Economic and Technical Evaluation of Suborbital Spaceflight for Space Tourism[1]

R.A. Goehlich, Technical University Berlin, Institute of Aero- and Astronautics, Spacecraft Technology, Marchstrasse 12, 10587 Berlin, Germany

e-mail: Robert.Goehlich@TU-Berlin.de; Internet: www.Robert-Goehlich.de

Abstract

Extensive travel by air, sea, and land for pleasure and business is commonplace in modern life. In contrast, travel in space is only available, essentially, to a small number of highly trained government astronauts, and the public's perception is that it cannot be otherwise. In fact, space tourism has already started evolving through a number of stages beginning with ground theme parks, space camps, zero gravity flights, and Soyuz flights to the International Space Station. Progress to suborbital trips with a brief experience of weightlessness will probably follow as a natural further development.

This study focuses on these near-term suborbital trips, examining suborbital vehicles that are in the development stage and comparing their capabilities. The investigation has three objectives: to provide an overview of the space tourism market as it currently exists and classify suborbital tourism flights within it; to determine if the investigated suborbital vehicles are technically feasible, by determining the maximum apogee altitude, estimating the necessary rocket engine propellant, and comparing systems qualitatively; to develop a statistical-analytical model called Suborb-Transcost to estimate the ticket prices for a realistic scenario in order to verify whether the launch vehicles are economically feasible.

1. Space Tourism Market

1.1 Defining Suborbital Flights

Suborbital spaceflight for tourism can be defined where customers pay an initially high price (estimates vary between US $ 5000 and US $ 1.1 million) [Reference 2] to go on a ballistic flight in a spacecraft into space (apogee altitude is about 100 km), have a few minutes of weightlessness and then return to Earth, as illustrated in Fig. 1. These space trips are very similar to the airplane flights offered by the first barnstormers, which provided the first commercial market for aviation in the early 1920s.

1.2 Order of Events

In general, a suborbital trip means up to one week of time commitment. Three days of that week may be spent at the launch complex getting ready. On day four, the space tourists are launched and, after the engines cut out, they float around the cabin for about five minutes. Then the tourists can play around in zero gravity, make videos of each other, and take pictures of the Earth. Back

---

[1] Executive Summary of Goehlich [Reference 1]

at the base, the approximately ½ to 3 h ride (depending on the flight sequence) is finished [Reference 3]. The last few days together are to digest their impressions.

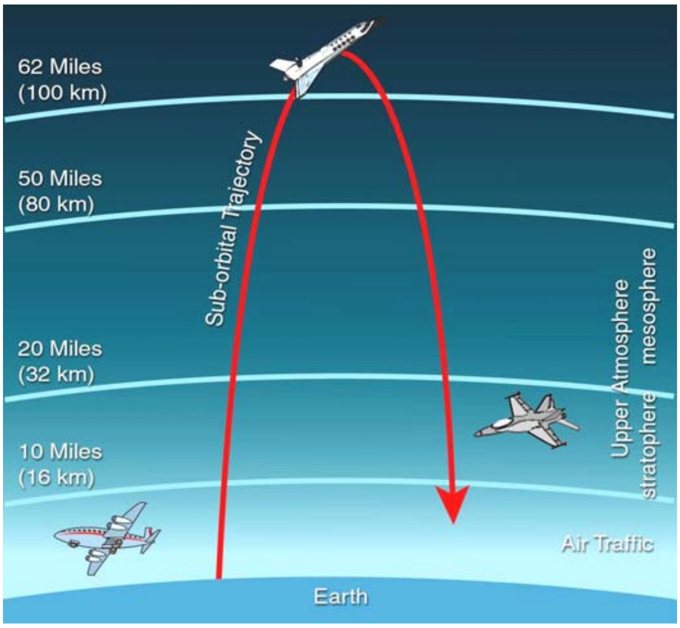

Figure 1. Suborbital trajectory [Reference 4]

1.3 Tourist Attractions in Space

Market research has shown that what most people want to do in space is to watch the Earth. There seems to be an endless fascination in seeing the different continents roll by, with no borders visible between countries. The wish to play and eat in weightlessness can also be satisfied by parabolic aircraft flights.

1.4 Suborbital Vehicles

In order to make space tourism feasible for the mass market, new kinds of vehicles are needed. Expendable rockets will not do the job. Instead, reusability is the key. Table 1 includes 27 worldwide proposed reusable launch vehicle studies for suborbital tourist flights, listed alphabetically by vehicle name. Vehicles high in information (indicated in grey) are investigated in detail in this study. Suborbital research vehicles, like some of the NASA X-series, are not listed due to the fact that their primary goal is research and not profit.

Vehicle	Developer	Country	Launch Mass [Mg]	PL [pax][2]	Status
Advent	Advent Launch Services	USA	n.a.	6	n.a.
Ascender	Bristol Spaceplanes	UK	4.5	2	active
Aurora	FunTech Systems	USA	n.a.	n.a.	n.a.
C-21	Cosmopolis XXI	Russia	2.0	2	active
Canadian Arrow	Canadian Arrow	Canada	n.a.	3	active
Cosmos Mariner	Lonestar Space Access	USA	62	4	n.a.
daVinci	The daVinci Project	Canada	>2.5	2	active
Eclipse Astroliner	Kelly Space and Technology	USA	327	40	inactive
ESTS	Earth Space Transport System	USA	n.a.	n.a.	n.a.
Gauchito	Pablo De Leon & Associates	Argentina	n.a.	n.a.	n.a.
Green Arrow	Graham Dorrington	UK	n.a.	n.a.	n.a.
Kitten	CFFC	USA	2.1	2	active
Lucky Seven	Micky Badgero	USA	n.a.	n.a.	n.a.
Michelle-B	TGV Rocket	USA	n.a.	n.a.	active
Pathfinder	Pioneer Rocketplane	USA	109	23	inactive
PA-X2	Aeroastro	USA	n.a.	n.a.	n.a.
Proteus	Scaled Composites	USA	6.4	3	inactive
Rocketplane XP	Pioneer Rocketplane	USA	n.a.	2	active
Roton (suborbit)	Rotary Rocket Company	USA	181	14	inactive
Space Clipper SC-1	Space Clipper International	USA	n.a.	10	n.a.
Space Cruiser	Vela Technology Development	USA	12.5	6	active
SpaceCub	David Burkhead	n.a.	18	4	n.a.
Space-Hopper	Astrium	Germany	328	n.a.	active
The Space Tourist	Discraft Corporation	USA	45	6	active
Thunderbird	Starchaser Industries	UK	20	3	active
XPV	Canyon Space Team	USA	n.a.	n.a.	n.a.
X Van 2001	Pan Aero	USA	3.6	2	n.a.

Table 1. Vehicle studies for suborbital tourist flights

1.5 Suborbital Flights within Space Tourism

Space tourism activities in the near future can be divided into different stages of complexity, resulting in different prices. Table 2 is an overview classification of suborbital flights within actual and near-term space tourism.

[2] The payload (PL) unit is given in number of passengers (pax).

Stage	Description	0-g Time	Altitude Reached	Preparation Time	Price	Realized
1	View Space Shuttle launch	none	ground	3 days	$ 1200	yes
2	Parabolic flight	0.5 min.	11 km	4 days	$ 5000	yes
3	High altitude flight	none	24 km	2 days	$ 13 000	yes
4	Suborbital flight	5 min.	100 km	5 days	$ 98 000	no
5	Orbital flight	3 h	LEO	2 weeks	$ 1 M	no
6	Orbital accommodation	10 days	LEO	½ year	$ 20 M	yes

Table 2. Different stages of complexity of space tourism

2. Technical Feasibility

This part of the investigation applies basic physical laws to check if the main vehicle specifications proposed by the developers are realistic. The first stage vehicle specifications are not critical, because the carrier aircraft have a proven performance, and will not be discussed here further. The jet engine phase used by some single stage vehicles to reach the altitude for rocket engine ignition is also assumed to be feasible. The more interesting questions are whether the single or second stage vehicles will reach the required minimum apogee altitude of 100 km by using their rocket engines, and if these vehicles use the correct propellant-engine combination. The last part of this investigation deals with a brief qualitative system comparison based on the following capabilities: soft abort, use of existing hardware, multiple missions, powered landing, usual runway, and single load path. All results are summarized in Table 3.

Vehicle	Altitude Check	Propellant Check	System Check	Technical Feasibility
Ascender	passed	passed	passed	uncritical
Eclipse Astroliner	passed	passed	passed	uncritical
Kitten	passed	failed	failed	critical
Pathfinder	passed	passed	passed	uncritical
Roton (suborbit)	passed	passed	failed	critical
Space Cruiser	failed	failed	passed	critical

Table 3. Results of the analysis of technical feasibility

3. Economic Feasibility

3.1 Developing Suborb-Transcost

To assess a launch vehicle's success, it is important to figure out the necessary price of the ticket. This is done by estimation of life-cycle costs for a simulated scenario. The life-cycle costs include the development cost, the vehicle cost, the operating cost, and the abolition cost. Due to the fact that companies hide their financial details, a model has been developed by the author [Reference 1] to transform the relevant technical data available for suborbital vehicles into costs. This user-friendly model – called Suborb-Transcost - is designed as an Excel input mask and structured in four interconnected submodels for development costs, vehicle costs, total operating costs and total profit. The model is based on a statistical-analytical model used in the aerospace industry [Reference 5].

3.2 Model Applications

The Suborb-Transcost model is applicable for single, first, or second stage winged and ballistic vehicles. Each vehicle can be created with jet engines, rocket engines, or both. The model takes into account the different number of vehicle reuses, jet engine reuses, and rocket engine reuses, which strongly influence the total operating costs.

3.3 Fleet Life-Cycle Scenario

Each investigated vehicle system is run under the same simulated fleet life-cycle scenario in order to be comparable. Shareholders invest in a three-year development phase from 2000 to 2003. A two-year production phase from 2003 to 2005 is taken by risk loan which comprises the production cost for one operating vehicle system. Two flights per week (104 launches/year) and the necessary follow-up production for vehicle replacement are carried out during an assumed 15 year operational phase from 2005 to 2020. Finally, a half-year abolition phase is needed to get rid of the vehicles, and retrain or dismiss the employees.

3.4 Model Results

Fig. 2 shows the total launch prices of the investigated vehicle systems, which are gained by using the Suborb-Transcost V1.0 Model [Reference 4]. Comparing the launch price modeled with Suborb-Transcost (e.g., for the Space Cruiser System, US $ 5.8 million) with the launch price assumed by the developers (e.g., for the Space Cruiser System, US $ 0.6 million) the different approaches can be evaluated:

The developers may well imagine that the first generation of suborbital vehicles has matured to have operating characteristics like airliners: the vehicles are capable of several flights per day to suborbit, and have a life of tens of thousands of flying hours. The author's opinion is that this approach is not realistic. The intermediate stage between today (no suborbital tourism flights) and the future (suborbital tourism flights operating like airlines) is missing. For example, in 1957 the former Soviet Union put just "one" Sputnik into orbit and not "thousands" of Sputniks, although nowadays the satellite market is profitable. The business market has to learn to pursue space tourism by developing the necessary infrastructure in a linear manner, not as a jump.

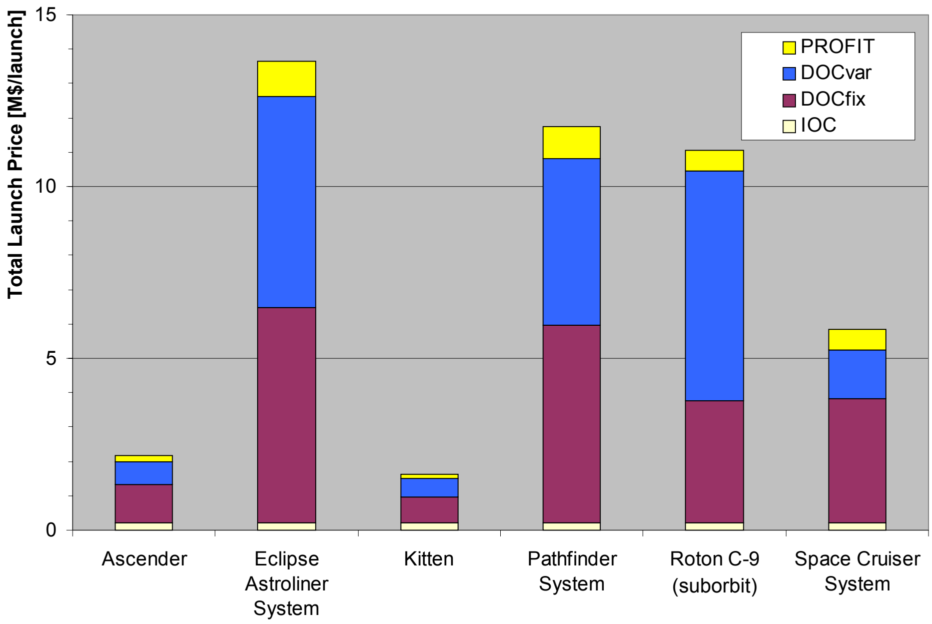

Figure 2. Calculated total launch prices[3]

Table 4 shows a comparison of the calculated ticket prices and those given by the developers or space travel services. The data show that, under a realistic scenario for suborbital tourism flights in the near-term, the ticket prices offered (US $ 5000 by Ascender, and US $ 8000 by Kitten) are critical economical feasible. This is due to the fact that the calculated ticket price is 220 and 100 times, respectively, higher than the claimed price. That is the meaning of "critical" in the sixth column of Table 4. The Space Cruiser's offered ticket price

[3] DOC_{var} is the variable Direct Operating Cost, DOC_{fix} is the fix Direct Operating Cost, and IOC is the Indirect Operating Cost.

is ten times smaller than the calculated ticket price and is also graded as critical. Pathfinder and Roton could have the potential for economic feasibility, because the company's offered ticket prices are very close to the calculated ones. Because Eclipse Astroliner's offered ticket price is the same as the calculated price, it is an economically feasible concept so far.

Vehicle	Ticket Price (calculated) [M$/launch]	Ticket Price (developer) [M$/launch]	Ratio (calculated/ developer)	Ticket Price Check	Economic Feasibility
Ascender	1.1	0.005	220.0	failed	critical
Eclipse Astroliner	0.3	(0.3)	1.0	passed	uncritical
Kitten	0.8	0.008	100.0	failed	critical
Pathfinder	0.5	(0.3)	1.7	passed	uncritical
Roton (suborbit)	0.8	(0.5)	1.6	passed	uncritical
Space Cruiser	1.0	0.1	10.0	failed	critical

Table 4. Results of the analysis of economic feasibility

4. Conclusion

Today, there are many experiences which are available to help the space tourism business in the near-term, including parabolic flights, high-altitude flights, and Soyuz flights to the International Space Station. The barriers to suborbital flights employing reusable rockets are not just technical, or financial, or due to existing federal regulations and policies, as most people believe. Actually, they are a combination of the three, each contributing in its own way. The developer's attitude of raising only one of the barriers has resulted in misunderstandings that continue to the present, and do not help to move the projects forward.

Currently, there exist about 27 suborbital vehicle developers, some of them as small as five-man teams. All of them have the vision of developing and producing a space fleet, as has been done for aircraft in the past and present, nationwide. At first glance the vehicle studies look fantastic, but some weak points concerning economic and technical feasibility become visible on closer inspection. Now the question is what to do in order to enable space tourists to make suborbital flights in the future.

The author's opinion is that one possibility could be to share the risk and share the know-how, instead of small teams competing against each other as is currently practiced. Another possibility is to convince governments to provide some financial aid or to make available the necessary infrastructure to realize a suborbital vehicle project, instead of working without government funds. Another approach would be to operate expendable rockets first, and then use reusable ones. The successful flights of space tourists Dennis Tito, in 2001, and Mark Shuttleworth, in 2002, to the International Space Station will probably generate more demand for those flights as well as increase the investor's interest in suborbital reusable rocket projects. However, the Soyuz is an expendable rocket and therefore not usable for high launch frequencies. Therefore, this is more a temporary solution to satisfy the near-term space tourism market but without any potential for cutting costs.

Acknowledgements

The present paper would not have been possible without personal communications with people in the space tourism community as well as in the aerospace industry during the research. I am very grateful to them for supporting my investigations of space tourism.

References

1. Goehlich, R.A.: *Space Tourism: Economic and Technical Evaluation of Suborbital Space Flight for Tourism*, ISBN 3-936231-36-2, Der Andere Verlag, Osnabrück, Germany, 2002
2. Bekey, I.: *Economically Viable Public Space Travel*, presented at the 49th IAF Congress, Melbourne, Australia, 1998
3. Bristol Spaceplanes, Ltd.: <http://www.bristolspaceplanes.com>, Bristol, UK, April 16, 2002
4. Space Adventures, Ltd.: <http://www.spaceadventures.com>, Arlington, USA, April 16, 2002
5. Koelle, D.: *Transcost – Statistical-Analytical Model for Cost Estimation and Economic Optimization of Space Transportation Systems*, TransCostSystems, Ottobrunn, Germany, 1999