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THE FIRST 100 YEARS OF PUBLIC SPACE TRAVEL

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ABSTRACT

As the first 100 years since the Wright brothers' first flight come to an end, we are witnessing the hesitant beginning of a whole new application of their aerospace heritage, namely the advent of public space travel. During the next 100 years, this has the potential of becoming a market sized in the tens of billions of dollars and coincidentally overtaking the hitherto leaders in terms of launch numbers, such as telecommunications and other applications satellites. This new sector can thus have a major impact on the future shape of the launch vehicle industry. There may well be significant spin-off benefits to the space program in general once the public has become newly and personally involved in space developments. The emergence of this sector as a new dominating customer segment will also provide the opportunity for achieving benefits in reduced cost to orbit as a result of economies of scale in vehicle manufacture and operation.

This paper maps out the early history and likely future of public space travel, both during the first twenty formative years of the industry (a period that has been well-researched as part of the ASCENT Study funded by NASA), and thereafter onward towards the next century milepost at 2103.

The general framework of a public space travel business is discussed, including technical, terrestrial infrastructure, marketing/packaging, regulatory and insurance issues, etc., and this framework explicitly addresses the two distinct kinds of opportunity that are being developed as the initial offerings of space tourism – namely sub-orbital and orbital flights. There is a discussion of possible and proposed architectures.

Data is provided from the Futron/Zogby Survey into Public Space Travel, a very robust and comprehensive fund of market data obtained by interviewing high net worth individuals. The data addresses public interest in both sub-orbital and orbital flight opportunities, and forecasts are provided that derive likely numbers of travelers at various price levels during the next twenty years, and hence form an essential backdrop to any business plan for the sector.

Finally, the paper looks forward a further 80 years towards 2103, and describes a possible series of further developments in public space travel that will be likely to take place in that timeframe. Many of them have already been studied qualitatively as possible emerging markets in the ASCENT Study conducted by Futron Corporation for NASA's Marshall Space Flight Center. These potential developments include, *inter alia*, space hotels, geo-stationary and/or Lagrangian Point space outposts, and even tourist trips into Lunar orbit.

INTRODUCTION

Public Space Travel is just beginning. During its first hundred years – in fact within half that time – it will become the dominant sector of the space business. The economic case for this assertion, based on economies of scale and reliability arguments, has been well set out by Collins et al (see references), and the market demand firmly established by the Futron/Zogby survey described within this paper. Regarding the time scale, the historical parallels are manifest and the necessary major paradigm shift to commercial operators is now under way, so we can have some confidence in the predictions. The Russians have shown the way. The Chinese will probably not be far behind. Entrepreneurial enterprises in the US, Canada, the

UK and elsewhere are aiming at being the first non-governmental operators taking travelers into space – and one of them may even succeed before the Centenary of the Kitty Hawk flight this December.

The changes that will be brought about by this new industry will be far-reaching. But perhaps the most significant among them will be a renewed involvement by the public in the possibilities of space, and an associated benefit in the education system, where there will be spin-off in interest in math and science subjects. According to several estimates, tourism has become the world's largest business enterprise, overtaking the defense, manufacturing, oil and agriculture industries, and it grows nearly twice as fast as the world GNP, generating millions of jobs. Public space travel will be the newest segment in this industry. Mount Everest and the Arctic are getting pretty crowded these days. The President's Commission on the Future of the United States' Aerospace Industry has drawn our attention to these possibilities.

It is perhaps appropriate to discuss briefly some matters of definition. What is Public Space Travel? Is it the same as Space Tourism, for example? Although it hardly matters much in the context of the 100-year span of this paper, and the two terms are often interchangeable, for our purposes we are assuming that public space travel involves travel into space (defined as beyond 50 miles altitude) as a paying passenger. This means *paying commercial passenger*, and therefore excludes any payments funded from governmental sources. We assume that space tourism, by contrast, is a *sub-set* of public space travel. The space tourist is assumed to fund his travel from his own personal resources. Other public space travelers will be funded from a variety of commercial sources, such as lotteries, TV game shows, corporate sponsorships and company reward schemes. Time will tell how many of these alternatives develop and become a significant part of the funding of public space travel.

Of course, as was the case with passenger air travel, the new era of passenger space travel will commence with wealthy individuals, and then their financial contributions will gradually make possible the opportunities for the less wealthy. We note, of course, that the comparison with passenger air travel is an inexact parallel – commercial air travel began with mail delivery and is premised, beyond barnstorming, on a journey to a destination. A significant impetus came from military developments, such as the DC3 Dakota, which were introduced in massive quantities during the war as troop transports, and were capable of being used afterwards to give a start as commercial airliners for new post-war airlines. Maybe the Orbital Space Plane (OSP) could have such a role for this new industry, maybe 30 years from now. Parallels are perhaps closer with the cruise and theme park and associated entertainment businesses. Disney may well prove to be a better partner than United Airlines.

What should be the role of government? This will be discussed in the paper. Some would argue that "they" should simply keep out of the way! However, there are a number of steps that can be taken by government to nurture and enable this new business, and perhaps the timing is opportune to consider them now. This is because of the ramifications of the Columbia investigation findings, the NASA budget turmoil, the pending decisions about the possible role of the OSP, and the recommendations of the Commission on the Future of the United States' Aerospace Industry.

One final trivial matter of definition: should this paper consider the 100 years to 2103 or the 100 years to 2090, since public space travel is already 13 years old? The only honest answer to the question is to state categorically that it is irrelevant – since the forecast uncertainties in timing of events within the last decade of a 100-year outlook are at least of that same 13 year order of magnitude!

EARLY HISTORY

Because this Symposium celebrates 100 years since the Wright Brothers made their first powered flight, it presents an excellent opportunity for seeing the future of public space travel within a historical context; a view which offers useful perspective.

The Wrights' first flight took place December 17th 1903. Their first passenger, mechanic Charlie Furnas, flew 2 years later, in 1905, when further developments of the Flyer permitted a second seat to be added.

By 1927, just 22 years later, Charles Lindbergh had flown across the Atlantic Ocean. Within another 15 years, the development of rocket technology made possible the first V2 flight in 1942, and Gagarin's first space flight 19 years later in 1961. Neil and Buzz were standing on the Moon in 1969 – only 8 years later, and just 66 years from the first flight.

What about public space travel? It partly depends on the precise definition, but what is certainly clear is that the first paying passengers did not fly from Kennedy Space Center, USA but rather from Baikonur in Kazakhstan during the Soviet era. The Japanese television journalist Toyohiro Akiyama flew on a Soyuz to visit space station Mir in December 1990; this was 29 years after the Gagarin flight. The second public space traveler was the British chemist Helen Sharman just half a year later. Both of these travelers were funded by external (commercial) organizations.

More recently, 10 years later, the Russians have flown Dennis Tito (April 2001) and Mark Shuttleworth (a year later) to the International Space Station (ISS), both using the tried and trusted Soyuz. They were therefore the first true space tourists, by the definition of this paper, having funded the missions from their own pockets.

At the time of writing this paper, there have as yet been no examples of true public space travel using a US space vehicle. However we may record that Senators Jake Garn and Bill Nelson both had government-funded rides in the Space Shuttle (in April 1985 and January 1986 respectively), and the teacher Christa McAuliffe died in the January 1986 Challenger accident before reaching orbit. During the Soviet era, there were also many comparable examples of "government passengers" being flown on Soyuz flights, usually as goodwill gestures to Soviet satellite states.

Table 1, below, summarizes some of this early history of aviation and space travel.

TABLE 1 COMPARATIVE EARLY HISTORY OF PUBLIC SPACE TRAVEL

DOMAIN	DATE	ELAPSED TIME	EVENT	CRAFT
	1903	0	Wright Bros	Flyer
	1905	2	First Passenger	Flyer upgrade
AIRCRAFT	1927	24	Lindbergh-Solo Atlantic	Ryan Monoplane
	1939	36	First Jet Aircraft	Heinkel HE178
	1947	44	Yeager/ Mach 1	Bell X-1
	1961	0	Gagarin - First in Space	Vostok
	1969	8	Neil & Buzz - Moon	Apollo
SPACE VEH	1990	29	Akiyama - First Pub Sp Traveler	Soyuz/Mir
	1991	30	Sharman- Second Pub Sp Trav	Soyuz/Mir
	2001	40	Tito - First Space Tourist	Soyuz/ISS
	2002	41	Shuttleworth - Second sp Tourist	Soyuz/ISS

INITIAL ARCHITECTURES

For the purpose of this section, we are considering the next 20-year period (as a continuation from the last 13 years of public space travel history). Within this timeframe there are only two main kinds of mission for the public space traveler: the sub-orbital flight, and the orbital flight to Low Earth Orbit (LEO).

First, there is the sub-orbital lob, with the natural historical comparison with Shepard and Grissom on Mercury/Redstone and also the later X-15 flights as examples. These flights generally result in around 5 to 10 minutes of weightlessness at the peak altitude of the parabolic trajectory, and in the case of the Mercury/Redstone flights, the whole mission was over in 15 minutes.

For the flights to LEO, the historical comparison would be with Gagarin's Vostok mission. Each orbit at LEO lasts about 90 minutes, and provides of course, one orbital sunrise and one sunset. The basic mission would therefore consist of a single orbit and recovery, but variations include longer missions (Glenn carried out 3 orbits), some of which include docking with a space station, which affords more room and a generally less constrained experience.

From a public space travel perspective, although an orbital mission would be more desirable, it must be recognized that it is significantly more difficult to develop the capability to get into orbit and return safely than it is to perform a sub-orbital flight into space. For this reason, there must be a significant difference in the price (or at least the cost) for a flight into orbit compared to a sub-orbital space flight. So the industry will probably get its marketing boost from the cheaper sub-orbital flights, once available, but for a mixture of geopolitical reasons the first public space travel was of the LEO variety, so we look at these first.

Currently advertised opportunities for Soyuz missions to LEO are quoted at around $20m, and include docking at the International Space Station (ISS), whereas sub-orbital flights are quoted at around $100K. While the Russian Soyuz is today the only means for a space tourist to get into orbit, the Chinese are now very close to operating their own developed version, known as the Shenzhou. So it is likely that they also will offer tourist flights to LEO during the 20 year timeframe. The Space Shuttle in the US would, of course, be capable of carrying paying passengers into orbit, but this is currently not part of US government policy. There is currently an open question about the follow-on to the Space Shuttle in the US. The OSP is being proposed, which is designed for launching on an expendable rocket. At least in principle, a version could be used to carry public space travelers into orbit (other roles would include carrying astronauts and scientists to the ISS for NASA, and maybe the US Airforce could have a version that meets its own needs). Of course there would need to be a common architecture developed for the OSP to make this multiple use a possibility. It does not seem to be the case, however, that this is currently being done. NASA does not seem to be so far taking into account the possible other uses, beyond servicing the ISS, but there is still time for a change of course.

The early astronauts and cosmonauts did not have a destination for their rocket launch, other than LEO itself. Although in principle, some pioneer public space travelers might also remain in the launched spacecraft, this is not a realistic basis for planning for growth in the eventual public space travel industry. During the 20-year forecast period under review in this section, it is unlikely that there will be more than one possible destination for the traveler in LEO, and that will be the ISS. The space station Mir, which had been used as a destination for the first public space travelers, was unfortunately de-orbited as the ISS began to be assembled in orbit. There is some possibility that a Spacehab-type module could be added to the ISS as a commercial facility for space tourists during these 20 years, but more sophisticated stand-alone space hotels will not be discussed until later in the paper. This is because they probably will emerge only as the space tourism industry becomes more developed, and the timeframe is unlikely to be before 2020.

It is somewhat ironic that all the existing examples of public space travel have been of the $20 m orbital variety. All of that is about to change, however. Although it would presumably have been a relatively simple matter for them to do, NASA has not developed the capability for sub-orbital space tourism in the 42 years since the Shepard flight. They would probably claim that developing this huge commercial business was not in their mandate. So now the commercial world has taken over. The X-Prize competition has resulted in a flurry of activity in several different countries, aimed at winning the $10m prize for the first commercial space trip. Some of the competing private teams are now very close to achieving the goal of a sub-orbital space flight, and soon we shall see the quickening of public interest and the opening up of this new phase of space tourism. The market potential for $100k flights is clearly much greater than the demand for $20m flights. The excitement of the competition has brought about a wide variety of different architectures. Time will tell which will prove to bring the commercial success that their builders are seeking. Some of the designs are water launched; most are land launched. Some take off vertically, following the Mercury/Redstone heritage; others are aircraft technology developments following the X-15 heritage. In between there is a wide assortment of hybrids and creative combinations of technology. Some designs rely on variations of an air-launched solution. Some use available existing engines in novel applications; others rely on entirely new engine designs. The X-Prize has already achieved a great deal in the encouragement of technological development.

Table 2 below provides a summary of some of the initial architectures for public space travel.

TABLE 2 SOME INITIAL ARCHITECTURES FOR PUBLIC SPACE TRAVEL

MISSION	DURATION	PRICE	SPACECRAFT	PROVIDER
ORBITAL	90 mins/orbit	$20m per 2 weeks	Soyuz (Russia)	Russian Gvt
			Shenzhou (China)	possible
			Space Shuttle (US)	possible
			OSP (US)	possible
SUB-ORBITAL	Approx 15 mins	$100K/flight	Advent Armadillo	Armadillo Aerospace
			Ascender	Bristol Spaceplanes
			Arrow	Canadian Arrow
			Blue Origin	Blue Operations
			Cosmopolis C21	Myasishchev
			Cosmos Mariner	Lonestar Space Access
			Millenium Express	Third Millenium
			Pioneer XP	Pioneer Rocketplane
			Spaceship 1	Scaled Composites
			SC1	Space Clipper
			Space Cruiser	Vela
			Thunderbird	Starchaser Industries
			Xerus	Xcor

SUPPORTING FRAMEWORK

Although, of course, it is necessary for the creation of the space tourism industry that suitable designs of spacecraft, and their means into space, are developed, this in itself will not be sufficient; there needs to be a supporting framework too.

The framework varies to some extent depending on the exact spacecraft option, but nevertheless always involves some elements of a) regulatory, b) insurance, c) terrestrial infrastructure and d) marketing/packaging matters.

Of these, the regulatory matters most clearly come under the aegis of government issues. The Federal Aviation Authority (FAA) is the US regulator that will probably be the agency that has to certify fare-paying passenger space flights over the US. This was not of course an issue for the Wright Brothers, but nowadays standards have been introduced, with public safety in mind. Deciding on the most appropriate standards for the certification of this new class of vehicle will be critical to the creation and nurturing of this new multi-billion dollar industry in its early stages. Although the Commercial Space Transportation Act of 2003, currently making its way through Congress, includes a timeline for a distinct regulatory regime for sub-orbital space vehicles to be developed, the vehicles will be ready before the law. If the certification requirements in the US are made too onerous, then the industry here will be delayed in its onset, or else it will continue to operate from countries with more favorable regulatory regimes. Many of the entrepreneurial companies that are nearing their first flights will have great difficulty carrying out a large number of test flights to satisfy a tough regulatory regime, before they can start bringing in tourist revenue to pay the bills. Burt Rutan of Scaled Composites, who is a likely winner of the X-Prize with his Spaceship 1, has already expressed such concerns.

Another key aspect of the supporting enabling framework of the space tourism business is the availability of insurance. This would include insurance for the traveler and also for the potential areas of damage under the flight path. There is every indication that the insurance industry will step up to this new challenge, however, the steps taken by the insurance industry will be influenced by, and to some degree legislated by, the new regulatory regime that has yet to emerge. To some extent, early pioneer public space travelers help to enable the new industry via the signing of waivers.

We can consider the other two factors (terrestrial infrastructure and marketing/packaging) together, because they are likely to be quite interrelated, and will develop together in concert. The market research survey discussed later described the sub-orbital mission in essence as a 15-minute space experience for $100,000. A week’s training was indicated. For the survey data related to the orbital option, respondents were advised of the need for 6 month’s training (currently assumed to be in Russia). For both the orbital and sub-orbital trips, the flight itself will represent the culmination of a period of preparation and training and health checks. It seems likely, therefore, that in the days and weeks before a space tourism flight there will need to be facilities for family members and friends of the travelers who intend to share in the experience. For such a major outlay of family funds, one would expect that the price would include such facilities. One can imagine the building of a combined space tourism and entertainment complex around the launch sites that would include movie theaters and simulators for both traveler and families; maybe some kind of a cross between Space Camp and Disneyland. The current Spaceport Authorities are no doubt beginning to think of these needs. They can be a great way to generate revenues and employment for the communities. This would all, of course, be a matter for the tourist companies to develop over time as the industry grows. The $100,000 ticket price for a sub-orbital mission will be much more acceptable as the price for a whole vacation experience that included the whole family for a week, rather than as a single $6666/minute joyride for the lucky traveler. One can imagine much more elaborate arrangements for family and friends in the case of orbital missions. Included in the $20m price might be a preparatory cruise ship experience that included the family, for instance. Again, there would be major spin-offs in terms of revenues and employment opportunities. There are already a number of entrepreneurial firms that specialize in putting together all the elements for a space tourism experience (eg Space Adventures, Inc.) –the first space travel agencies.

Where will the launch sites, with their tourist infrastructure, be? The answer remains to be determined and will partly be a consequence of the regulatory work still to be done. Existing governmental launch sites are generally of one or two types; they are either in isolated desert zones where the potential danger to the general population is limited (eg Baikonur, Ukraine, or Woomera, Australia), or else on the coast (eg Vandenberg or Kennedy Space Center in the US), where any debris from a failed launch will fall out to sea. Several inland spaceports are currently being developed in the US by various Space Authorities, which are seeking to derive benefits from the new space tourism industry for their States. Many of the entrepreneurial firms are operating out in the Mohave Desert. Maybe the developing space tourism industry will gravitate towards inland desert sites for sub-orbital trips, and coastal sites for orbital experiences. It is too soon to tell. However, the infrastructure will be needed, and this may be more difficult to achieve in the desert locations. Certainly Florida would seem to have a decided advantage for any links with the Disney or cruise industries, but maybe Wallops could become an ideal site for space tourists from the Washington DC area.

MARKET DATA AND 20-YEAR FORECASTS

Probably the best available market data today about demand for public space travel comes from the Futron/Zogby survey (the full report is available from Futron Corporation). How was the survey carried out?

There were a lot of checks and balances. First of all, since space tourism in its early years is expensive, only wealthy individuals were surveyed for their opinion. They were selected to have a net worth of at least $1,000,000, or to have an income of at least $250,000 per year, or a combination. They were selected to provide a representative geographic spread from all over the US. There were insufficient funds for a global survey, but it was assumed that US millionaires would serve as a surrogate at this early stage of the space tourism business. These wealthy respondents then took part in a full 30-minute interview to make sure that they really understood the space tourism proposition, and in order to allow for the important follow-up checks and balances questions for validation of responses. Two clearly defined trips were considered (the parabolic sub-orbital experience and a two-week orbital trip to the ISS). A former Space Shuttle Commander checked out and reviewed the interview scripts for realism, and to ensure that not only the positive aspects of space flight were being considered. Respondents were told about health impacts, such as back-ache and nausea, the probable relatively limited flight qualification of sub-orbital vehicles, and the current need to train and fly from Russia for the orbital missions. Note, however, that questions were subsequently asked to understand what difference would result from training and flying out of the US. It was made clear that six months of training was required for the orbital flight (a week was assumed for the sub-orbital lob). The point was even made that the initial sub-orbital missions would probably not allow much room for experiencing the full zero-g experience. Again, later questions explored how having more room increased the level of interest. A range of realistic prices were proposed to the respondents, centered at around $20m for an orbital, and $100k for a sub-orbital space flight experience (which was stated to last for only 15 minutes).

To make sure that the survey responses were believable, questions were asked that allowed cross checking of answers, and comparison of intentions with actual previous behaviors. For instance, there were questions asked about attitude to risk. The wealthy respondents were asked if they had ever done risky activities like mountain climbing, sky diving or skiing. Checks were made about the duration and cost of previous vacations. Data was collected on respondent age and health. Another test for realism made sure that the respondents considered alternative ways to spend that amount of money- alternatives that they were offered included homes, cars and yachts. Almost half the respondents, incidentally, preferred to invest the money- an answer that in itself gives a high degree of credibility to the survey findings! The survey findings were statistically valid with a survey margin of +/- 4.7% for the full sample. Some of the key results are included below in Tables 3 to 6.

TABLE 3 SPENDING,VACATION & LEISURE PATTERNS
OF MILLIONAIRES

SURVEY DATA ITEM		PROPORTION %
Discretionary Income Spending	– Travel/Vacat	32%
	-Car/Vehicle	12%
Proportion Spending > $50K Last Year on a Purchase		10%
Duration of Vacation	-More than 6 mths	2%
	- 3 mths or more	6%
	- 1 mth or more	26%
Risky Activities Undertaken	- Skydiving	1%
	- Mountain Climbing	2%
	- Skiing/Snowboarding	19%

TABLE 4 SUB-ORBITAL TRAVEL FINDINGS

SURVEY DATA ITEM			PROPORTION %
Interest level at $100K/flight - "Definitely Likely"			12%
Other Preferred Ways to Spend This:			
	- Dream Vacation		18%
	- Sports Car		7%
	- Invest it		56%
Price Elasticity of Demand :			
	- at $200K/flight	0.6 X	
	- at $100K/flight	BASE	
	- at $50K/flight	1.4 X	
	- at $25K/flight	1.7 X	

TABLE 5 ORBITAL TRAVEL FINDINGS

SURVEY DATA ITEM		PROPORTION %
Interest Level at $20m/flight - "Definitely Likely"		10%
Other Preferred Ways to Spend This:		
	- Home in Exotic Location	22%
	- Yacht	6%
	- Jet	4%
	- Invest it	46%
Price Elasticity of Demand:		
	- at $25m per flight	0.8 X
	- at $20m per flight	BASE
	- at $10m per flight	2.3 X
	- at $1m per flight	4.3 X

TABLE 6 RESPONSES TO VARIATIONS IN MISSION PROFILE

MISSION TYPE	SURVEY DATA ITEM	PROPORTION %
SUB-ORBITAL	Training Period Reduced Below one week	12% "much more likely to accept"
	Ability to leave seat in zero-g	26% "much more likely to accept"
ORBITAL	Training period reduced from 6mths to 1 mth	30% "much more likely to accept"
	Training provided in US rather than Russia	37% "much more likely to accept"

To convert survey data into forecasts is a process that needs two main numerical calculations. One is to relate the sample size to the global population at large. In this case, we need to assess how many people there are who can afford to spend either $100k for a sub-orbital flight, or $20m for an orbital experience. The second factor is related to how long it will take for the industry and its infrastructure to be developed so that all who both want to fly, and can afford to, are able to do so. Let's consider first of all the population question.

There is a global base population today of 8 million affluent households (ie with a net worth greater than US$1 m). An affordability analysis then determines the proportion of this base population that can afford ticket prices of $100k or $20m. This was done by making an assumption on the maximum percentage of net worth that was likely to be spent by anyone on a single large discretionary purchase. Tito and Shuttleworth, for example, each spent $20m out of a net worth of $200m for their trips, which would lead to a 10% figure to be used for the maximum percentage of net worth. If we use the 10% figure, then there is a potential pool of 6000 travelers who could at least contemplate the once-in-a-lifetime experience of an orbital flight at today's prices (ie who have a net worth greater than $200m). In the case of the $100k ticket for a sub-orbital flight, then assuming the 10% figure in the calculation process would lead to the entire 8 million affluent households in the global base being eligible. Futron, in developing its forecasts for the as yet untested and totally new sub-orbital segment, was more conservative, however. Based on an analysis of the survey responses about previous maximum expenditures, a figure of 1.5% of net worth seemed to be more valid as a maximum amount of discretionary income for spending on a single item than the 10% used for the orbital missions. When this lower figure is used, then the 8 million pool is reduced to only 1 million (because we need to calculate how many would have the $7m of net worth necessary in order that the $100k ticket price only represents 1.5% of their net worth). Now let's consider the second question, about the likely timeframe for the development of the space tourism industry.

To estimate the time to achieve a fully developed space tourism business, we can scarcely do better than refer to history for precedent. This will not be a rapid process. Table 1 suggests that maybe a range of values around about 40 years would be reasonable for the process.

There are other factors involved in developing the forecasts, and they are fully explained in the study report referenced at the end of the paper, but they include the level of interest (see Tables 4 and 5), physical fitness and a range of other reasonability checks.

Table 7 provides a summary of the forecasts derived in this way in the Space Tourism Market Study by Futron Corporation. Clearly there are enough steps in the analysis to allow for a fair amount of uncertainty in the outcome, of course, despite all the care that went into undertaking the survey itself. We can get some idea of the range of possibilities by simply varying the key driving assumptions. In the case of the sub-orbital missions, for instance, the annual figures could be 8X larger (ie increasing to over 100,000 trips per year by 2020) if we use the 10% rather than the 1.5% driver for maximum allowable percent of net worth in the calculation. For the orbital trips, the numbers would be higher if operations had a US rather than a Russian base.

TABLE 7 BASELINED DEMAND FORECASTS-PASSENGERS/YEAR

Source : Futron Space Tourism Market Study

MISSION	TICKET $	2006	2010	2020
SUB-ORBITAL	$100K	500	1330	13000
	$25K	850	2260	22100
ORBITAL	$20m	3	10	54
	$1m	13	43	232

THE OUTER YEARS – 80 YEARS TO 2013

The 20-year demand forecasts of the Futron/Zogby survey and forecasts provide a good basis for further projections. If we assume a forty-year period until a fully established space tourism industry is operating, then clearly the 2020 forecast figures are only approximately half way to their saturation levels, and the figures for 2040 would be approximately doubled. However, this approach is very simplistic. The real market place is much more complex. Beyond 2020 we can certainly expect that the initial architectures will have changed, and that as a consequence the ticket prices will have reduced. So a doubling of demand from Table 7 figures would probably understate the actual results. It is therefore probably not very productive to attempt any further quantification of demand much beyond 2020.

It is possible, however, to list some of the likely developments during the 80 year period, if only by reference to the historical evidence of Table 1. By 36 years after the Wright Brothers' first flight we had the first jet aircraft flight. 44 years took us to both Mach 1 and the V2 rocket. So it seems highly likely that by 2050 we shall have some revolutionary forms of propulsion – perhaps based on the Chiang-Diaz engine research, for example. Even before then, we can hope that the OSP development work and operational experience may have resulted in a vehicle fully adapted for space tourism.

Within the Futron/Zogby survey, questions were asked about interest in future possible developments beyond the initial architectures that were the subject of the base forecasts. Respondents clearly indicated a preference to stay on a space station, and furthermore expressed an interest in this destination being a commercial space station – a space hotel – rather than a scientific research station. The author has also had the opportunity to work with 8th graders (who will be aged 63 by 2050!) who have very clear ideas about what they want to see in a space hotel. They are fascinated to explore various alternative approaches to a swimming pool in orbit, for example. Several potential space hotels are already being conceptualized, such as the Bigelow design. There are implications for entirely new professional astronaut duties, such as space tour pilot or space hotel activities organizer. Some of the survey respondents declared an interest in an EVA experience, even when advised that it would cost more, and might involve up to a year of training.

The final report of the ASCENT Study (that was conducted for NASA's Marshall Space Flight Center and was issued on 31 January 2003), listed a number of so-called Emerging Space Markets. These future markets were not expected to develop before 2020, but would be dependent on the success of a space tourism industry for them to be able to emerge. Amongst these were included hotel and resort facilities, a space sports center, space hospitals and even an on-orbit education facility. Some or all of these might be in orbit as part of the public space travel infrastructure, by 2103. Zero-g might provide an ideal way to treat certain kinds of hospital patients, for example.

It may reasonably be expected that, wherever government astronauts go, there also will space tourists follow. Before 2103, there may be a human outpost at geo-stationary orbit (GEO) and/or maybe at one of the Lagrangian Points of the Earth Moon system. There is very little extra energy required to get to the Moon once one has attained GEO. Furthermore, the commercial world is already taking steps to send some un-crewed missions to the Moon (eg Transorbital, Inc.), and it could therefore be a reasonable extrapolation that there might be tourist missions to Lunar orbit and back a hundred years after the dawn of public space travel. This author prefers to consider the Arthur C Clarke space elevator concept as something for the subsequent century, but there are today organizations already working on the core enabling technologies, some funded by NASA.

It may also be possible for some kind of combined cargo and tourist delivery service to be introduced using high apogee parabolic trajectories within the 100 year time span, but the business case has not yet been proven.

THE AEROSPACE COMMISSION FINDINGS

In November 2002, the Commission on the Future of the United States Aerospace Industry delivered its final report to the Vice President. Most of its recommendations were related to the aviation sector, but some of them have direct relevance to public space travel. It is to be hoped that these recommendations will be a trigger for action.

The Commission raised the alarm about a workforce crisis in the aerospace industry; the workforce is aging with 26% of them due to retire in the next 5 years, and there are declining performances in the US K-12 education system with regard to math, science and technology skills. Our future is in the young. Orville Wright was 32 for his historic flight. Von Ohain was only 28 when he saw his jet engine invention power a plane for the first time. The Commission tried to draw attention to some steps the government could take in reversing this downhill trend, and to the dangers if this were not done.

The Commission recognized that public space travel would play an important part in this. Their conclusions in this regard were embodied in its Recommendation #3, which in part said:

"The Commission recommends that the US create a space imperative. DoD, NASA and industry must partner in innovative aerospace technologies…..(which will)……provide major spin-offs to our economy…..and open up new opportunities for **public space travel**…..in the 21st century".

In a more specific reference the report contained the following statement:

"The Commission believes that there are opportunities to help alleviate the capacity and demand mismatch in the commercial launch market. **Space tourism** markets may be key to help fund the launch industry through the current market slump by providing increased launch demand and thus helping to drive launch costs down…………**Public space travel** could lead to a market that would ultimately support a robust space transportation industry with airline-like operations. The government could help encourage this by **allowing NASA to fly private citizens on the Space Shuttle".**

This last recommendation, if acted upon, would be an excellent way of exploring the requirements of the new space tourism business. It would in effect provide a test framework for the new industry and the necessary new professional astronaut designations. In this context, in April 2003, John Young in a presentation at the National Air and Space Museum described his experiences as an Astronaut and Moonwalker, and subsequently in management at JSC, Houston. When asked about space tourism, he expressed his opinion that it was a good idea, and that furthermore he had considered at JSC the possibility of installing a module for that purpose for maybe 25 to 30 people that would fit in the Shuttle bay. So maybe there is hope that the Commission recommendations will bear fruit.

CONCLUSIONS

The one thing certain about 100-year projections is that they will prove to have been wrong! But in this paper, we have tried to temper enthusiasms for public space travel with the wisdom to be gleaned from a backwards look at 100 years of achievement, and augmented this with as sound a basis as could be conceived for a 20-40 year forecast. Beyond that point, the direction of the future will be determined by the development of new technologies yet to be invented- using Clarke's term "indistinguishable from magic"! Imagine what Orville Wright would have thought about the jet engine, for example, or the idea of standing on the Moon. Yet, both of these had happened only 66 years after the first successful flight of the Flyer.

Public space travel shall, we may be sure, be a major industry over the next century, however. Space will therefore become fun again for a significant proportion of the population who will be involved directly or indirectly. This will have positive impacts both in terms of aerospace industry economics and workforce demographics. Young people will be joining the industry again. *But the government must play its part and seize the opportunity*. The Aerospace Commission has made its case to the White House. The hope is that a revitalized NASA will act on the report's recommendations and thus help bring this new industry into being. The OSP may have an important role to play in this regard. The government, furthermore, must take care not to over-regulate the fledgling industry.

Although public space travel began with orbital missions over 13 years ago, the next exciting phase of the development of the industry will be via the new entrepreneurial vehicles being developed for sub-orbital space flight by the X-Prize competitors. We do not have to wait long now before the first one of this new generation ventures across the threshold of the atmosphere into space, carrying its contingent of the new spacefarers of the future – the space tourists.

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