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Review Article

From Space Tourism to Commercial Suborbital Travel

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ABSTRACT

After several announcements last years, the recent successful flights with Jeff Bezos and Richard Branson as passengers have brought the space tourism topic back at the top of news headlines. Indeed, several projects have undergone incremental and careful development steps last years to ensure a sufficient reliability of such flights with passengers on board. The perfect re-entry of both the New Shepard system of Blue Origin and the Unity system of Virgin Orbit in July 2021 are now opening the path for commercial space tourism flights, with several hundreds of candidates having paid either substantial advance payments or even the total ticket price and a rising demand after these demonstrations.

This evolution can be compared with the first flights in the aeronautical field starting in 1919, when, at the end of WW1, experienced pilots and proven (ex-military) planes were used to carry air tourists at short turn-around flights. This rapidly evolved a few years later in regular commercial Point-to-Point air traffic, with the first air connection Paris London Paris.

We can easily forecast a similar evolution in suborbital transport of cargo and passengers after the first wave of space tourism. Similar as with the first aviation tourism, where passengers got a first sensation of flying and were then brought back to the starting point after a few minutes, suborbital space experience will soon evolve in so called point-to-point suborbital flights, covering intercontinental travel in 60-80 minutes in one go, which now takes up more than 21 hours, like a trip London-Sydney with one stopover.

This article will focus on the feasibility of such development, focusing in the first place on the potential business case and the economic rationale. It will be demonstrated that for 'time-poor, cash-rich' people such suborbital intercontinental travel will be a viable option and a potential market.

Keywords: Space tourism; Commercial suborbital spaceflight; Point-to-Point suborbital travel

INTRODUCTION

Analogy between air and space tourism evolution

The Wright Brothers made their first motorized flight in Kitty Hawk on 17 December 1903, and took a first passenger, E Zens, with them on 15 September 1908 [1]. Whereas the military authorities saw initially a potential in using aircraft for artillery observations, the number of aircraft and trained pilots grew very rapidly thanks to government contracts. As an illustration, Table 1 shows the number of flight ready aircraft and trained pilots in 1914 [2].

When other military applications of aircraft became evident, production rates rapidly increased. An important type of plane was the De Havilland DH-4 which was produced in the USA at a rate of more than 1000 monthly by the end of WW1 [2], played a role in the post war transition to commercial air traffic.

At the end of the war there was therefore a surplus of aircraft, very experienced pilots, and airstrips. Therefore, many of these ex-military pilots offered short duration air trips to paying passengers or gave stunt flying demonstrations (Also named 'flying circuses' and 'barnstorming').

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Country	Aircraft	Trained pilots
France	260	171
Russia	100	28
Germany	46	52
Great Britain	29	88
Italy	26	89
Japan	14	8
United States	8	14

Table 1: Number of Aircraft and planes in 1914 [2].

In particular, the aforementioned DH-4 planes, which had a largo cargo bay (They were initially designed as bomber aircraft) were transformed into early passenger planes. Already in 1919, a first commercial company (Farman) offered flights on the Paris-London-Paris trajectory. The very high ticket prices did, however, not allow making this endeavor financially viable.

With government support, from 1920 onwards, other destinations were exploited such as the London-Paris-Constantinople trajectory, which then lead to regular air traffic with additional (Government supported) companies entering the market. An interesting example in this context is Pan Am, which started operations in 1923 with nine ex-Navy aquaplanes, which were saved from a scrap yard. From a tourism point of view, we should also mention the then reputed Franco-Romaine group with the London-Paris-Constantinople trajectory, connecting at that time (from 1920 onwards) several attractive touristic destinations [1].

We can draw here a parallel with the space tourism market. Whereas the first air-trips picked up passengers for a short flight and brought them back to the same airport, we see now the same happening in space tourism. Soon after, air traffic evolved in Point-to-Point flights, bringing passengers to other destinations; it looks logic that this evolution will also take place in the suborbital spaceflight. Is analogy has been also well expressed by Belfiore [3], as follows:

'Private companies took air travel out of the exclusive domain of militaries and governments and gave it first to the very rich; then low-cost carriers such as Ryanair started turning around aircraft fast, increasing the frequency of flights and thus making them affordable for many more people. Space travel is taking the first step in this process'.

LITERATURE REVIEW

Suborbital space tourism

In view of the accepted risk related factor, we can qualify present space tourism as adventure recreation, in the same category as climbing the Mount Everest or skydiving. This explains the market potential, as this adventure tourism market, in US alone, is estimated over 100 BUSD yearly.

It is important to understand the requirements from the customer point of view. One of the most reputed and quoted studies in this field, the so-called Futron/Zogby study [4], summarized the requi-rements as per Table 2, based upon a large survey of a representa-tive sample of potential customers.

Motivation	Barriers	Risk Appraisal
Pioneering (32%)	Strapped in seats	Skydiving (3%,7%)
Lifelong dream (18%)	>One week training	Mountain Climbing (3%,6%)
See Earth from Space (16%)	Private developments	Space travel (3%)
Space Enthusiast (8%)		Skiing (2%,2%)
		Private Piloting (1%, 9%)

Table 2: Requirements and risk perception of potential clients [4].

Interesting conclusions from this study were that potential customers:

- Want to see the Earth from Space.
- Want to witness weightlessness and free floating.
- Do not consider space travel as more risky than other adventure activities, even perceiving the risk lower than Skydiving and mountain climbing.

Combining this with tourism customer behavior studies such as [5,6], we can therefore summarize that the expectations of space tourist must comply with the following offerings:

- Viewing space and the earth.
- Experiencing weightlessness and being able to float freely in zero gravity.
- Experiencing astronaut training and other sensations.
- Communicating from space.
- Being able to discuss the adventure in an informed way.
- Having astronaut-like documentation and memorabilia.

These objectives need to be combined with-sometimes conflicting-constraints such as

- Guaranteed safe return.
- Limited training time.
- Minimum medical restrictions.

If we take as an example the Blue Origin New Shepard present trajectory, as presented in Figure 1, we can see that

- Weightlessness is provided for some 4 minutes, flying above the so called Karman line (100 km).
- A safe re-entry is secured by a parachute landing system.
- The system is fully automated, requiring very limited training (only for emergency egress).

- The age range of the first New Shepard passengers (from 18 to 82 years) demonstrates the wide range of acceptable physical restrictions.

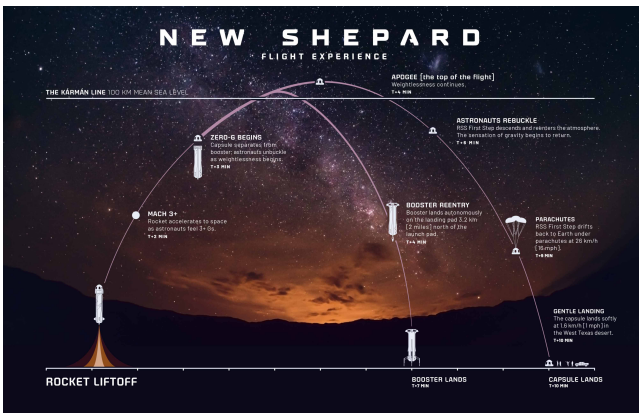

Figure 1: New Shepard flight trajectory.

Note that the limited flight-time of approximately 10 minutes and the relatively low g-loads are allowing a very large part of the population to participate from a medical point of view (except for e.g., cardiovascular problems).

We must mention here an ongoing discussion which will need some clarification. There is no legally agreed definition where space begins. Weightlessness begins from approximately 80 km above the Earth surface onwards. However, 100 km, which is called the Karman line, is in general accepted by the space community as the point where space begins. So even if this height is not reached, one can still claim that one can offer weightlessness experience. This also is linked to the discussion when the name 'astronaut' can be assigned to the passengers.

Let us now reflect on the market size of this space tourism market. Several forecasts were made the last decades on the market size of suborbital space tourism. A good overview of the different approaches can be found in [7]. It is interesting that the authors insist on reusability of the vehicles to come to a profitable business model, a condition which was demonstrated recently in the two flights of Blue Origin and Virgin Orbit, where the first stages were both recuperated safely.

As an indication, a recent review, considering the delays of the start of the operations and impact of the COVID pandemic, estimates this market to rise to 1.7 BUSD by 2027, with a CAGR (Compound Average Growth Rate) of more than 15% [8].

The real size of the market will be strongly influenced by the ticket price evolution. With hundreds of candidates waiting, the original ticket price of Virgin Orbit for a flight of 200,000 USD has now evolved to the range of 500,000 USD. Blue Origin (the private company of J. Bezos) presently works with an auction system with ticket prices at present of several million USD.

With a market prospect in this order of magnitude several competitors will come on the market (As an example a Chinese project is already well advanced), so ticket prices will rather quickly reduce.

Referring to Table 2, we must draw though the attention to the pioneering effect which is recorded as very important. It is not evident how many people will be willing to pay such high prices for an experience when many others have done this before them.

This will lead unavoidable, as each Product Life Cycle (PLC) to a decline in demand which can only be compensated by considerable price reductions.

Also, as in each PLC process, it can be assumed that the operators will look for an extension of their offering. Point-to-Point (P2P) flights are, in analogy with aircraft activities, the logic next step (Figure 2).

Point-to-Point (P2P) sub-orbital flights

The principle of suborbital flights can be explained using the diagram in Figure 2 below.

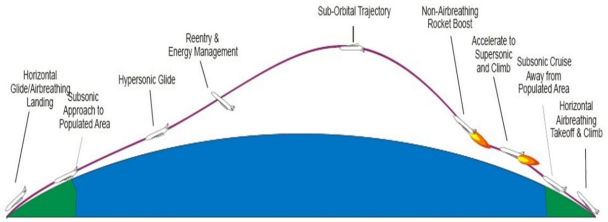

Figure 2: Point-to-Point (P2P) suborbital flight pattern [1].

The plane takes off horizontally on a normal runway using conventional air breathing propulsion. From a certain height onwards, a rocket motor is ignited to allow reaching a sub-orbital trajectory, where there is minimal air resistance, so that extremely high speeds can be reached. Close to the destination, the plane returns in the atmosphere and lands on a conventional runway.

In order to perform such pattern, a few boundary design conditions need to be taken into consideration, namely [9,10]:

- Only distances of minimum 3500 km shall be considered for sub-orbital flight patterns, whereas an optimal economical effect (From a flight efficiency point of view) can only be reached from 7000 km onwards.
- Flight apogees shall be limited to max. 500 km height to avoid radiation exposure for the crew and passengers.
- Vehicles and trajectories shall be designed to reduce g-loads for passengers.
- The interior design needs to be adapted to these g-loads (Like reclining seats) and comfort of the passengers (Like windows above the seats, in view of a horizontal position of the passengers during the ascent phase).

An example of a suborbital plane and its internal design is presented in Figure 3, allowing passengers to experience free floating experience within a safe and dedicated personal area.

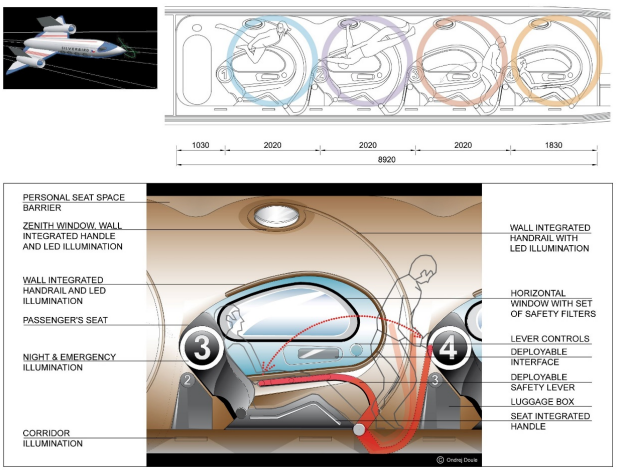

Figure 3: Interior design proposal for a sub-orbital plane [10].

When these conditions are fulfilled, considerable time savings could be achieved. As an illustration Table 3 provides a comparison between normal (Present) flight durations and the calculated suborbital flight durations.

Route	Distance (km)	Aircraft duration (hr)	Suborbital duration (av. min.)	Time saving
London-New York	5,900	7 h 30	70	6 h 20
London-Singapore	9,560	11 h 30	76	10 h 14
New York-Tokyo	10,900	12 h 50	83	11 h 27

Table 3: Comparison of flight durations [9].

In view of completeness, we must add here that there is also interest from the cargo transport industry in view of transporting amongst others

- Time sensitive items (Like contracts and documents that need to be on time, or radioactive and biological material with short lifetime).
- Organ transplants (As some organs can only be kept in a medically good condition for a few hours).
- Transports where border crossing and landing stops (With changing cargo from one plane to another) are preferred to be avoided (Like art objects, precious metals).

Point-to-Point (P2P) Space Travel: The business case

For commercial space travel, we can assume following parameters

- Time saving will be the paramount factor.
- The trip shall be comfortable and without risks.
- Connections to other airports and business centre infrastructures are important (Hence landing at commercial main airports).
- The space aspect is of interest but not the main motivator.
- The ticket price will need to be competitive with alternative transport means (Like private jets).

The target market groups we are considering are 'time-poor, cash-rich' people, such as

- Wealthy tourists that dislike the discomfort of a long trip.
- Wealthy tourists having limited time available and do not want to spend part of this time on long trips in aircrafts and airport waiting times.
- Top executives
- Board members
- Sports stars (golf, tennis, formula 1)
- Celebrities (movie stars, musicians)

Evaluation of the first four categories result in hourly cost figures (In terms of opportunity cost, i.e., the alternative income generated by other options than travel time) in the order of 4,500 $, with the latter two categories even reaching levels of 30,000 $/hr [11,12].

The first category of travelers represents the more frequent user group, and is therefore important for a sustainable market, hence could be used as a prime basis for a business model approach.

Let us illustrate our assumptions on a New York, Tokyo trajectory.

We can compare for this specific case:

- The present, normal flight including a first class ticket@14,400 $
- An alternative spaceflight with a time saving over 11 hrs@4500 $/hr opportunity cost.

Resulting in a theoretical break-even space ticket price of 49,500+14,400=63,900 $.

Hence, based upon the estimated sub-orbital ticket price of 75,000 $ [9] we are reaching equitable levels, but with the intangible asset of having at the same time. been in space as an extra bonus!

An additional comfort element can be illustrated as per Figure 4. P2P flights between London (and Paris) and New York would allow the executive to leave around 10 am in London (or Paris), have a four hours meeting in New York and be back, the same day, around 11 pm in London/Paris. Certainly, this will be a real asset for frequent travelers which prefer to avoid stays in hotels.

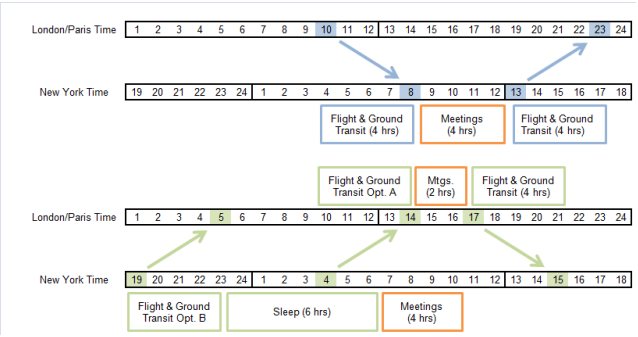

Figure 4: Possible travel schedule London/Paris-New York [12].

It seems evident that many aspects, technical and regulatory ones, will require a debugging phase before we can implement

this business case, in particular in the fields of flight comfort and safety. Cargo flights might therefore become an interesting intermediate and incremental step.

DISCUSSION

The recent demonstration flights from Blue Origin and Virgin Orbit have shown the feasibility of suborbital space tourism based upon reusable flight hardware. Therefore, this opens the way for a flourishing space tourism market, which is estimated to reach 1,7 BUSD by 2027.

However, after a certain number of space tourists will have been on these flights, the pioneering effect will disappear, hence the demand will decrease, and prices will have to be lowered. We can assume that after 5-7 years this market will start to decline as is the case in each Product Life Cycle (PLC).

If we compare this evolution with the aeronautical one, a real sustainable market will be created by regular suborbital so-called Point-to-Point (P2P) flights using suborbital vehicles. The relatively high initial ticket prices, as was also the case in 1920 for the first tickets of e.g., Paris-London, will only be in reach of 'cash-rich, time-poor' persons such as very wealthy tourists, top-executives and possibly celebrities in high demand.

CONCLUSION

First estimates demonstrate that, considering the opportunity cost of these passengers, the time saving of several hours for long trajectories can justify the extra-cost, compared with first-class tickets, whereby the additional attraction of having been in space is no doubt a very intangible but important asset.

Whereas there is, therefore, a viable business case, flight safety and comfort requirements will have to be mastered. A possible pathway towards this could be achieved by considering P2P experience with cargo flights which can be built easier without windows and with less onboard life support systems. But also, further space tourism developments over the next few years could be used to gain experience on these topics, paving the way for a sustainable suborbital flight market.

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