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LEGAL AND REGULATORY ISSUES FOR PASSENGER SPACE TRAVEL

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Abstract

Work aimed at establishing a space tourism industry which will enable the general public to travel to and from space on a commercial basis has made good progress in the past few years, particularly in the USA and Japan. Developing the vehicles needed for space tourism is an engineering challenge, involving developing re-usable rocket engines with low maintenance costs, light-weight robust vehicle structures, low-cost operating procedures and other targets. However, it is also an institutional challenge, since in order for rocket vehicles to provide commercial passenger travel services to and from space, extensive innovation is needed in applicable law and regulations, both at the national and international levels. It is now becoming accepted that civil aviation is the appropriate model for a future passenger space travel industry, and studies in both USA and Japan are now focusing on details of aviation regulations and their applicability to the design, manufacture and operation of passenger space vehicles.

INTRODUCTION - RECENT PROGRESS TOWARDS SPACE TOURISM

Much of the work performed over the past few years aimed at establishing commercial space tourism services for the general public is usefully referenced and collected in (1). One of the more significant activities is the Space Tourism Study Program of the Japanese Rocket Society (JRS) which is now in its 6th year. A series of papers on the design and operation of the "Kankoh-maru" VTOL passenger launch vehicle have been published (2, 3, 4, 5), and reports (in Japanese) have also been published on the economics of the development, manufacturing and commercial operation of Kankoh-maru. Preliminary studies on Kankoh-maru pilot procedures (6), and airline-like operation of scheduled flights to orbiting commercial facilities (7) have also been published.

From 1996-97 the JRS held a series of Rocket Symposiums to consider the design requirements of rocket vehicles to be used for space tourism as identified in this study program (8). This work is deliberately shifting the paradigm of rockets from being considered as (expendable) missiles to being seen as (reusable) passenger vehicles.

From 1995 through 1998 the Space Transportation Association (STA) and NASA conducted a joint study of space tourism of which the Final Report, "General Public Space Travel and Tourism" (Volume 1 Executive Summary, NP-1998-03-11-MSFC) was published early in 1998 (9). This

study reached very positive conclusions about the feasibility and commercial promise of commercial passenger space travel services, which it suggested are now a timely target for the space industry, and show promise of growing to a larger scale than satellite launch.

In 1996 the "X" Prize of $5 million was announced in the USA for the first private group to fly a piloted vehicle capable of carrying three passengers safely to 100 km altitude twice within two weeks (10). Some 15 teams have announced their intention to compete, and several venture companies are now developing piloted reusable rocket vehicles, notably Bristol Spaceplanes, Kelly Space, Pioneer Rocketplane, Rotary Rocket and Vela Technology. This activity has helped to generate increased media interest in the subject of *sub-orbital* space tourism, which is likely to be realised within 5 years.

In March 1997, the 1st International Symposium on Space Tourism was held in Bremen, and the 2nd will be held there in March 1999. In 1997 the IAF and in 1998 the ASCE both held conferences with a full session devoted to space tourism for the first time. The Space Tourism Society has been established in Los Angeles, and the 1st Space Tourism Fair was held at Long Beach in July 1998. The AIAA co-hosted an inter-national workshop in January 1998 of which one recommendation was "In light of its great potential, public space travel should be viewed as the next large, new area of commercial space activity"(11).

This technical and commercial progress listed above has brought forward the likely date at which passenger space travel will begin, and prospective passengers are now waiting to travel into space. This has created an urgent need to resolve the regulatory issues involved - or else the growth of this promising new field of business will be postponed, at great cost in lost economic growth. However, realising passenger space travel requires close coordination between legal, technical, business and other experts. This paper is a contribution from the technical/business side, somewhat as a "wish list" for legal experts interested in contributing to this new field.

REGULATORY NEEDS

In contrast to the early days of aviation, activities in both the atmosphere and space are governed today by a complex legal framework which is not appropriate for, and does not currently permit commercial passenger flights to and from space. Space activities are treated quite differently from other international transport industries, such as shipping and air transport, which are governed by a comprehensive framework of national and international commercial law, supported where necessary by international treaties. By contrast, space law comprises inter-governmental treaties negotiated during the cold war.

It is increasingly recognised that this existing legal/regulatory environment needs to be reformed. US Congressman Robert Walker stated "Most of our laws and regulations governing space activity were written to make it easier for government to function in space. Now we need to make it easier for the private sector to undertake space development" (12). This perception has led to progress within the US government, such as H.R. 1702, the Commercial Space Act of 1997 of which a key provision is to amend the earlier Commercial Space Launch Act to license commercial space transportation vehicles to reenter Earth's

atmosphere and return space payloads to Earth - an essential requirement for companies developing passenger space vehicles. This is now expected to become law during 1998.

For space tourism in particular, in order for operating companies to be able to plan passenger services and place orders for the vehicles which they require, and in order for manufacturers to finalise passenger vehicle design details and raise the investment which they need to put the vehicles into production, appropriate legislation and regulatory innovation is required in order for investors' risks to be understood and controlled.

Aviation Paradigm Revolution

A major development has occurred over the past few years which, although with no fanfare, amounts to a revolution in the regulatory handling of space activities: it is gradually being accepted that the most appropriate regulatory framework for passenger space travel activities is to treat it as an extension of aviation. In 1995 the US government's Office of Commercial Space Transportation was moved into the Federal Aviation Administration (FAA), and the office of the Associate Administrator for Space Transportation is now actively working on developing a licensing procedure for commercially operated reusable space vehicles.

The FAA has also begun a study on extending the air traffic control system to include low Earth orbit (13). Such a system of "aerospace traffic control" will be needed as tourist activities in space grow to a significant scale - such as the 1 million passengers/year envisaged within 20 years by the scenario being studied by the Japanese Rocket Society (4). This study will have to deal with novel and technically challenging issues, such as the difficulty of even defining traffic routes in orbit in physical terms due to the fact that the paths followed by orbiting spacecraft continously change their position relative to the Earth's surface, and so to airlanes within the atmosphere, as discussed in (14, 15).

In parallel with these activities by the US government, private groups have also started to study the regulatory system of the aviation industry as the model for the passenger space travel industry.

JRS Transportation Research Committee In 1997 the third phase of the JRS Transportation Committee's activities started, being a study of the requirements for certification of "Kankoh-maru" for passenger-carrying. This involves studying existing aviation regulations and airworthiness standards; identifying those which are applicable to the current "Kankoh-maru" system design; identifying areas in which existing rules are unsatisfactory or inapplicable for various reasons; and considering redesign of the "Kankoh-maru" passenger space transportation system and/or the development of new standards and rules as required to achieve acceptable safety.

Provisional conclusions of this study to date include the following.

1) Type certification will need to be defined according to the vehicle's launch and landing configurations.
2) Critical design conditions involve space radiation, space debris, the high vacuum environment in orbit, and the thermal loads caused by reentry and by the use of cryogenic propellants.
3) Since Kankoh-maru and other space tour vehicles will have highly

autonomous flight control systems, the control authority given to the pilots within the flight management system is a critical topic for the safety design standard.
4) Flight operations need to be defined for both nominal and abort conditions in the event of various vehicle failures.
5) Structural verification procedures on the ground need to be studied.
6) Redundancy requirements to ensure the ability to shift to safe abort flight in the event of engine failures need to be studied.
7) Design requirements for onboard equipment, such as the environmental control and life support system and space clothing, need to be defined.
8) Requirements for the flight manual must be carefully considered for Kankoh-maru and for every type of space tour vehicle.

Universal Space Clipper Company
The above work parallels work carried out in the USA in which an initial evaluation of the existing US Federal Aviation Regulations (FARs) was conducted to assess their applicability to the design of reusable space vehicles (16). This study recognised that the existing FARs do not cover all areas of reusable space vehicle (RSV) design, production, test and evaluation, and operations, but it suggested that the certification requirements for new RSVs can be developed within the existing FARs, and that the FARs and policies for RSV should therefore be very similar to that of commercial aircraft (15).

Following the "aviation paradigm" this study broke these requirements for passenger space vehicles down into:
- Type Design Certificate
- Production Certificate
- Airworthiness Certificate
- Commercial Operator's License
- Spaceport License
- Other Approvals (component manufacture, maintenance and repair, training, etc)

This study also emphasized that "Although individual nations need to put their own policies into place, their implementations need to be carried out in an atmosphere of international cooperation. This international planning should begin now during the most formative stages of the Spaceways" (16).

JRS Commercial Space Transportation Legislation Research Committee This committee was established in September 1998 under the Chairmanship of Mr Yoshiyuki Funatsu and is starting to study regulatory issues, but from a wider viewpoint than that of vehicle design as being studied by the Transportation Research Committee. This committee comprises experienced members of the airline industry, vehicle designers, and legal and other experts.

OPERATION FROM AIRPORTS

In order to be commercially viable, passenger space vehicles must provide flights to and from orbit on a large scale. This will be greatly facilitated if they are able to operate from existing airports rather than needing to build new, dedicated spaceports. However, in order for rocket-powered vehicles, whether VTOL or HTOL, to operate from existing airports there is a need for innovation in a number of systems including vehicle certification, use of cryogenic propellants, noise regulation, air traffic management, and other areas. Having surveyed each of these topics, as described briefly below, the initial JRS study on operating the VTOL Kankoh-maru from airports

concluded that "...there will be no substantial difficulty for airports to be used for space tourism vehicles" (5).

Vehicle Certification

Aviation regulatory authorities have many decades of experience of vehicle certification in a commercial context, both national and international, and are well-suited to performing this task, as a natural extension to their work concerning aeroplanes, helicopters and other vehicles. In order to extend existing aviation regulations to apply to passenger space vehicles, appropriate rules concerning vehicle structural integrity and damage tolerance, fire-suppression systems, passenger evacuation standards, maintenance procedures and other matters must be developed.

VTOL vehicles such as Kankoh-maru will require particular innovation, for example concerning the flight test programs needed for certification. By analogy with aircraft VTOL vehicles will be required to perform some hundreds of progressive engine-tests and test-flights, but the appropriate sequence and performance require-ments remain to be decided. Another example is the ability to land (or dock) safely in the event of engine or other failures in any phase of flight. In contrast to aircraft which routinely dump fuel from their tanks before emergency landings, the quickest way for a rocket to dump fuel is through the engines, due to their approximately 100 times faster propellant con-sumption than jet engines. Conse-quently the appropriate emergency requirement for a VTOL vehicle may be a requirement to be able to continue in hovering flight using undamaged engines for a specified number of minutes before landing.

Cryogenic Propellants

Kankoh-maru and other passenger launch vehicle designs use cryogenic propellants, which require different handling procedures from kerosene. Liquid hydrogen has already been studied for some years in both the automobile and aviation industries as a potential fuel in the future, and a range of trials have been carried out. After reviewing this work, Naruo concluded that the automobile and aircraft industries are "far in advance" of the space industry, and passenger space vehicles will benefit by following the lead of these more advanced commercial industries (17).

Hydrogen and oxygen fires also have different physical characteristics from kerosene fires, and safety standards for passenger space vehicles will need to take this into account. Studies have already been made of the use of liquid hydrogen fuel at airports, and it is considered that satisfactory engineer-ing solutions exist for all requirements for passenger space flight (5).

Noise

Although rocket engines make more noise than jet engines, passenger space flights will be far fewer than airline flights, making the nuisance propor-tionately less, as recognised by the units widely used for quantifying airport noise, WECPNL (Weighted Equivalent Continuous Perceived Noise Level). Based on preliminary study of two off-shore airports in Japan, it is believed that during take-off Kankoh-maru would exceed current allowable noise-levels in certain limited areas on land, but that this will not be a serious constraint (5). At a traffic rate of even one million passengers per year, traffic to and from orbit will be 30-100 flights per day - or less than 0.1% of the number of airline flights. Conse-

quently only a small number of airports will need to handle passenger space vehicles - though more can be expected to choose to do so in order to gain commercial benefits as "aero-space-ports".

Research to develop quieter rocket engines for commercial passenger launch vehicles was identified as an important theme for rocket research (5, 8). As passenger rocket flights become more frequent, it can be expected that they will be required to be less noisy, as has happened with jet airliners. As has also happened with jet engines over the decades of their use, new technology is likely to be developed to satisfy this requirement.

Air Traffic Management

This field is currently undergoing rapid change as aviation authorities around the world work to implement new-generation systems using GPS, GLONASS and other navigation satellites. There is also movement towards "free flight" in order to make use of the enormous advances that have been made in telecommunications and computing technology since the current international air traffic system was standardised (18). Passenger launch vehicles travelling to and from orbit will clearly need to be integrated into these air traffic management systems. This will require such steps as determining appropriate in-flight separation rules for these new categories of vehicle, and standardising flight-paths between airports and the orbits used for passenger accommodation facilities.

The latter will involve significant innovation since, unlike airlanes within the atmosphere, orbits do not maintain a fixed position relative to the Earth's surface, and so a practical procedure for defining orbits needs to be devised and agreed (14, 15). To date, allocation of "slots" within a particular orbit has been carried out only for the geo-stationary orbit. Although that orbit is uniquely easy to define, the matter of allocating geo-stationary orbital "slots" is nevertheless the subject of substantial legal activity involving both telecommunications law and space law (19). This activity will have some relation to the matter of defining and regulating the use of space "traffic lanes" and low Earth orbits, as is now starting to be considered (13).

In addition, both when launching to a particular orbital position and when returning from orbit it will be impractical for launch-vehicles to carry sufficient propellant to tolerate delays of more than a few seconds, or to enable them to change course substantially. Consequently a system is needed that will permit them to take-off and land within narrow, irrevocably guaranteed time-slots of only a few seconds (6, 7). This will require adjustment of existing air traffic procedures, somewhat as was agreed in the past to accommodate the supersonic airliner, Concorde. Since VTOL vehicles such as Kankoh-maru will not use a runway, accommodating this requirement should not be difficult.

Sub-orbital flights

Another use of rocket-powered vehicles, which was first discussed several decades ago, will be sub-orbital transport of passengers and cargo, providing high-speed service between designated sites on the Earth's surface (20, 21). These services will use similar vehicles to passenger travel to and from orbit, which will spread the development costs of sub-orbital rocket transport vehicles over a much wider

market than only the small market for high-speed international travel.

The "X Prize" competition (10) and the short-duration passenger space flight services which it is intended to stimulate are creating additional near-term demand for sub-orbital flights which pose new requirements on aerospace traffic control systems. With lower entry costs than orbital flight services, sub-orbital flight services are already starting to create near-term demand for regulatory innovation.

Staff training and licensing

Systems will be needed for training, testing and licensing of pilots, cabin staff, maintenance staff and others. Existing commercial aviation procedures provide a good model for the required systems, and could readily be extended to cover a new category of vehicle.

LIMITATION OF LIABILITY

In the early days of aviation, the Warsaw Convention played a historic role in helping to establish international air travel by limiting airlines' liability for damages in the event of injuries to passengers or loss of baggage, and by establishing a uniform international system. This enabled insurance companies to tackle a new means of international passenger and cargo transportation with confidence.

Today the limitation of liability included in the treaty is controversial and frequently challenged in law, since the level of damages receivable in other areas of life has grown much higher. It has also become unnecessary in many countries because, as airline operating experience has accumulated, reliability has increased greatly and the statistical risks are known much more precisely. As a result, Japan's airlines, for example, have formally repudiated the Warsaw limitation of liability.

Like air travel, passenger travel services in space will certainly need insurance, and insurance companies' confidence concerning the risks involved in the new services will depend fundamentally on statistical data. In its early stages, the small scale of the space travel industry and the limited statistical base will not be sufficient to permit insurance calculation with high confidence. Thus it has been proposed that limits on liability for the owners and operators of space facilities and vehicles will be needed; however, this remains unclear. The experience of the venture companies Bristol Spaceplanes, Kelly Space, Pioneer Rocketplane, Rotary Rocket, Vela Technology and others which are currently developing piloted reusable space vehicles, in negotiating with aviation authorities and insurance companies will be of great interest in setting the direction in this issue.

It should be noted that limiting carriers' liability for injuries, as under the Warsaw Convention, need not deter customers. Risks will in any case have to be objectively small or passenger space travel will not be acceptable, and passengers will be able to purchase additional insurance. If it is decided that there is a need for limitation of spacelines' liability, the need for it will decline as operating statistics accumulate and risks can be assessed with greater confidence, as has happened in aviation.

ORBITAL ACCOMMODATION

Market research has shown that most potential customers for space tourism services wish to stay in orbit for a few days or longer. The JRS study is considering a scenario in which 8 Kankoh-maru vehicles are produced and put into operation each year; this leads to passenger numbers growing by some 100,000 each year. If passengers stay in orbit for 2 or 3 days on average, the required accommodation capacity will reach a scale of several thousand guests.

Although it might be thought premature to discuss regulations relating to orbital accommodation before passenger launch vehicles have been developed, there are several arguments that it is timely. First, market research shows that orbital accommodation enabling passengers to spend a few days in orbit is what the market wants. Thus space tourism services will not reach their full business potential unless there are suitable accommodation facilities in orbit. Second, orbital accommodation is technically easier than launch vehicles - for example, Russian "Almaz" facilities, based on the Soviet "Salyut" space station which was in operation more than 25 years ago, are commercially available today, and could be attractive investments once launch costs are lowered. Third, there will be a need for hundreds of orbital test flights of vehicles such as Kankoh-maru, and so these could be used to provide very cheap cargo launch, which could include components of orbital "hotels". Design studies have already begun on the small-scale orbital accommodation facilities that will be required in the early stages (22).

It has been suggested that, in order to obtain the insurance that will be necessary to raise investment for orbital accommodation facilities, there will be a need for "orbital building codes" covering such matters as fire safety, emergency procedures, reliability of systems for atmosphere control, external doors and security, construction standards, staff training and licensing, and other matters.

However, orbital accommodation will differ significantly from terrestrial hotels, and will be closer in many respects to aircraft, cruise ships and submarines than to buildings. Creating appropriate regulations will therefore require selecting and adapting material from each of these fields. In addition orbital accommodation will have unique features, and so innovative work will be required to develop acceptable rules and standards.

For example, in terrestrial hotels and commercial buildings fire safety standards require the ability to evacuate the building within a specified time, and they define minimum numbers of exits, their size, accessibility, signs and other factors.

For orbital accommodation a more appropriate requirement than evacuation would be to provide secure shelter to all guests and staff in the event of fire, depressurization or other emergencies. By analogy with ships and submarines it might be decided that such a shelter must have the capability of autonomous life support for a specified period, autonomous communications, and external access. The appropriate length of time for which emergency shelter would be required will depend on factors such as the frequency of flights to and from Earth, the ease of diverting flights to and from other destinations, and the

size of the facility relative to the size of passenger vehicles, and these requirements will change as the overall scale of orbital activities grows.

REVISION OF SPACE LAW

In order to encourage commercial operation of passenger launch vehicles, changes in space law at both national and international levels are also required. Such aspects of current-day space law as government responsibility for damage caused by launch vehicles launched from their territory, the need to register all launches with the United Nations, and the need to treat all space travellers as "envoys of mankind" are not practical for commercial space travel, and are ripe for revision to become convenient commercial procedures. This objective should therefore be put on the agenda in fora wherever space law and international law are discussed, as recommended also in the recent AIAA report (11).

Space Debris

As space activities increase, the risk of damage caused by space debris will increase. Large permanent space facilities such as orbital accommodation face risks of collision more than 10 times higher than launch vehicles, which have a smaller cross-sectional area and remain on orbit for only a few hours at a time. Thus in order to reduce the risks of damage to orbital accommodation to an acceptable level it will be necessary to actively remove space debris. This possibility has been studied for some years already, and is considered to be technically feasible (23). Once low-cost reusable launch vehicles are in routine commercial operation it will be economically desirable, but in order to ensure safety it will need to be regulated. However, there is also a major role to be played by appropriate revision of space law; for example it will eventually be necessary to introduce legal liability for damage caused by debris in order to make space travel as practical as other forms of travel, despite the difficulties that creating such legislation will pose (24).

ROLE OF GOVERNMENT

In order to bring about the regulatory innovations discussed above, taxpayer funding seems appropriate for two main reasons. First, market research has shown that travel to and from low Earth orbit is a very popular idea for a majority of the populations of the rich countries, in contrast to the weak public support shown for existing government space activities. Second, providing a supportive environment for manufacturers and operators of passenger space vehicles will be a major way for countries to obtain a competitive advantage in the vigorous new field of economic growth that is expected to develop from commercial passenger space transportation.

The "paradox" that it is politically more acceptable to waste taxpayers' money on activities that benefit noone than to spend it on profitable activities that benefit one group of the population more than others is sometimes quoted as a reason for government organisations not to work to help the realisation of space tourism. This is relevant because space tourism services will be available initially to wealthier members of the population. However, there are many ways in which governments could facilitate the growth of such a new industry without being seen as favouring one section of the population over others, as discussed at length in (9).

In addition, in the case of aviation, air travel services are now available to

some 1 billion middle class people all around the world. Few people would argue that it would have been better for governments not to have invested in aviation research in order to help the safe development of that industry, thereby helping to create wealth and employment on a large scale.
As progress is made over the next few years it will become increasingly clear that those countries which participate in a profitable space tourism industry will play a leading role in the commercial use of the space technology that has been developed at great taxpayers' expense to date. In order to achieve this, the creation of an encouraging regulatory environment is as essential as is the development of the space vehicles required, and the articulation of market demand. In order for companies to be able to provide space travel services profitably their home countries must create an attractive environment for these services to grow in. Thus international economic competition alone should be a strong justification for governments to make public resources available to tackle this new legal and regulatory task.

Space Agencies

As the Cold War and its imperatives recede into the past, there is debate about the proper role of government space agencies. Although space science is appropriate for government funding on a par with other scientific research, it is increasingly recognised that government organizations developing vehicles and performing space activities conflict with the objective of encouraging the growth of commercial space activities.

By contrast, national aviation research activities are relatively uncontroversial: instead of development or operations, these generally involve research to improve the competitive performance of national aviation industries. Government civilian space activities following the "cold war pattern" have absorbed nearly $1 trillion over the past 40 years, but they have been *much less* effective in promoting commercialization in astronautics than government aviation activities have been in aeronautics.

In order to help realize a commercial space tourism industry, government agencies could usefully perform research on such topics as safety of reusable rocket vehicles, rocket-engine noise reduction, and maintenance procedures, as clarified by the JRS study (8). Medical research would be useful on typical medical problems that will be seen in orbiting hotels, such as treatment in orbit of day-to-day ailments like colds, influenza, and minor injuries, and trials in orbit of common medications used by average people in ordinary states of health, during short stays in orbit.

In the early days of aviation it was learned from experience that the regulatory function must be entirely independent of research, development and operation, since otherwise disasters occur (25). Consequently government organizations ceased to develop aircraft. Accidents such as "Challenger" and the first flight of Ariane 5 show that the same approach needs to be followed in the space industry. This is beginning to be recognised in the USA where the FAA has been made responsible for developing regulation of reusable space vehicles.

The process of creating appropriate regulations may draw on the experience of space agency staff, but

establishing procedures for operating reusable launch vehicles is likely to draw more on airlines' experience of operating jet aircraft than on space agencies' experience of operating expendable rockets. Performing research to support a commercial space travel industry seems a more appropriate future role for government space agencies than regulation or operations.

CONCLUSIONS

Expendable launch vehicles cannot open the new frontier of space to the human race. However, a large new source of launch demand is required to repay $ billion investments in developing reusable space vehicles. It is finally being recognised that only the pent-up demand for passenger flights to and from space by the general public offers the prospect of large-scale launch demand in the near future.

As this understanding spreads, attention has turned to the requirements for operation of passenger flights to and from space on a large scale. In addition to technological issues, there are a wide range of interesting new regulatory issues to be resolved in many different fields. Resolving all the issues satisfactorily will require major, coordinated efforts both nationally and internationally, but they will open unlimited new fields for economic growth.

The discussion on how best to regulate this new field of activity requires continuing dialogue between legal experts, companies interested in manufacturing and operating the vehicles and equipment needed, the regulatory bodies concerned, insurance companies, investors and a range of independent experts.

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