support cargo and limited travel for journalists.

E. Overall Consensus and Vision

If a vehicle is developed and demonstrated to be adequately safe and reliable at an acceptable cost, then financially viable general PST and tourism businesses will be created.

V. EARLY PRECURSORS

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John Spencer
Design Finance International

Howard Wolff
Wimberly, Allison, Tong, and Goo

A. Introduction

Throughout history, the great pioneer explorers of the oceans, jungles, polar regions, and deserts have always been followed by homesteaders, vacationers, and entrepreneurs. Once tamed, wild frontiers can quickly become favorite resort destinations.

Just as we have become tourists passing over land, above and under the oceans, and through the skies, so shall we eventually "float away" our leisure time in luxurious vessels orbiting the planet. Thus, there is an emerging need for evolving an infrastructure that will provide the paying tourist with an unforgettable vacation in space.

The problem facing private entrepreneurs of general PST and tourism is the current difficulty of access to the space environment. Initially, business developers must look elsewhere for the needed experience and industry growth. Appropriately, initial ground facilities, theme parks, and other Earth-based precursors can provide the evolving infrastructure necessary for the development of a sound business.

That is, actual general public orbital space travel and tourism will be preceded by businesses that exploit the demand for surface space-related theme entertainment. Theme parks and flight training facilities developed around space travel launch and recovery sites can both prepare the public for the space experience and provide profit from the enterprise; and such profits could fund the evolution from existing Earth-based travel to actual space travel.

Inherent in all of Earth-based space tourism precursors are common parameters applicable to any tourism business. Vehicle and facility design, length of stay, numbers of staff/crew, types of recreational activities, and vacation prices are central to the sustainability of any tourism enterprise.

Creating a compelling vacation experience and sound business enterprise in a remote environment requires careful balancing of human factors, economic, and technological/operational issues. These issues range from state-of-the-art Gore-tex™ sleeping bags to marble-tiled double staterooms aboard luxurious ocean liners.

Much, perhaps even most, of what space entrepreneurs need to know to grow the general PST and tourism business exists today on Earth. Every year millions of people spend at least a billion dollars enjoying space-theme tourist attractions and analogous leisure activities in the U.S. alone.

B. Wealth From Space Travel and Tourism

Tourism and travel is the world's largest industry—\$3.4 trillion a year (see app. B). The new paradigm for general PST and tourism will come about from calculating how much profit can be made per pound of (human) payload sent to/from orbit. Profitably operating a small fleet of space cruise ships could provide the backbone of this business.

1. Trends Shaping the Design of Future Destinations

Today's tourists come from all walks of life and look for a variety of vacation experiences. Such experiences include shopping, eating, exercising, pampering, viewing, interacting with new people, getting married, gaming, and personal growth.

2. Evolution of the Modern Cruise Trade and Its Application to Space Tourism

The ocean cruise business is growing and offers direct comparisons to the kinds of activities and expectations space guests will require. Success will depend on the actions of private enterprise guiding the appropriate Government regulatory agencies, technological developments, the ability to raise necessary development capital, and the expressed desire, financial ability, and will of the general populace to go into space.

3. Submarine Tourism

Approximately 48 purpose-built tourist submarines have been constructed in the last 10 yr. Tourist submarine operations span the globe, providing approximately 2 million passengers each year with the opportunity to view the creatures of the sea while contributing \$150 million in revenue to the providers of these trips.

4. Theme Park Industry Overview

Tomorrow's theme parks are evolving into highly participatory experience parks that will strive to entertain and educate at the same time. Space is a well-proven and accepted theme.

C. Key Recommendations

Approach the development of general PST and tourism with a new attitude that springs from an appreciation of terrestrial travel and tourism abundance rather than scarcity; i.e., travel/tourism and entertainment are now the world's largest businesses.

When we talk about general PST and tourism, we must remember we are talking about the future. We need to present a positive and healthy view of the future, a future that is fun, exciting, and

alive with possibilities. Space trips must be fun and exciting if they are to attract the wealth market and become a realistic dream for millions of people.

A long-term integrated development effort should evolve which includes scientific and engineering research, building worldwide public awareness and support, and financial positioning with high profit and visibility as key goals.

A group modeled after the National Geographic Society could become a powerful advocate for the new business activity.

1. Abundance Versus Scarcity

The wealth in the world is growing at an accelerating rate as new markets for products open and new communication technologies make it easier to advertise new products and services. The wealthy are always looking for something “new and exciting” to do, and, if a safe opportunity opened to take a cruise in Earth orbit with lots of unique things to do, there are many thousands of people who could afford hundreds of thousands of dollars for such an experience.

2. Lotteries and Sponsorships

A lottery system for the average person could widen the market base. Today almost \$34 billion per year is spent in the U.S. on lotteries. Large corporate sponsors could purchase space cruises as prizes or awards. An example of this is one of the large Japanese newspapers which paid the Russians \$11 million to take a journalist to the *Mir* station for a week.

3. Pounds of Profit

If space tourism can prove to be highly profitable and prestigious, then the old question of how much does it cost to send a pound into orbit will become secondary to how much profit can be made by sending each pound into orbit.

Once the financing requirements are met, we will be able to establish detailed engineering requirements that our talented scientists and engineers can solve.

4. Tapping Into the Wealth Community

Many wealthy people, especially those associated with the entertainment business, are interested in space and become very excited when space tourism and the potential for them to actually go on such a trip is discussed with them. Tapping into this flexible and interested wealth base for support could provide the resources needed for critical research and marketing.

D. Conclusions

By focusing on the aforementioned key recommendations, we can accelerate the development of a profitable general PST and tourism business and begin to truly open the space frontier.

1. The Cruise Line Business as a Model for Space Tourism

The cruise line business may be a better model to follow than the hotel business for in-orbit facilities development and operation. The financing methods, operations, and marketing methods of the cruise lines are more comparable with the needs of space trips than are hotels.

a. From the Cruise Lines International Association—Executive Summary. (Note: These numbers relate to only North America (U.S.A. and Canada).)

Over the next 5 yr, the cumulative market potential for the cruise business is over \$50 billion—a 20-percent increase since 1992.

The cruise line business is the most exciting growth category in the entire leisure market. Since 1970, it has had a compound annual growth rate of 10 percent per year.

Since 1970, an estimated 50 million passengers have taken a deep-water cruise (2 or more days). Of this number, 70 percent have taken such a trip in the past 10 yr.

It is now projected that, by the year 2000, as many as 7 to 8 million passengers per year will take a cruise.

Taking a cruise is a dream of 60 percent of all adults, with the highest interest being exhibited by the emerging baby-boomer category. Shorter cruises (2 to 5 days) are the growth trend, up nearly 400 percent since 1980.

Based on public information as of July 1995, a total of 30 new ships are contracted for or planned to be added to the North American fleet by 1999. At an average cost of \$150 million a ship, this would be an investment of \$4.5 billion.

b. From Other Sources of Information. A 6-mo cruise in the master suite of the *Queen Elizabeth II* costs over \$350,000 per person. Many wealthy cruise takers spend over \$100,000 per person per cruise. Proposals are on the drawing boards for ultraluxury cruise ships that are huge floating cities costing over \$1 billion per ship.

2. Trends Shaping the Design of Future Destinations

Historically, the hospitality industry has not been known for rapid change, nor for embracing radical new concepts and technologies. In fact, most hotels and resorts today look much the same as they did 10, 20, and even 50 yr ago: Brick and mortar, lobby and guest rooms, restaurant, and swimming pool. Most innovations in architectural design are not created by visionary architects skilled at winning design awards and accolades from their peers. They are created by responsive architects skilled at observing the human species, anticipating what people want, and scripting experiences that make their dreams come true.

The travelers of tomorrow will not be a homogeneous group. They won't all choose the same destinations, and their expectations, once they arrive, will be quite diverse. What it comes down to is that the hotels, resorts, and destinations of the future will be shaped by what people like to do on trips.

A majority (88 percent) of the international travelers identify shopping as their favorite pastime. (It ranks second among domestic travelers.) The hotels and resorts of the future will have, or have access to, a significant amount of retail space, whether ground-based or orbiting. Shopping has become a leisure activity. People think of it as entertainment.

What else do travelers love to do? Eat. In this arena the big trend is toward offering choices. As much as marketers may want to put people into categories and give them a clever label, those groups are not homogeneous. The only thing predictable about their eating habits is that they are unpredictable. A wealthy traveler, for instance, may have dinner at a fine dining establishment, eat breakfast in the room, and have lunch at Jack-in-the-Box. If the first tourists in space are up there for any length of time, they will likely want to be offered choices.

There's another leisure-time activity that has progressed beyond just being a fad. In fact, it's a trend that's likely to strengthen in the future—getting exercise. Baby-boomers are intent on growing old youthfully. The future is likely to offer us a proliferation of health clubs, wellness centers, fitness facilities, and some newer variations on this theme. How about spending your summer vacation at an athletic camp for adults? Or investing 2 to 4 wk learning how to prolong your life at a “longevity center?” Several of these already exist. One firm alone has designed what could be described as “health-management resorts” in Australia, Germany, and Arizona. There may be many space-related wellness opportunities, as well.

A trend that goes hand in hand with the quest for fitness is the penchant for pampering. Look for more standalone spas and resorts catering to the stressed. As an early indication of this trend, several hotels designed with spa facilities are now changing their names to reflect that. The Hyatt Regency Kauai, for instance, is now officially the Hyatt Regency Kauai Resort and Spa.

According to a recent *USA Today* survey, even business travelers want to be pampered. Therefore, look for business hotels to offer spa facilities, whirlpools, and even massages. The pampering will extend into the guest room as well, with increased emphasis on the bathroom. While the first group of space travelers may expect Spartan conditions, as the business matures people will demand more luxurious accommodations.

What else do travelers do on trips? Well many of them meet friends, family, and business acquaintances. In the future, even with the advent of and increasing sophistication of video conferencing technology, people will seek out more opportunities to be with others of their species. There is already a booming market in the design and expansion of convention centers and conference facilities in the U.S. and throughout much of the world. As people grow apart and live apart, reunions, perhaps in space, will also be an increasingly popular reason to travel.

There's something else people like to do in their leisure time that's growing in popularity. They get married. The popularity of good, old-fashioned romance and marriage are on the rise. Two key trends are leading to this phenomenon. First, with a divorce rate around 50 percent, long-term marriages are increasingly rare. But giving up on a marriage is different than giving up on marriage: 80 percent of those who divorce remarry. Serial monogamy equals more marriages. Second, as our life expectancy continues to grow, it increases the odds that we'll have more than one spouse.

How does this impact the design of hotels and resorts? Simply put, it can be a big part of their future business. Hosting a wedding can be quite lucrative, both for the food and beverage revenues, as well as for filling rooms. And then there is the honeymoon. Among first-time marriages in the U.S., 98 percent take a honeymoon vacation. And they don't skimp. Honeymoon spending per couple has quadrupled in the last 20 yr. As a result, and in anticipation of this trend continuing, we're seeing a number of resorts adding wedding chapels, pavilions, and other related facilities to attract this lucrative market. For those lovebirds in search of the ultimately unforgettable experience, who can match the novelty and romance of a space-based or space-theme wedding and honeymoon?

Looking at Las Vegas may have some relevance. This patch of desert is expected to attract over 30 million visitors this year. While the recent growth in hotel construction was fueled by the popularity of gaming as entertainment, Las Vegas has become an example of a destination in which "supply creates demand." The more they build, the more people come. And visitors don't just come to gamble. Here, they can do all the things they love to do: Shop, eat, exercise, be pampered, meet other people, get married, and gamble.

There is at least one more early indication of what future travelers seek. A beach resort destination listed "environment and culture" as the number one criterion influencing their selection. This trend will fuel the growth of resorts offering such experiences as archeological digs, tours of the rain forest, or expeditions into space. The successful hotels and resorts of the future will facilitate and enhance a traveler's desire to combine learning and leisure with adventure.

The more exposure we have to other worlds, the stronger our desire is to experience them first hand. Where will we go in 10 or 20 yr in order to have a transforming experience and to see something new and unspoiled? Many of today's destinations are likely to be overbuilt or seem "old hat" to tomorrow's increasingly sophisticated leisure travelers.

In fact, according to the World Travel Organization, traditionally popular destinations as in Europe and the U.S. are declining in popularity compared to the growth in travel to such destinations as Asia and the Middle East.

The two most likely resort destinations of the future are sure to involve the exploration of space and our living seas. And what travelers will expect to find when they get there—wherever there will be—is a hotel or resort which reflects and respects the environment in which it is situated and an experience that enhances their lives in a meaningful and memorable way.

3. Theme Parks

In 1995 the domestic location-based entertainment business produced over \$6 billion in gross revenues. Two hundred and fifty million people visited U.S. theme parks in 1994 compared to 225 million in 1986. Parks captured over four times the number of paying customers as Major League baseball.

Theme parks have now entered their third stage of evolution, the “Experience Park.” The first stage was the “Amusement Park,” begun in the mid-1800’s. The second stage, which is continuing today, is the “Theme Park,” which originated with the advent of Disneyland in southern California in 1955. The expression was coined to describe a development in which there was a physical division of the amusement or leisure park into zones, each bearing a single theme.

As the population has become more skewed toward middle-aged “boomers” and their children, thrill rides are out, and “theming” is in. According to the International Association of Amusement Parks and Attractions, parks spent twice as much money enhancing themes in 1994 as they did in 1991.

The American audience has become increasingly sophisticated through their many years of exposure to high-quality entertainment. Therefore, to attract an audience and to motivate them to return to your attraction, the quality of the visitor experience and the “newness” of the experience must continue to evolve.

With a flexible visitor experience program rather than fixed rides, an experience park can adapt to entertainment trends and new technologies (emerging high quality/response VR systems as an example) and can respond on a seasonal basis. For example, during the nontourist season, the experience parks will emphasize their educational and exposition aspects rather than their entertainment aspects, thus drawing from an even wider market.

4. Participatory Experience

The following attractions are examples of the trend towards participatory experience entertainment: The Renaissance Pleasure fairs, the Civil War reenactments, the Murder Mystery trains, the Dodger Baseball camp, the Amateur Indy 500 sports car races, the Dungeons and Dragons™ simulation role playing games, both live and on the Internet, the Paint Ball Wars games, the amateur scientific expeditions to find dinosaur bones, and the Space Camps (both for kids and adults) around the world.

The guests (participants) dress in theme clothing and interact in a theme setting. A master story or event guides the general entertainment of the day. These kinds of experience events are fast becoming the “in” thing, worldwide. The park’s staff will be trained in group dynamics and facilitation. They will direct these situations, offering even more enjoyment and meaning.

This participatory approach significantly enhances repeat visitation because each visit will be markedly different from the last one because of the unique interaction of the visitors and changing programs.

5. 1996 Space Museums and Attractions Worldwide

• National Air and Space Museum	8,000,000
• Kennedy Space Center	2,300,000
• Johnson Spacecraft Center	800,000
• Space World–Japan	2,000,000
• Space Camp–Huntsville	600,000
• U.S. Space and Rocket Center	400,000
• Star Trek/Sci-Fi Conventions	<u>200,000</u>

Total Direct Market: Approximately 14,000,000

The second most successful movie of 1995 was “Apollo 13,” starring Tom Hanks. It earned over \$300 million in worldwide revenue—and the audience already knew the end of the story. It demonstrates a continuing general public fascination for space activity.

VI. RESEARCH AND DEVELOPMENT, TECHNOLOGY REQUIREMENTS, AND USE OF EXISTING SPACE ASSETS

Dr. Jerry Grey
American Institute of Aeronautics and Astronautics

Larry Rowell
NASA Langley Research Center

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A. Introduction

Technology requirements are addressed in three categories: (1) Passenger-carrying STS(s), (2) orbital facilities (including on-orbit operations such as servicing) and human factors (crew and passenger training and recreation, on-orbit environmental control, etc.), and (3) ground infrastructure. An example tourism trip scenario is used in discussing possible targets for technology development activities. Some general comments are made as are considerations for other working groups.

B. Part I

1. Research and Development

R&D activities pertinent to the three system areas of interest are being conducted primarily under the cognizance of NASA's Office of Aeronautics and Space Transportation (Code R) and Office of Space Flight (Code M). Some DOD efforts are also potentially applicable.

a. STS's. Current NASA-led programs relevant to space launch systems of interest include the RLV program (X-33, X-34, and X-37 Initiative), the ASTP, which includes rocket-based combined-cycle propulsion system studies, the HRST study, Hyper-X scramjet research, and the X-38 crew-return vehicle program.

Relevant Air Force programs include the Military Spaceplane (Transatmospheric Vehicle) study by the United States Air Force (USAF) Space Command and Material Command, the Integrated High-Payoff Rocket Propulsion Technology effort, the Integrated Powerhead Demonstration rocket research program, and the HyTech program (scramjet research/flight testing).

b. Orbital Facilities and Human Factors. Government R&D activities relevant to orbital facilities and human factors are being conducted primarily through the *ISS* program, involving not only NASA Centers but also overseas partners' facilities in Europe, Russia, Japan, and Canada. Current space trip operations related to relevant R&D on orbital facilities and human factors are being conducted aboard the Russian *Mir*, the U.S. Shuttle, and by the Shuttle-*Mir* joint program.

c. Ground Infrastructure. The ongoing R&D relevant to ground infrastructure primarily will be spinoffs from U.S. Shuttle advances and the RLV program. However, major issues remain to be resolved in operations for passengers and cargo that support safe, timely, low-cost handling, and loading pertinent to future general public travel and tourism-suitable facilities. These will require significant advances in technologies and operations.

These R&D activities bear significantly on the technologies and systems that are required to establish and maintain a sustainable business. Aside from paper studies being conducted in the U.S. and Japan, there is little or no R&D dedicated specifically to private sector general PST and tourism.

2. Technology Requirements

a. STS's. The primary requirement for the establishment and sustenance of a viable large-scale general PST and tourism business is universally recognized: safe, low-cost, reliable, readily accessible, timely access to space, and eventually comparable in all ways to today's commercial air travel. Note that these STS characteristics are not required solely by the general PST and tourism market; they are also needed by the U.S. Government's civil and military space programs and by the commercial space business. This Government requirement is not new; it has been recognized for decades. It was the original goal of the Space Shuttle program, formulated in the 1960's.

NASA was charged by the President's Space Transportation Policy Directive of August 5, 1994, to conduct the R&D needed to develop a next-generation STS to meet these requirements. The outcome of this mandate, following NASA's Access to Space Study in 1994, was the current RLV program and several even more advanced studies (Advanced Space Transportation Program (ASTP) and (HRST)). Clearly, reusability is the key (indeed, it was the original objective of the Shuttle concept). Many of the necessary technologies have been well known for decades, and the RLV program has been constructed to develop and demonstrate them in flight vehicles.

While the cost goal of the RLV program, if attained, could be adequate to serve our initial high-priced adventure trips market, according to market studies it is still too high to create the demand needed for a large-scale viable space tourism business. Hence, the follow-on ASTP and HRST programs were formulated to define concepts and technologies that would enable much more aggressive cost reductions (and also extend space transportation capabilities beyond LEO).

Technology requirements, therefore, may be categorized in several phases. First are those which are to be demonstrated by the current RLV program, which is expected to reduce costs to the order of \$1,000 per pound to/from LEO and increase operating safety and reliability by at least an order of magnitude. These include:

- Composite structures and tanks
- Advanced thermal protection systems
- Simplified avionics and health-monitoring systems
- Simplified operations and maintenance
- Improved rocket propulsion.

Next are the technologies implied by the HRST effort, whose cost goal is \$200 per pound to/from LEO. These include:

- Combination propulsion systems
- Combined-cycle propulsion
- Use of off-board energy for launch assist
- Revolutionary propulsion concepts
- Streamlined operations
- Advanced manufacturing technologies
- Thrust augmentation and upper stages.

Although it is not yet possible to identify those technologies that will eventually enable the safety, reliability, cost, and operability goals of an STS suitable for general PST and tourism, some ongoing R&D efforts are aimed in the direction needed to make that determination. However, it is not yet possible to predict the degree of success they will achieve in meeting their identified programmatic goals, much less the more ambitious ones required for a viable large-scale business. Moreover, until the RLV, ASTP, HRST, and USAF efforts have progressed somewhat further, it will not be possible to identify the subsequent efforts that may be needed to develop suitable space transportation technologies.

b. Orbital Facilities and Human Factors. The technology requirements for low-Earth orbital facilities that would be suitable for general PST and tourism are relatively straightforward compared with those for transportation. Although the present *Mir* and Shuttle environments are not suitable, the forthcoming *ISS* should demonstrate at least the rudiments of tourist-suitable facilities. However, the primary tourist-suitable technology requirements that will not be demonstrated by the *ISS* are as follows:

- Personnel transfer to and from the Station
- Recreational facilities
- Extravehicular activity
- Orientation and training programs for tourists
- Large-scale rescue capability (e.g., lifeboats, etc.)
- High-volume logistics capability.

c. Ground Infrastructure. Existing infrastructure does not provide any similarity to commercial air travel in terms of access, comfort, efficiency, timeliness, availability, safety, cost, etc. Entirely new processes and hardware must be envisioned to even approach the features and environment now enjoyed by commercial airline passengers. Technology needs, in broad terms, might include:

- Orientation and reservations theaters
- Simulation and training facilities
- Flight equipment and security facilities.

3. Existing Space Assets

The only current assets that might be converted to tourist use are (a) the real estate holdings now used for launch/recovery and general support, (b) development testing facilities (especially for

propulsion subsystems), and (c) the manufacturing capability of the current aerospace industry (but not its current tooling).

Existing STS's and infrastructure (including the Shuttle), current orbital facilities (including the forthcoming *ISS*), and the current systems/technology-relevant policy and regulatory framework are neither suitable nor adaptable to even the early stages of a space tourism business. Although the Shuttle and the *ISS* might be used for early general passenger R&D studies and service demonstrations, an entirely new technical and operating structure is required before large-scale marketing and sales of services could begin.*

C. Part II

1. Mission Model

The viability of a large-scale general PST and tourism-in-orbit market will be related to cost of the service and the price charged to provide it. A simple and conservative model allows discussion of the technology targets that might be used to define the needed advanced technology program content. The model used at this workshop is as follows:

- One-week trip duration; one vehicle per trip; 50 trips per year
- Forty passengers per trip
- Ticket price: \$100,000 per trip, half for round-trip transportation, half for on-orbit stay
- Total individual volume requirements including common habitability needs (e.g., showers, dining, corridors, etc.), but not including recreational facilities: 1,000 ft³
- Recreational volume: 13,000 ft³.

2. Implications for Technology

(a) If 500 lb are allowed for each passenger, launch costs must not exceed \$100/lb (half of the HRST goal) to meet a scenario target of \$50,000.

(b) Cost of installed habitable volume (i.e., including launch cost and all installed facilities) should not consume more than half of the on-orbit portion of the ticket price; i.e., <\$25,000. If current *ISS* modules are used to fulfill volumetric space requirements, six are needed for individual space and two more for recreational space. At \$100 million dry-mass cost (Boeing's estimate of production cost) and an RLV launch cost (25,000 lb @ \$40 million), total habitable volume cost is \$1.12 billion, or roughly \$300 million/year for 7 yr including a 15-percent discount. Hence, the per-ticket cost is \$150,000, or at least six times the target cost. Thus, Space Station technology is inconsistent with target goals; other technological approaches are necessary.

*With imagination and the use of a large-scale lottery or auction, some of the modest but inherently useful excess capacity available on most Shuttle trips could be used to create the earliest orbital adventure tourism service. And entrepreneurs could offer other surface activities to be associated with these particular Shuttle operations, the profits from which could be used to offset some of the high tourism trip costs. It is to be noted that United Space Alliance and Space Tech have agreed to work together to maximize the number of commercial payloads to be carried by the Shuttle fleet.

(c) Power requirement: 15 kW (minimum) per person. Current space power cost (*ISS* technology) is \$2,000/W; ground-based photovoltaics cost \$5/W. The median—20 times the ground-based cost and 1/20 of the space-based cost—is \$100/W, which comes to \$4,000/ticket. Allow 20-percent growth: \$5,000/ticket.

(d) Average cost of support personnel = \$100,000 per person per year. Allowing \$5,000 per ticket, that would allow 4,100 support personnel to be split as appropriate between ground and on-orbit crews. For comparison, the Shuttle requires 20,000 personnel, the *ISS* is estimated at 2,000, and a typical airliner requires about 100 people per airplane in flight. Note that the 100 support personnel could include as many onboard crew members as desired.

(e) Summary of what is required:

\$50,000	Launch/return cost
\$25,000	Installed habitable volume cost
\$5,000	Power cost
\$5,000	Ground-support cost
<u>\$15,000</u>	Everything else, including profit
\$100,000	Ticket price.

3. Technology Requirements

a. **STS.** See earlier HRST program objectives.

b. **Habitable Volume.** Current technology is inadequate to meet the assumed cost goals. New technologies will be required to meet both packing fraction and cost per unit volume goals and must be developed, validated, and demonstrated at the system level. Possibilities include inflatables, bellows, popup structures, etc.

c. **Power.** Current terrestrial technologies and manufacturing facilities could meet the cost goal but need to be validated and space-qualified.

d. **Operations.** Autonomous systems, health-monitoring technologies, and other automation technologies would help provide the necessary onboard reliability, abort capability, etc.

e. **R&D Requirements.** Some R&D requirements for technologies required by on-orbit facilities can be met by current programs; e.g., the Shuttle, the *ISS*, New Millennium, etc., just as some of the transportation technology requirements can begin to be addressed by the RLV, AST, and HRST efforts. However, these facilities do not provide the operations, reboost technologies, power distribution needs, etc., of tourist-suitable orbital facilities that can meet the \$100,000 ticket price goal. Nevertheless, operations experience gained during the *ISS* program will be valuable, and both the Shuttle and *ISS* can be used for technology validation, biomedical countermeasures research, testing (e.g., for space sickness remedies), etc.

D. Part III

1. Orbital facilities technology is not available for the \$100,000/ticket price goal. Hence a funding/programmatic mechanism is needed to advance, develop, validate, and demonstrate wholly untested new technologies at the system level.
2. Are there marketable options to combine the space transportation vehicle and the orbital facility? Or for very brief "excursion" or "barnstorming" trips in the early phases of activity that do not require an orbital facility?
3. Common technology requirements are currently not being addressed by disparate R&D programs; e.g., New Millennium does not address large-system or human-occupancy needs. But general PST and tourism requirements are so broad and universal that they could support many other technology development programs.
4. The life-support system needed for low-cost general PST and tourism trips must be nearly self-sufficient (i.e., not even replaceable filters); that is, almost 100-percent closed-cycle (for air and water).

APPENDIX A—International Space University Study

During the conduct of this study, a number of internal memoranda were prepared. They are being made available on the web site www.spacetransportation.org. One report was kindly prepared for the NASA Space Transportation Association (STA) study leaders by the International Space University (ISU). It deals with the health and medical circumstances of concern to people residing in LEO. It is a summary of the detailed ISU report “Distant Operational Care Center.”

The subject is of such importance that this summary report is reproduced here.

DISTANT OPERATIONAL CARE CENTER (DOCC)

At the 1996 Summer Session of the International Space University (ISU), 51 students from 23 countries worked together to design a remote integrated medical facility, which would be capable of treating patients in remote locations. The goal of the project was to design the system that was subsequently called the DOCC: Distant Operational Care Center. The DOCC was to be a modular medical facility that would maintain human health and performance in space, and be adaptable to a range of remote human habitats. This facility can be applied to the space environment, such as on an LEO space tourism station, aboard transplanetary spacecraft, and planetary surface habitats. This facility consisted of both an in situ facility for the remote location, and a ground network to support it.

Motivation for the DOCC Project

Space is a dangerous place for humans. While human abilities are the strength of the space program, human fragility, with regards to environment, is its weakness.

Until now, the care of humans in space has been left in the hands of the space agencies that launched them. However, space is a future frontier for a range of remote human habitats. From a few days to half a year, from LEO to Mars, the space frontier now beckons professionals and nonprofessionals, explorers and entrepreneurs, scientists and politicians with rich new opportunities. It is essential that tomorrow's medical community be prepared to face the challenges that such a diverse group of space-faring patients would present.

In previous treatments of the problems posed by humans in space, a “mission first” approach has been taken. To design the DOCC, a “medicine first” approach was taken instead. That is, work began from a general medical perspective, studying and establishing a foundation of common medical functions and hardware in order to design a modular facility which could be used in a wide range of remote locations. It was felt that this approach would deal most comprehensively with the increased frequency, duration, and complexity of future human spaceflight, while maintaining a functional interrestrial application.

The Core Module

The design process of the DOCC starts with the medical risk assessment. This covers all medical events which are likely to be encountered during the space flight, the medical procedures, the countermeasures, the treatment, and the hardware needed to cope with these medical events.

Medical events are divided into two categories: primary medical events and occupational hazards. Primary medical events, like infections and injuries, are events that could occur in any environment where humans are working. Occupational hazards are medical problems resulting from or having an increased incidence due to the space environment such as Space Adaptation Syndrome and deconditioning of the cardiovascular, skeletal, muscular, neurosensory, and immune systems. These hazards require the development of specific medical procedures and treatment, as well as appropriate countermeasures.

On the basis of the identified medical events, a modular approach was used in designing a core module. The DOCC core module consists of two elements: the remote facility and the Ground Control Center (GCC).

The remote facility can handle those medical events identified as common to a majority of missions in remote environments, particularly in space. It includes a Computerized Health Maintenance System, an Intensive Care Unit, a Crew Psychological Support System, and countermeasures equipment.

The GCC monitors, maintains, and resupplies the facility. It also serves as the hub of a communications network that links the remote facility with medical specialists all over the world, medical and imaging databases, and hardware manufacturers.

Case Applications

To demonstrate the capabilities of the core module, the report discusses its application to two scenarios: providing constant medical care aboard a commercial international space station and providing medical support for a Mars mission. The DOCC demonstrates its range in these two scenarios, since it must deal with a wide range of variables: the level of microgravity, mission duration, astronaut skill level, capability to return to Earth in emergency conditions, communication difficulties, and the ability to resupply.

Possibilities for Commercialization

The competitive advantages of the DOCC are its ability to adapt its health care capabilities to a variety of environmental or industrial needs, and the DOCC's provision of centralized ground support services, which include global medical networks.

The report identifies the main cost drivers for the DOCC and notes that it is expected that both the government and the private sector will play a role in the initial phases of the development of the DOCC.

Policy and Legal Issues

The report also examines the political rationale for which governments would participate in a project such as DOCC. These include sharing project costs and risks, international and national prestige, poten-

tial spin-offs, the advancement of the field of medicine on Earth and in space, and the possibility of encouraging longer and more frequent space missions.

Liability, privacy issues, and ownership of intellectual property rights for innovations made by DOCC users are identified as the main legal issues that would need to be addressed. The World Health Organization is viewed as having a role in standardizing operating procedures and medical equipment.

Concluding Remarks

If the future exploration and exploitation of the solar system are to be fully utilized, the need to promote and maintain the health of astronauts and "semi-professional" astronauts will be of paramount importance. As mission duration increases, greater importance will need to be placed on countermeasures and support of illnesses and injuries. For this, a dedicated medical facility such as the DOCC is essential.

In addition, the development of new medical tools and technology to deal with the particular challenges posed by the space environment will also prompt the rapid development of those tools for Earth.

For further information concerning the DOCC, please contact the ISU Central Campus in Strasbourg or the ISU North American Office:

International Space University
Strasbourg Central Campus
Parc d'Innovation
Boulevard Gonthier d'Andemach
67400 Illkirch-Graffenstaden
France
Tel: +33 (0) 3 88 65 54 30
Fax: +33 (0) 3 88 65 54 47

International Space University
North American Office
3400 International Drive, NW
Suite 4M-400
Washington, DC 20008-3098
USA
Tel: +1 (202) 237 1987
Tel: 800 677 1987 (Canada and USA only)
Fax: +1 (202) 237 8336

APPENDIX B—Travel and Tourism, The World's Largest Industry

From: "Global Paradox" 1994, by John Naisbitt

- Tourism employs over 200 million people world-wide, or one in every nine workers.
- Tourism is the world's leading economic contributor, producing an incredible 10.2 percent of the world gross national product.
- Tourism is the leading producer of tax revenues at \$655 billion per year.
- It is the world's largest business with a gross output approaching \$3.4 trillion per year.
- Tourism accounts for nearly 11 percent of all consumer spending and capital investment, and nearly 7 percent of all Government spending.
- Expectations for annual growth in global tourism are 6.1 percent, 23 percent faster than the world economy.
- Between 1990 and 1993, travel and tourism employment grew 50 percent faster than world employment.
- Travel and tourism is expected to create over 140 million new jobs world-wide between now and the year 2005.
- For many countries, tourism is by far the biggest moneymaker and the strongest sector in funding the global economy. For the U.S., travel and tourism are now the number one source of foreign exchange earnings.
- In 1991 foreign revenues totaled \$51 billion (including \$11 billion spent on U.S. airplanes, cruise ships and other carriers). This total surpassed agriculture (\$39 billion) for the first time as the country's primary export industry.

APPENDIX C—Study Workshop Participants

Dr. Buzz Aldrin (Starcraft Enterprises)
Robert Armstrong (NASA Marshall Space Flight Center)
Victoria Beckner (LunaCorp, Inc.)
Ivan Bekey (BDI; Steering Committee, Workshop; Initial NASA Study Lead)
Collette Bevis (X-Prize Foundation)
William Bierbauer (Lawyer)
Gloria Bohan (Omega World Travel; Steering Group)
Dr. Molly Brennan (CCI; also, Workshop Organizer)
Steve Brody (NASA OSS/Mission From Planet Earth Office)
Keith Calhoun-Senghor (DOC/Office of Air & Space Commercialization)
Robert A. Citron (Kistler Aerospace; Steering Group)
Kelvin B. Coleman (DOT/FAA/Office of Comm. Space Transportation)
Ed Cooper (Omega World Travel)
Dr. Peter H. Diamandis (X-Prize Foundation)
Marcus Dinsmore (Omega World Travel)
Norman Fast (F.B. Partners/Incredible Adventures; Steering Group)
Stephen Fogleman (NASA OLMSA; general participant)
Dr. Jerry Grey (AIAA)
David Gump (LunaCorp, Inc.)
Robert L. Haltermann (Haltermann & Associates)
Rick Hauck (INTEC)
Patt Hill (Omega World Travel)
Joe Howell (NASA Marshall Space Flight Center)
Walter Kistler (Kistler Aerospace)
Sandra Morey Kreer (Travel Network)
Chuck Larsen (DOT/FAA/AST)
Charles J. Lauer (Orbital Properties, LLC)

John C. Mankins (Workshop; NASA Study Lead)
Gregg Maryniak (X-Prize Foundation)
Dr. Neville Marzwell (California Institute of Technology)
Wallace McClure (Boeing North American)
Tidal W. McCoy (Thiokol)
James Muncy (House of Representatives Staff)
Dan O'Neil (Workshop; NASA Study Organizer)
Scott Pace (RAND/Critical Technologies Institute)
Michael R. Paneri (Wimberly, Allison, Tong and Goo)
Dr. William M. Piland (NASA Langley Research Center; Steering Group)
Gene Pinder (US Space & Rocket Center)
Jack Pozza (CCI; Workshop Organizer)
Carl S. Rappaport (DOT/Office of Commercial Space Transportation)
Tom Rogers (STA Study Lead)
Larry Rowell (NASA Langley Research Center)
T.C. Schwartz (Society Expeditions; Steering Group)
Charles Scottoline (Boeing North American (ret.); general participant)
David Smitherman (NASA Marshall Space Flight Center)
Eric W. Stallmer (STA Study Organizer)
Thomas C. Taylor (Global Outpost, Inc.)
Harvey Willenberg (Boeing Defense and Space Group)
Dr. Lawrence R. Young (MIT; Steering Group)
John Spencer (Design Finance International)
Dr. Harvey Wichman (Claremont McKenna College)
Howard Wolff (Wimberly, Allison, Tong and Goo)
Gordon Woodcock (Consultant; Steering Group)

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