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A Study and Discussion on the Cost Issue of Suborbital and Orbital Space Tourism

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Abstract

The major purposes of this paper are to study the current costs, or say the ticket prices, for suborbital and orbital space tourisms and to discuss the rationality. On 27 February 2017, SpaceX has announced it plans to launch two paying passengers on a tourist trip around the moon next year (2018). Two private citizens who were not named have paid significant deposit to be sent around the moon to mark the furthest humans have ever travelled to deep space. It could be believed that the cost is tens of million USDs per person. Between 2001 and 2009, 7 millionaires paid and travelled 8 times to the International Space Station by taking the Russian Soyuz spacecraft and launch vehicle systems. Recently, Blue Origin successfully tested the full-envelope escape system of its New Shepard's crew capsule with the first crewed test flights planned for early 2018. Also, the Virgin Galactic's second SpaceShipTwo took to the skies for the first test flight of the revamped atmospheric re-entry system, and expected commercial passenger service to be underway before the end of 2018. Through the background review, this paper concluded that the current prices announced are too high, and the ticket price for suborbital space tourism should be no more than one tenth for that of orbital, Strategies for reducing price were discussed. For the sustainable and prosperous development of space tourism, the cost must be affordable by many tourists, not simply by a few very rich persons.

Keywords: Price of suborbital space tourism; Price of orbital space tourism; SpaceX; New Shepard; SpaceShipTwo; Reusable suborbital launch vehicle

Introduction

On 27 February 2017, the SpaceX announced that "We are excited to announce that SpaceX has been approached to fly two private citizens on a trip around the Moon late next year (2018). They have already paid a significant deposit to do a Moon mission. …" [1]. In the years between 2001 and 2009, 7 millionaires already travelled to the International Space Station (ISS) 8 times with all facilities belong to the government. In both of these two examples, besides all of the technological and passenger physiological conditions required, one big challenging question was the "significant" amount of cost. In other words, after six decades of space technology development from 1957 to 2017 supported either by the governments or private sectors, travelling to the Earth suborbit, orbit and beyond is still not affordable for the general public [2-5]. Recently, Blue Origin performed an in-flight test of the full-envelope escape system of its New Shepard's crew capsule on 5 October 2016, with the first crewed test flights planned for early 2018 [6]. Also, the Virgin Galactic's second SpaceShipTwo (SS2) took to the skies on 1 May 2017 for the first test flight of the revamped atmospheric re-entry system, and expected commercial passenger service to be underway before the end of 2018 [7,8]. These two evidences show that the commercial suborbital space tourism (SST) is possible to happen in the near future.

The SS2 belongs to the horizontal-takeoff-horizontal-landing (HTHL) type and the New Shepard is the vertical-takeoff-vertical-landing (VTVL) type. Since both of them use rocket engine as propulsion system, the flight environments such as high-g acceleration and deceleration, weightlessness, high level vibration and noise, etc. are very different from that of the conventional airplane flight. Their trajectory dynamics and effects on passengers have been briefly analyzed by Chern and Chang [9,10].

Obviously, the commercial suborbital operators expected to offer thousands of people the excitement of traveling to the von Karman line at 100 km altitude, which was considered to be the lower edge of "space". According to Finance Online [11] and Wall [12], the prices of ticket were still very high and ranges from 75,000 to 250,000 USD. The purposes of this paper were to review the historical background of price model for space tourism, and to discuss the current prices proposed by potential SST providers and operators. After this Introduction section, the historical background of space tourism price model was reviewed. The current prices for SST proposed by potential providers and operators were then presented. Strategies to reduce ticket prices were discussed. Conclusions were finally presented.

Historical Background of Price Model for Orbital Space Tourism (OST)

In more than 30 years ago, the ticket price model for OST had been studied. Table 1 showed the estimated number of passengers per year versus the price at different phases in 1985. Phase 1 is the pioneer phase at very high price with the market expected for very wealthy and high interest in space individuals. In the second phase the service could become regular basis and the service could be more comfortable with more extensive facilities than in the first phase. Since the price would still remain at a high level so that high income groups would be the

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Phase	Price (1985 $)	Passengers/year
1) Pioneer	1) 1,000,000	50
	2) 500,000	100
2) Exclusive	1) 100,000	500-1,000
	2) 50,000	5,000
	3) 25,000	30,000-40,000
3) Mature	10,000	100,000-1,000,000

Table 1: Estimation of passenger number per year vs. price in 1985.

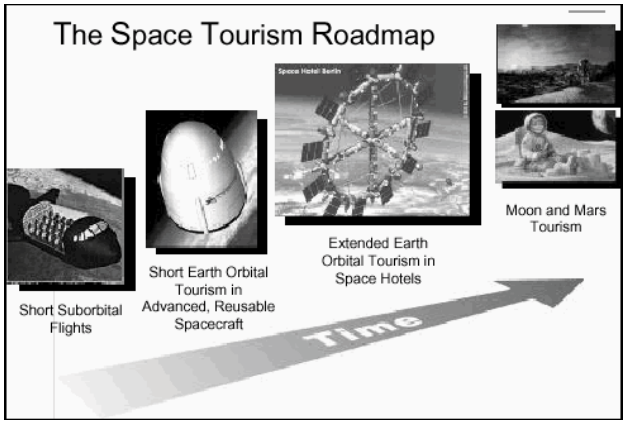

Figure 1: European space tourism roadmap with its four sub-scenarios [14].

primary customers. Then in the mature phase, the prices could have fallen drastically to a popularized level due to the factors of economic prosperity, advancement in technology, market competition, establishment of commercial business chain, and many other factors. The market capacity could become large enough to bring the service to a significant proportion of the general tourists. On the other hand, turnover would be much higher than phases 1 and 2 [13].

The polls in UK, Germany and England in 1980s

To be the initiative country of Moon Register, an opinion poll had been carried out in UK in early 1980s. Results showed that more than 50% of those under 45 and 65% of those under 25 would like a holiday in space. Subsequent market studies conducted at the German Aerospace Centre reported initial research indications that 4.3% of the German population was willing to spend roughly an annual salary (around several 10,000 USD in mid-1990s) for a holiday-trip into space [3,14]. Survey results in Southern England held in mid-2011 showed that 55% (38% male and 17% female) were very possible and possible in participating the space tourism, 36% (10.5%male and 25.5% female) were not so possible and impossible, and 9% (4.7% male and 4.3% female) were neutral [15]. Figure 1 showed the European space tourism roadmap with four sub-scenarios. Most likely the space tourism business could be initiated by short SST, followed by short OST in an advanced reusable spacecraft that allow several orbits around Earth. Extended stays in space hotels would become a reality in the far future. Preliminary analyses showed that excluding transportation, accommodation in the Space Hotel Berlin would cost about 100,000 USD per night [3,14].

A survey in Japan in 1993

Since 1993, the Japanese Rocket Society (JRS) had carried out its Space Tourism Study Program with many papers and reports published. It had impelled the growth of related activities and caused an increased recognition of Japanese in space tourism development. On 4 April 1993, the JRS held the first Space Tourism Conference as a part of the organization's Annual General Meeting. Its study program consisted of the research areas in space medicine, enterprise, transportation and passenger service [16,17]. In 1993, the survey of 3,030 Japanese people revealed that more than 70% under 60 years old and more than 80% under 40 years old would like to visit space. Besides, 70% would be willing to pay up to three month salary for the trip. The study was done under the auspices of the Japanese National Aerospace Laboratory (NAL) and was considered convincible [16,18,19].

In 1997 and 1998, the JRS established three committees to study the above mentioned space tourism issues: Transportation Research Committee, Space Tourism Business Research Committee, and Commercial Space Transportation Legislation Research Committee. As shown in Figure 2, concept design of the transportation system Kankoh-maru for space tourism had been announced. The designed capacity is 50 passengers [20-22]. Based on the assumption of $25,000 (1998 USD) per ticket and 100,000 passengers per year, the initial profit rate could achieve 10%. The rate could reach 20% if the growth in passengers was 100% annually. These data were in line with the Transportation Research Committee's assumption of manufacturing 8 Kankoh-maru vehicles per year.

A market survey in USA

Every year, there are tens of millions people visiting the Smithsonian Air and Space Museum in Washington DC and similar museums in many other countries. Various other space camps and conventions also represent the large and continuing space tourism market taking place on the Earth's surface. Earlier in the 1980s, an independent market study made in the USA on true travel to space found that over 40 million people would like to take a trip on a space shuttle, and some 55 million would like to take a cruise ship-like space trip. In total, they would be willing to pay some 900 billion USD to do so, or about 40 billion USD per year [3,23]. In 1984, a US Congress report noted that "Only when a large number of our citizens, representative of a broad cross-section of our society, begin to experience the 'space adventure' directly, will the space domain and space activities gradually begin to move into the mainstream of our 'non national security' interests and concern" [23]. The Society Expeditions, an American company specializing in exotic vacations, studied the feasibility of providing space tourism to the general public. In August 1985, the company presented a plan to NASA, and then announced on 29 October 1985 that it was taking reservations for space tours scheduled in 1992. Space Travel was another USA company proposed to offer passenger tickets for riding on the Shuttle. However, NASA rejected all proposals. NSAA's philosophy

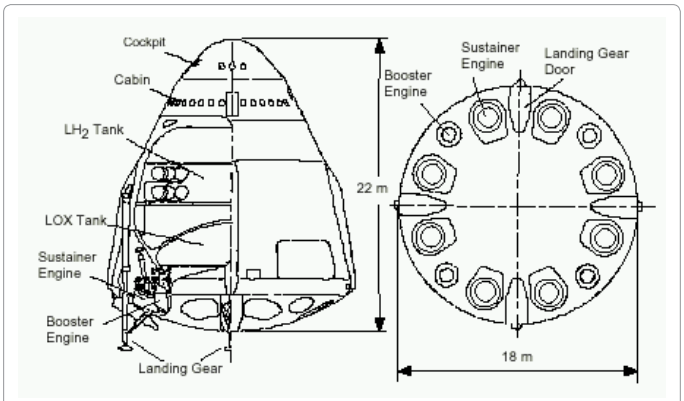

Figure 2: Kankoh-maru spacecraft [28].

was to share space with all citizens, instead of opening it to the tourists. Finally on 16 September 2014, NASA announced a critical component of Launch America, the country's highly anticipated next chapter in human spaceflight. Boeing and SpaceX share the USD 6.8 billion "space taxi" contract [24].

OST activities in Russia

Roscosmos, the Russian state space agency, is the only institute realized the OST activities so far. It sent 7 tourists (one of them made the travel two times) to ISS by using its Soyuz rocket and spacecraft systems from 2001 to 2009 [2,3,25]. One of the major purposes of Roscosmos in doing the space tourism activities was to raise budget to support the space program of Russia. Therefore, each trip priced tens of million in USD. After the entire retirement of space shuttle fleet on 21 July 2011, USA Government purchases seats of Soyuz systems in order to send its astronauts to and bring them back from ISS. Also, the number of resident staffs onboard ISS was expanded. It resulted that both Soyuz systems and ISS have no spare seats for tourists. The Russia's OST activities were halted since then. However, this is the true commercial OST activity even up to now. According to news report, Russia plans to resume OST activities in 2018 [26,27]. For the training of a general public to become an OST tourist, the candidate must be trained one half year in the Russian Federal State Organization's Yuri Gagarin Cosmonaut Training Center (GCTC).

OST and SST developments in private sector

The Phoenix concept of vertical-takeoff-and-landing (VTOL) single-stage-to-orbit (SSTO) was conceived in 1972 as a means to provide inexpensive access to space. The basic concept was carried into the 1980s and was improved so that the vehicle could be built with existing technology and be suitable for use by non-astronaut passengers [28]. At about the same time of dealing with NASA, the Society Expeditions announced in September 1985 the signing of a contract with Pacific American Launch Systems, a private company planning the development of a low-cost, reusable launch vehicle, the Phoenix. It was an agreement for Pacific American to provide launch services to Society Expeditions over 5 years from 1992. The proposed service was a 12 hours flight in polar orbit using a reusable launch vehicle which can carry 20 passengers with ticket priced at $50,000 per person. Based on the operations of one flight weekly, it represented a demand of about 1000 passengers per year. As of June 1986, some 250 people had placed deposits of $5000 each with Society Expeditions to book seats for 1992, meant that the demand did exist at the level estimated by Society Expeditions [13,28-30].

Historical Background and Current Price Model for SST

The development history of SST is rather short for just about one decade. Therefore, basically there was no historical price model background for SST. In this paper, we would presumably assume that the SST price could be reasonable to be at one tenth of that for OST. With this assumption and considering an **average inflation rate** of 2.60% per year between 1985 and 2017 the USD experienced, $1 in the year 1985 is worth $2.2725 in 2017. Table 2 showed the current SST price model under the two assumptions described above. It showed that in the pioneer phase, the estimated SST prices match pretty well [11]. Prices of the two sub-phases of pioneer phase are within the range between 100,000 and 250,000 USD as shown in Table 3 for SST.

Six kinds of true or simulated commercial space travel had been introduced. The contents and prices were summarized in Table 3 where the XCOR Lynx had been replaced by Blue Origin's New Shepard

Phase	OST price (1985 $)	SST price (2017 $)
1) Pioneer	1.1) 1,000,000	227,250
	1.2) 500,000	113,625
2) Exclusive	2.1) 100,000	22,725
	2.2) 50,000	11,363
	2.3) 25,000	5,681
3) Mature	10,000	2,273

Table 2: Estimation of SST price per ticket at one tenth of OST with inflation from 1985 to 2017.

Operator	OST or SST, vehicle	Price ($)
World View Enterprises	Neither, 30 km altitude, balloon	75,000
Blue Origin New Shepard trip	SST, New Shepard (see Figure 3 [30])	(To be determined)
Virgin Galactic SS2 space trip	SST, SS2 spaceplane (see Figure 4 [31])	250,000
SpaceX Dragon space trip	OST, Dragon space ship (see Figure 5 [31])	2 million
Zero Gravity Corporation	Parabolic arc flight, B727 (see Figure 6 [31])	4,950
Mars One Foundation and Interplanetary Media Group	Immigration of pioneer settlers to Mars	Free (selected volunteer basis)

Table 3: Six kinds and prices of real or simulated commercial space travel [11].

[11]. In terms of cost and affordability, optimistic observers think that once commercial SST becomes steadily successful, it would not take too much time for the business to be prosperous and in high demand. A major problem is that the price is still too high for a rather short journey. Is there any chance the space travel could become more affordable like current airfares? It could be or could not be. The SST providers and operators might expect an initial high cost for the fund of more researches, and also to establish the business model. They might mean to lower human space travel cost and enable the experience for all general public in the future without investing a huge amount of dollars. While expanding the playground for those rich people on the upper levels of pyramid, it is also expected to open new opportunities in career, business, education, science, technology, finance, law, and commerce for the general public community (Figures 3-6).

However, it is not an easy business. For aviation tourism, it took at least 30 years from the innovation of airplane in 1903 to 1930s to become popular. And the aviation tourism did not reach its exclusive or mature phase until 1950s, or say, more than 50 years from 1903. By quoting the historical background that many people would be willing to pay up to three month salary for an OST trip, and assuming they are willing to change to SST due to the current realistic situation, a reasonable mature price would be about or between 2,500 and 5,000 USD. As mentioned above, the journey is relatively short in between 30 and 90 minutes. It might take up to 3 days including training. Therefore, the two factors of once-for-a-lifetime and observing Earth from 100+ km altitude could be very important to attract passengers.

If the SST could be realized in 2018 or 2019, it is about 15 years after the invention of SpaceShipOne (SS1) in 2004, just about one half of 30 years. Then the exclusive phase of SST might be reached in about 25 years (one half of 50 years), i.e., near 2030.

Potential Methods to Reduce Ticket Price for SST

In summary, cost issue is one of the major issues or even the most important one for the future sustainable and prosperous development of SST. Among the many potential methods to reduce the ticket price

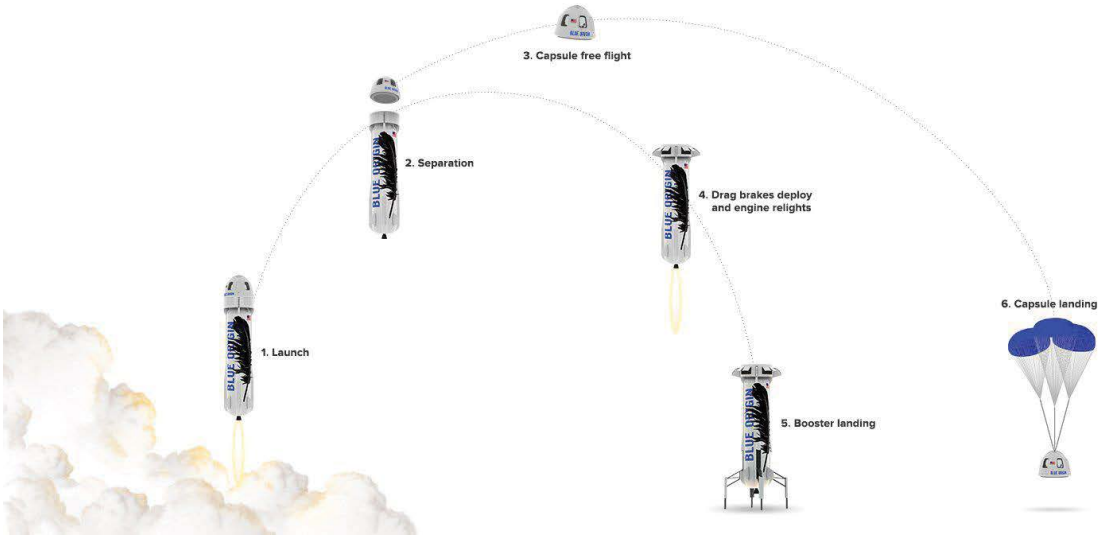

Figure 3: Flight plan of New Shepard system to 100+ km altitude with about 5 minutes of weightlessness phase.

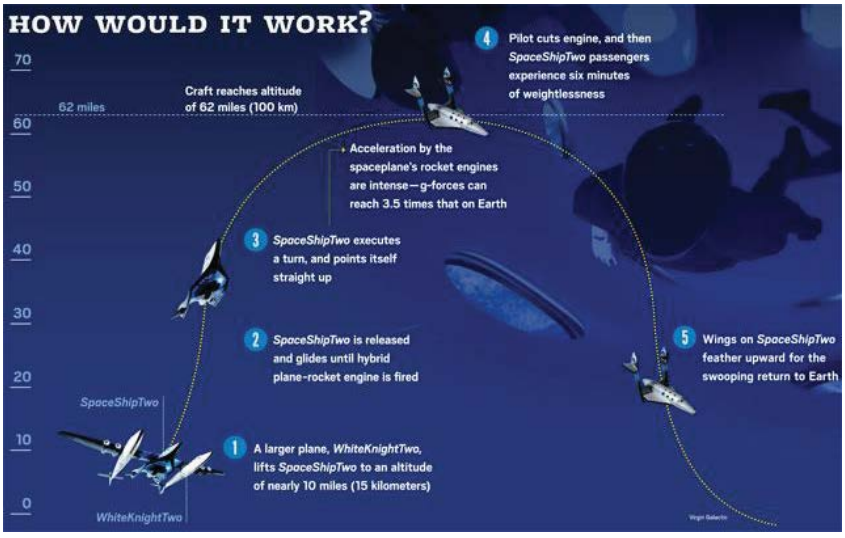

Figure 4: SS2 can reach 100+ km and provide passengers about 6 minutes of weightlessness flight phase.

Figure 5: Dragon V2 capsule of SpaceX could transport astronauts to and return from ISS, and for OST use, too.

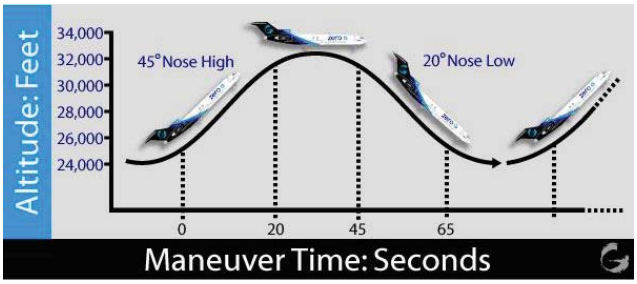

Figure 6: Airplane to fly in a series of parabolas for weightlessness experience.

for SST, the following three conditions were considered in this paper and could be the most important ones.

(1) Condition one: To make the spaceplane reusable. As the current situation of SST, both SS2 and New Shepard satisfy this condition.

From the example of SpaceX's Falcon 9 rocket, the importance of this condition could be seen easily. A new Falcon 9 rocket might cost 54 million USD, while the fuel needed only costs about 200,000 USD [31]. Of course, it takes time and manpower to refurbish the recovered rocket engine and refuel. However, the reusable rocket can save a lot of cost. Actually, since as early as 2011, the SpaceX has been working to make its rockets partially reusable, particularly the first stage. This critical milestone has been successfully reached in 2017 [32].

(2) Condition two: To shorten the turnaround time between flights. In order for the commercial SST business to be sustainable and prosperous, the market must be large enough so that an industry could be established. A spaceline company, once formed, must be able to provide at least two routine flights per day as an airliner. Therefore, the turnaround time between two flights must be shortened to several hours.

(3) Condition three: to improve the safety and reliability of spaceplane and to avoid any possible risk. Crash of the first SS2 caused several years delay of the commercial SST. Instead of being a happy journey of tourism, the SST could be considered as an extreme adventure, at least at the pioneer phase. It has been six decades from the first artificial satellite launch in 1957 to 2017, but the failure rate of rocket launch is still at a high value of about 5%. This percentage must be lowered to less than 1%, which corresponds to the rate of people who attempt to climb Mount Everest but sacrificed. And there is still about 1,000 climbers attempt it each year [31,32]. From aviation tourism to SST, the former is more like "must have" and the latter is rather than "better to have" for the general public. For a sustainable and prosperous SST market, 1,000 tourists are far from enough. As such, safety is far more important than Mount Everest climbing, if exclusive and mature phases are to be expected and reached.

Conclusions

According to the current development situations in suborbital space tourism (SST) and orbital space tourism (OST), the realization of both could be right at the corner. By inspecting the historical background of OST price models, it has been found that at the coming pioneer phase, the ticket prices for either SST or OST are extremely too high. In this paper, it has been assumed that a reasonable SST ticket price would be one tenth of that for OST. A reasonable price at mature phase would be about or between 2,500 and 5,000 USD. For the sustainable and prosperous developments of SST and OST, and for enhancing from the pioneer to exclusive and then to mature phase, three strategies have been introduced for the reduction of SST and OST ticket prices: to make the spaceplane reusable, to shorten the turnaround time between flights, and to improve the safety and reliability of spaceplane and to avoid any possible risk.

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