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A REPRESENTATIVE SCENARIO FOR DEVELOPING SPACE TOURISM

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Abstract

This analysis attempts to develop a scenario for mass space tourism flights, which satisfy operator's, passenger's, and public's needs and wishes by a systematical approach. Focal point of research is to span the gap between today's "pioneer space tourism" (one or two spaceflights per year to the International Space Station ISS) and desired future's "mass space tourism" (100 000 spaceflights per year to orbit). This might be realized by firstly, increasing public awareness, secondly operating suborbital vehicles for semi-regular flights, and thirdly operating orbital vehicles for regular flights covering a total period of 70 years. Assumed passenger demand could open a new market of annual revenues of $10 billion within the frame of this representative scenario.

KEYWORDS: **Cost Estimation, Hopper, Kankoh Maru, Orbital Flight, Reusable Launch Vehicle, Space Tourism, Suborbital Flight**

Introduction

Apart from scientific viewpoint of space, there is an increasing interest for new ventures like space entertainment and space tourism. Affordable space access is essential for development of new space business, especially space tourism as shown in Figure 1.

Figure 1: Example for a Typical Future Space Tourism Flight (Space Adventures)

Properly designed Reusable Launch Vehicles hold promise for low-cost access to space. Financing research and development of Reusable Launch Vehicles (RLVs) require public and/or private investors. Investors are only interested in supporting Reusable Launch Vehicle developments if it is guaranteed that they

earn acceptable benefit returns in terms of revenue, prestige, advertising or security reasons at an acceptable risk.[1]
Thus, the objective of this study is to present a feasible scenario as a recommendation for the establishment of a mass space tourism market. Development, production and operation of reusable launch vehicles are based on novel industrial processes driven by cost engineering techniques.

Model Structure

Figure 2 shows the iteration process of the approach to results, which are presented in this study. Each investigated issue and related results are presented as a separate section but the investigation has been performed in conjunction with all research topics.

Section "Space Tourism Market" deals with general conditions concerning space tourism. Research is done on existing and future space tourism partial markets, market size as a function of ticket price, worldwide vehicle concepts, space travel agencies, organizations and external influences in coming decades.

Section "Selection of Candidate Vehicles" covers the selection of suitable vehicles. From a list of a total of 153 proposed concepts, two vehicles, one for suborbital and one for orbital use, are selected by comparing theirs with ideal vehicle characteristics. These characteristics have been determined by using the method of paired comparison.

Section "Model of a Program Scenario" contains the key position of this study and examines a viable business model for space tourism flights. Special research is done on suborbital and orbital flight competition in an oligopoly market environment. Used tools are TRASIM 2.0 and TRANSCOST 7.0, which are statistical-analytical models for cost estimation.

The benefit aspects of space tourism flights are addressed in section "Benefit Estimation". Benefits are determined for different interest groups such as operators, passengers and governments as well as different markets such as suborbital and orbital flights.

Hurdles and showstopper events are examined in section "Hurdles and Opposing Forces". It includes discussions around ethics, environmental pollution, health, envy and safety issues concerning space tourism flights.

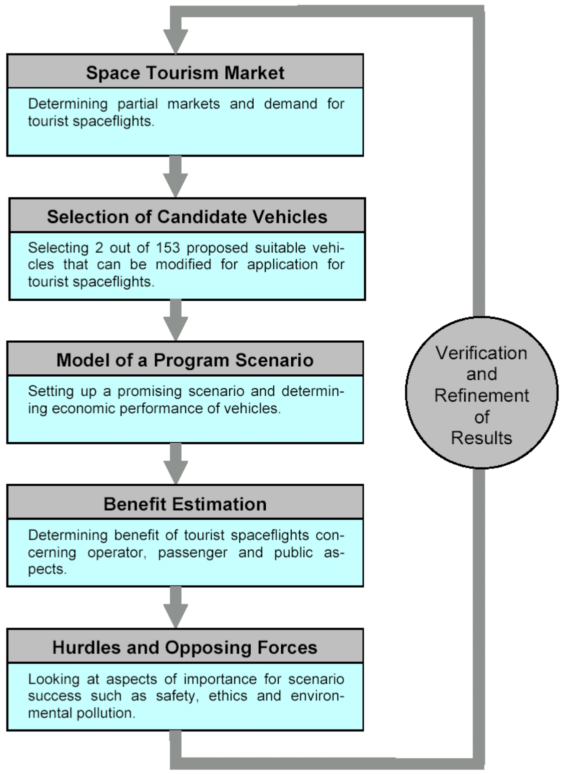

Figure 2: Iteration Process of an Approach to Results

Sections

Space Tourism Market

Demand

Market analysis studies supply evidence that prospective passengers are largely driven by ticket prices. Different survey data are used by the author for determining a market demand model, resulting in Figure 3. A special relationship between price and demand for suborbital and orbital flight is determined based on results of various market surveys and polls. In general, the figure shows that passengers are willing to pay more for orbital flights than for suborbital flights. There is a risk that the suborbital space tourism market would be almost instantly replaced when a product capable of reaching orbit was introduced. Therefore, the question, which is investigated in this study, arises: "Would a suborbital market last long enough for manufacturers be able to recoup their investments prior to the introduction of a transportation system capable of reaching orbit?"

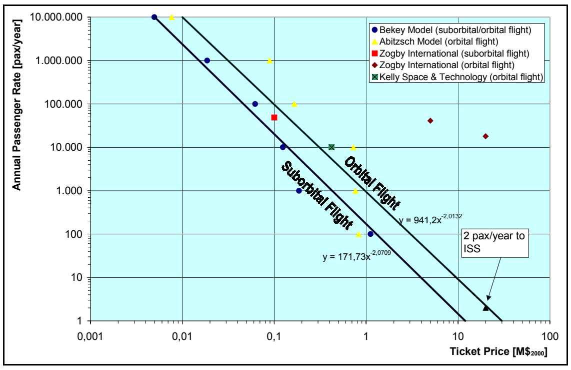

Figure 3: Model of Annual Passenger Rate as Function of Ticket Price

Supply

Space transportation is one of most essential elements for enabling activities in space. For current rockets, reliability is too low and launch cost is too high, when compared to aircraft operations. Reusable Launch Vehicles could ameliorate these conditions and are investigated by many companies. Table 1 summarizes 153 worldwide-proposed vehicle concepts for RLVs. Only three of the 153 proposed concepts have been realized so far, namely X-15, Space Shuttle and Buran as shown in Table 2.

Table 1: Comparison of Worldwide RLV Concepts

Country	Suborbital	Orbital	Total
Argentina	1	0	1
Canada	2	0	2
China	1	3	4
France	1	4	5
Germany	2	11	13
India	0	1	1
Japan	0	7	7
Romania	1	0	1
Russia	2	28	30
United Kingdom	4	6	10
USA	30	49	79
Total	**44**	**109**	**153**

Table 2: Comparison of Worldwide RLV Realizations

Country	Suborbital	Orbital	Total
USA	1 (X-15)	1 (Space Shuttle)	2
Russia	0	1 (Buran)	1
Total	**1**	**2**	**3**

Selection of Candidate Vehicles

General

The basis for the selection of candidate vehicles is a morphological box listing alternative characteristics available for each design feature as shown in Table 3. This box assists in the determination of one theoretically optimized vehicle for suborbital and orbital flights, each. These are compared with proposed vehicle concepts to find the vehicle concept closest to the theoretically optimized one. The selection process is performed separately for technical, economic and political feasibility, but only aggregated results are presented in this summary.

Table 3: Morphological Box of Design Features and Characteristics

<table>
<tr><th>Design Features</th><th colspan="12">Choice of Characteristics</th></tr>
<tr><td>Number of Stages</td><td colspan="3">1 Stage</td><td colspan="3">1 Stage + Assist</td><td colspan="3">2 Stages</td><td colspan="3">2 Stages + Assist</td></tr>
<tr><td>Configuration</td><td colspan="4">Tandem Staging</td><td colspan="4">Parallel Staging</td><td colspan="4">Nested</td></tr>
<tr><td>Propellant</td><td colspan="4">LOX/LH2</td><td colspan="4">LOX/RP-1</td><td colspan="4">LOX/C3H8</td></tr>
<tr><td>Launch Method</td><td colspan="4">Vertical</td><td colspan="4">Horizontal</td><td colspan="4">Air Launch</td></tr>
<tr><td>Landing Method</td><td colspan="3">Ballistic (Rocket Eng.)</td><td colspan="3">Ballistic (Parachute)</td><td colspan="3">Aerodynamic (Jet Eng.)</td><td colspan="3">Aerodynamic (Glider)</td></tr>
<tr><td>Impact Absorber</td><td colspan="4">Landing Legs</td><td colspan="4">Air Bags</td><td colspan="4">Brake Rockets</td></tr>
<tr><td>Mission Duration</td><td colspan="4">Short
Suborbit: < 0,5 hour
Orbit: < 3 hours</td><td colspan="4">Medium
Suborbit: 0,5-3 hours
Orbit: 3-24 hours</td><td colspan="4">Long
Suborbit: > 3 hours
Orbit: > 1day</td></tr>
<tr><td>Mission Success</td><td colspan="4">0,99 probability (low)</td><td colspan="4">0,999 probability (medium)</td><td colspan="4">0,9999 probability (high)</td></tr>
<tr><td>Catastrophic Failure</td><td colspan="4">0,0001 probability (low)</td><td colspan="4">0,001 probability (medium)</td><td colspan="4">0,01 probability (high)</td></tr>
<tr><td>Reusability</td><td colspan="3">< 100</td><td colspan="3">100 to 1000</td><td colspan="3">1001 to 10 000</td><td colspan="3">> 10 000</td></tr>
<tr><td>Turn-around Time</td><td colspan="4">< 2 days</td><td colspan="4">2 days to 1 week</td><td colspan="4">> 1 week</td></tr>
<tr><td>Seat Capacity</td><td colspan="4">< 10</td><td colspan="4">10 to 50</td><td colspan="4">> 50</td></tr>
<tr><td>Passenger Comfort</td><td colspan="4">Seat bound (low)</td><td colspan="4">Some movement (medium)</td><td colspan="4">Free floating room (high)</td></tr>
</table>

Suborbital Vehicles

The result of suborbital concepts evaluated and ranked by the author with regard to the overall goal achievement is shown in Figure 4 after weighing each group. Weighted goal achievements vary from 52 % to 73 % with the Hopper (suborbital) concept closest to the theoretically optimized concept. Therefore, the Hopper (suborbital) concept will be used in a modified version called Hopper Plus for a scenario presented in section “Model of a Program Scenario”. A 100 % goal achievement is impossible due to some conflicting, desirable design features.

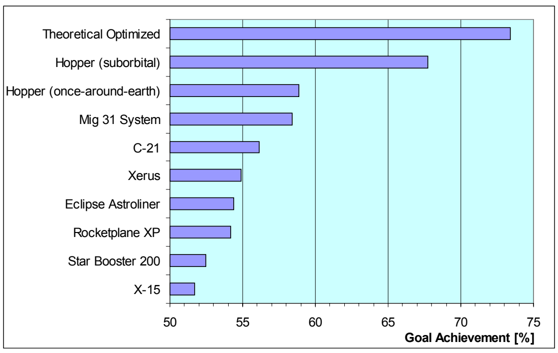

Figure 4: Estimated Total Goal Achievement of Suborbital Vehicle Concepts

Orbital Vehicles

The result of orbital concepts valuated and ranked by the author with respect to the overall goal achievement is shown in Figure 5 after weighing each group. Weighted goal achievements vary from 50 % to 73 % with the Kankoh Maru concept achieving highest score of 65 % beside the theoretically optimized concept. Therefore, Kankoh Maru will be used in a modified version called Kankoh Maru Plus for a scenario presented in section “Model of a Program Scenario”.

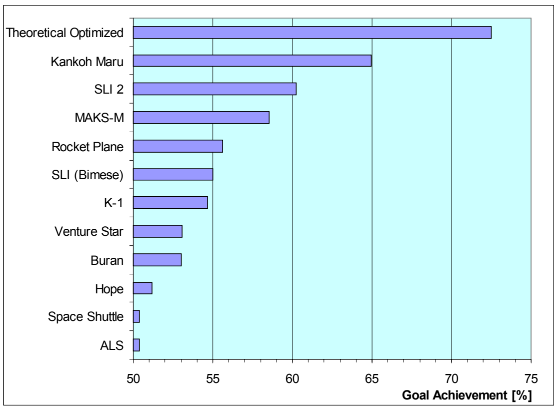

Figure 5: Estimated Total Goal Achievement of Orbital Vehicle Concepts

Model of a Program Scenario

Vehicle Fleet Performance

Table 4, Table 5 and Table 6 summarize the main system, business and market performances of Hopper Plus and Kankoh Maru Plus. Used tools for cost estimation are TRASIM 2.0[2] and TRANSCOST 7.0[3], which are statistical-analytical models for cost estimation and economical optimization of launch vehicles. Using both tools each other for reciprocal verification of results lead to a cost estimation process of high quality. Used tool for financial estimation is FINANCE 1.0[4] to process the results achieved from cost estimation models.

Table 4: System Performance

	Hopper Plus	Kankoh Maru Plus	Unit
Initial Development Activity	2004	2020	year
Initial Operating Capability	2013	2030	year
Fleet Operational Period	29	40	years
Cumulative Flights	2144	42 450	flights
Cumulative Transportation Volume	64 320	2 122 500	pax
Average Yearly Flights	74	1061	flights/year
Average Yearly Transportation Volume	2218	53 063	pax/year
Total Vehicle Production	6	122	-
Total Vehicle Losses	2	37	-
Total Vehicle Withdrawn	1	30	-
Total Vehicle at End of Operation	3	55	-
Total Ground Facility Production	1	16	-

Table 5: Business Performance

	Hopper Plus			Kankoh Maru Plus			Unit
	Enterprise	Fiscal	Total	Enterprise	Fiscal	Total	
Cumulative Receipts	16,2 (before sales tax)	0	16,2	258,1 (before sales tax)	0	258,1	B$
Cumulative 10 % Sales Tax Fee	-1,6	1,6	0	-25,8	25,8	0	B$
Cumulative Interest Credits	0,2	0	0,2	68,3	49,4	117,7	B$
Cumulative Frontend Cost	-0,8	-7,1	-7,9	-5,8	-3,9	-9,7	B$
Cumulative Recurring Cost	-11,2	0	-11,2	-107,1	0	-107,1	B$
Cumulative Financing Cost	-0,8	0	-0,8	-2,0	-2,2	-4,2	B$
Cumulative 25 % Yield Tax Fee	-0,5	0,5	0	-46,4	46,4	0	B$
Cumulative Yield	1,5 (after yield tax)	-5,0	-3,5	139,3 (after yield tax)	115,5	254,8	B$
Break-even Point	15	unattainable	-	8	14	-	years
Average Yearly ROI	4,7	0	-	46,5	56,3	-	%/year

Table 6: Market Performance

	Hopper Plus			Kankoh Maru Plus			Unit
	Enterprise	Fiscal	Total	Enterprise	Fiscal	Total	
Launch Cost (average)	5,6	3,3	8,9	2,7	0,1	2,8	M$
Launch Price (average)	6,8	0,7	7,5	5,5	0,6	6,1	M$
Ticket Cost (average)	0,186	0,110	0,296	0,053	0,002	0,055	M$
Ticket Price (average)	0,226	0,025	0,251	0,110	0,012	0,122	M$
Ticket Price (first year)	0,629	0,070	0,699	0,782	0,087	0,869	M$
Ticket Price (last year)	0,113	0,013	0,126	0,089	0,010	0,099	M$

Comparison with Aircraft

Today's 22 years old Space Shuttle is a first generation, partially RLV. It is primarily used as an orbital scientific platform, for satellite deployment, retrieval and repair. The objectives of the Hopper Plus project are the reduction of operating and manufacturing costs and the enhancement of performance margins. It would be primarily used for space tourism flight demonstration and satellite deployment. Kankoh Maru Plus would introduce an era of space flight, as nearly routine as today's air travel. It should enable new markets in Low Earth Orbit (LEO) and provide multiple platforms for departure to new destinations. It is expected that for the successor generation of Kankoh Maru Plus there is nearly no distinction between a commercial airliner and a commercial launch vehicle and it would enable routine passenger space travel. Table 7 shows possible characteristic parameters of vehicle generations as forecasted by this study compared with today's aircraft data.

Table 7: Possible Future Vehicle Characteristics

	Today	From 2013	From 2030	From 2060	Today
Vehicle Example	Space Shuttle	Hopper Plus	Kankoh Maru Plus	4. Generation	B 747 Aircraft
Destination	LEO	Suborbit	LEO	LEO	Intercontinental
Launch Costs (average)	$20 000/kg	$1900/kg	$500/kg	$20/kg	$2/kg
Catastrophic Failure (max.)	1 in 100 flights	1 in 1 000 flights	1 in 1 000 flights	1 in 100 000 flights	1 in 2 000 000 flights
Passenger Escape	none	yes	yes	not required	not required
Fleet Flights per Year (max.)	6	90	2000	10 000	millions
Turnaround Time	5 months	1-2 weeks	2-10 days	6 hours	1 hour
Reusability	partial	full	full	full	full
Range Safety	flight unique	mission class unique	space traffic control	aerospace traffic control	air traffic control

Benefit Estimation

By comparing other vehicle concepts based on the same model assumptions it is possible to find concepts with a high overall goal achievement, which is crucial for any future strategic space activity. Figure 6 shows an overview of the total group benefits of investigated vehicles. Hopper Plus would reach a total group benefit of 51 % at the beginning of operations, changing to 60 % at the end of operation 29 years later. Kankoh Maru Plus would start with a total group benefit of 52 % growing to 77 % at the end of operations 40 years later. A total group benefit of 100 % would mean a complete goal achievement of all objectives, which cannot be realized due to the fact that a desirable benefit indicator value for one sub objective may be an undesirable benefit indicator value for another one. Therefore, Hopper Plus and Kankoh Maru Plus seem to be suitable candidate systems for the investigated scenario.

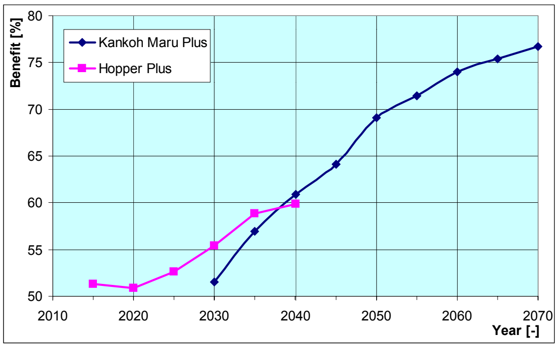

Figure 6: Overview of Benefit for Hopper Plus and Kankoh Maru Plus

More research is needed to understand the dynamics of the space tourism market. To bridge the gap between supply, demand and regulatory issues will be the challenge for coming decades. One approach might be the systematic use of benefit models for decisions like “When operate a RLV?”, “Why operate a RLV?” and “What kind of RLV to operate?”. The benefit of reusable launchers could be changing with time differently for passengers, operators and the public. Additionally, benefits might be also change with vehicle concepts. This leads to the assumption that an optimum timing for the introduction of a suborbital vehicle fleet as well as an orbital vehicle fleet is rewarded with a high benefit for all interest groups.

Hurdles and Opposing Forces

General

Spaceflight has intrigued the popular consciousness since before mankind even knew of its possibilities. As evidenced by government programs, it is technically feasible to send humans into space for extended periods and return them to Earth. An assessment of current market potential and available technologies enables some conclusions to be drawn: today, there are many experiences that are available to help the space tourism business in near-term, including parabolic flights, high-altitude flights and flights to the International Space Station. Nevertheless, there are barriers to suborbital and orbital flights for mass space tourism employing reusable rockets, which can be viewed separately from passenger, operator/investor and public/government side.

Passenger

The passenger desires a similar reliability and safety standard for space transportation vehicles as for modern aircraft. Additionally, in history, travel in space has been only available to a small number of highly trained government astronauts with some exceptions and the public’s perception is that it cannot be otherwise.

Operator

While some space ventures already built their reputation on promising revolutionary cost reductions for access to space, the acceptance of potential investors is low. As long as revolutionary launchers have not got off the ground, such claims are lacking proof. If this situation remains, analysts have to rely on the cost data history of previously flown launchers. But those historical launchers are based on the philosophy: “Highest performance at whatever the cost”. Technology merit was all what counted and economic performance was secondary because projects were government funded.

Public

Governments, seeking the goal of zero risk, might attempt to impose partly unreasonable standards on space tourism vehicles and operations. For instance, the reliability of equipment needs high standards but if the level of training demanded is as rigorous as that currently provided to government astronaut candidates, it would scare off most of potential space tourists due to high cost, high terms of mental health and loss of time.

Comparison with other Studies

General

Many authors have investigated business cases for suborbital and orbital vehicles. Due to very different assumptions in these studies, an exact comparison seems to be impossible. However, a rough comparison is tried in order to enlarge the basis of discussion for suborbital vehicles and orbital vehicles. Cost values are adjusted for inflation to the fiscal year 2000 (1 MY is equivalent to $208 000). It should be kept in mind, that the results of investigated vehicles, namely Hopper Plus and Kankoh Maru Plus, are modeled under the assumption of an oligopoly market structure, while the vehicles used for comparison are modeled under the assumption of a monopoly market structure.

Suborbital Vehicles

Some key values of selected studies, which have been performed in detail by J. Olds et al., W. Inden and W.A. Gaubatz, are presented in Table 8 and shortly discussed below. Most of papers of suborbital vehicles are not detailed enough to generate all figures for a comparison with the present study. Nevertheless, they are cited for the mentioned aim of the enlargement of the basis of discussion.

Table 8: Suborbital Flights

	Unit	Olds et al. 2000	Inden 2001	Gaubatz 2002	Goehlich 2003
Vehicle	-	(Cosmos Mariner)	MiG-31 System	ClipperStormer	Hopper Plus
Passenger Capacity	pax	10	2	4	30
Initial Operating Capability	year	n.a.	2008	n.a.	2013
Fleet Operational Period	years	n.a.	10	5	29
Average Total Ticket Cost (range: first year-last year)	M$	n.a.	n.a.	n.a.	0,296 (0,392-0,139)
Average Total Ticket Price (range: first year-last year)	M$	(0,800)	0,100	n.a. (0,100-n.a.)	0,251 (0,699-0,126)
Cumulative Transportation Volume	pax	n.a.	n.a.	250 000	64 320
Average Yearly Transportation Volume	pax/year	n.a.	n.a.	50 000 (80-n.a.)	2218 (360-2700)
Average Yearly Flights (range: first year-last year)	flights/year	n.a.	n.a.	12 500 (20-n.a.)	74 (12-90)
Special Feature	-	Detailed stochastic model	Investigation in a very low-investment business case	Detailed sensitivity analysis	Investigation in oligopoly market with suborbital and orbital flights

J. Olds et al. investigated in a published paper the driving economic factors and launch vehicle characteristics that affect businesses entering the space tourism industry. A stochastic simulation model, called LMNOP, has been used to perform a life-cycle cost analyses on a single-stage vehicle concept, a derivative of the Cosmos Mariner vehicle concept, capable to transport ten passengers to a suborbital altitude.[5]
The study results show that the optimum ticket price concerning Net Present Value (NPV) would be in a range from $500 000 to $900 000 taking into account the number of passengers, expanding market size, vehicle life-time, number of launch sites and other variables. A positive NPV of about $100 million might be achieved for this spectrum of price variation. The author disagrees with this result, because NPV is assumed to be much more sensitive to ticket price strategy.

A published paper by W. Inden elaborates a business case for a very small two-stage vehicle concept with two passenger seats. It is based on a Russian concept using a MiG-31 carrier aircraft and an ARS rocket glider. The carrier aircraft already exists, while the rocket glider would need to be developed.[6]

The author agrees with Inden's study remark that this project would represent a credible test case for market verification. However, the disadvantage of such a small system would be that it might not be adapted for mass space tourism flights because it would be limited in transportation volume resulting in a limitation in the potential of offering low ticket prices. Therefore, it seems to be advisable to operate a completely new suborbital vehicle such as Hopper Plus concept, even if initial investments and ticket prices in the first years might be much higher than for a small partially new developed vehicle such as MiG-31 system concept.

W.A. Gaubatz published a paper investigating a business case of a small single-stage vehicle concept called ClipperStormer capable of transporting four passengers. Impacts of factors effecting markets, revenues, changes in operational resources, vehicle costs and lifetime are evaluated by using the business design tool "SpaceBIZSIZE".[7]

The author agrees with Gaubatz's study results that a suborbital space tourism business might be a starting point for a viable space tourism industry, that uncertainties in regulatory requirements could result in longer times for first revenue flights, and that major impacts on business performance could come from vehicle flight rates, first unit costs and vehicle reuses. The author disagrees with the claim that profits generated could be used for developing an orbital space tourism business. As shown in the present study, the benefit for orbital vehicles from suborbital vehicles is the gain in experience and proof of necessary technology rather than an investment.

Orbital Vehicles

Some key values of selected studies, which have been performed in detail by S. Abitzsch, H.H. Koelle and J.P. Penn/ C.A. Lindley, are presented in Table 9 and shortly discussed below.

Table 9: Orbital Flights

	Unit	Abitzsch 1998	H.H. Koelle 2002	Penn/Lindley 2003	Goehlich 2003
Vehicle	-	Kankoh Maru	Kankoh Maru	Spaceliner (TSTO)	Kankoh Maru Plus
Passenger Capacity	pax	50	50	100	50
Initial Operating Capability	year	2015	2020	2006	2030
Fleet Operational Period	years	50	50	16	40
Average Total Ticket Cost (range: first year-last year)	M$	0,047 (0,161-0,035)	0,044 (0,144-0,029)	0,010	0,055 (0,171-0,037)
Average Total Ticket Price (range: first year-last year)	M$	0,071 (0,260-0,062)	0,094 (0,192-0,038)	0,078 (n.a.-0,016)	0,122 (0,869-0,099)
Cumulative Transportation Volume	pax	3 221 250	2 522 500	2 400 000	2 122 500
Average Yearly Transportation Volume (range: first year-last year)	pax/year	64 425 (1250-100 000)	50 450 (2500-70 000)	150 000 (n.a.-750 000)	53 063 (1250-100 000)
Average Yearly Flights (range: first year-last year)	flights/year	1289 (25-2003)	1009 (50-1400)	1500	1061 (25-2000)
Special Feature	-	Detailed market demand model and 3 scenarios	Business case for achieving high profits	Investigation in various flight rates	Oligopoly market with suborbital and orbital flights

S. Abitzsch developed in his dissertation three space tour scenarios for Kankoh Maru. An important result of this analyses is that even at low transportation volumes (worst-case scenario) an economically viable space tourism scenario could be established.[8] The reference scenario is shown in the table. He also discussed the use of Kankoh Maru as a transportation system for a space hotel, lunar roundtrips and Earth-to-Earth flights.

The average ticket price of $71 000 in Abitzsch's study would be relatively low compared with $122 000 in the author's study. The reason for this are two different assumptions: Firstly, Abitzsch's study assumed a higher yearly transportation volume, thus ticket prices have to be lower than in the author's study to generate a higher necessary demand. Secondly, the author used the effect of a skimming-price strategy. This allows relatively high ticket prices in particular in the first years of operation, which can be understood when regarding the ticket price-passenger demand trend curve of Figure 3.

A published paper by H.H. Koelle compiled relevant methods to structure and support a process that may be leading to space tourism within the next two decades. The study investigated an attractive business case for the Kankoh Maru concept by achieving high profits and a short payback period for enterprise and fiscal. It has been demonstrated that an investment of $7,5 billion could lead to an average Return on Investment (ROI) of 30 %/year for private investors and of 48 %/year for public investors with a positive cash-flow after only 7 years of operation.[9]

One reason is the assumed aggressive increase in annual vehicle fleet flights in the first years of operation. After eight years of operation, 700 flights per year are assumed in Koelle's study, while only 150 flights per year are assumed in this present study. To determine the optimum fleet architecture over time in terms of profit and risk is a challenging task at this level of knowledge about RLVs and need to be discussed in future research.

Recently, J.P. Penn and C.A. Lindley published a paper on an investigation in a Two-Stage-To-Orbit spaceplane concept for very high flight rates of up to 0,8 million flights per year. Subsystems allocations for reliability, operability and costs were made. The vehicle's ability to satisfy the traditional space market as well as space tourism missions and Earth-to-Earth transportation is shown. Also discussed is one imaginary vehicle "expendable B 747", an airliner operated like an ELV, which shows excessive transportation cost.[10]

The author agrees with this study in many respects that passenger RLVs should be operated with a satellite and upper stage in the cargo bay in the very early flights and that charging premium ticket prices for the earliest customers would be advisable to increase profit. To accomplish very low launch costs, it is assumed for this study that the operations concepts have to be made an integral part of the vehicle design, that a very high vehicle lifetime of 3600 flights would be performed, and that a very low catastrophic failure rate of 0,0001 could be achieved. The author cannot confirm such optimistic prospects from results gained in the present study.

Conclusion

On the basis of technical, economic and political investigation, a space tourism business for space flights appears to be feasible in the future, but some relevant facts must be taken into account: a start-up market environment with high profits after a few years as realized in the IT sector is an illusion for the space tourism sector. The space tourism sector is assumed to grow slowly and will in one way or another require government support. The reasons are mainly long development periods for new reusable launch systems (around 10 years), high development cost (between $5 to $15 billion) and relatively late break-even points for positive cash flow (between 5 to 15 years).

A program model is presented and verified in this study to incorporate these facts, which consists of following three steps as shown in Figure 7: 1. Increasing space awareness in the general public (from today to year 2030). 2. Developing and operating a suborbital vehicle fleet for semi-regular flights (development: 2004 to 2013, operation: 2013 to 2042). 3. Developing and operating an orbital vehicle fleet for regular flights (development: 2020 to 2030, operation: 2030 to 2070). Other approaches for developing space tourism such as using a modified Space Shuttle successor vehicle for tourists might be promising too but are not further discussed in this study.

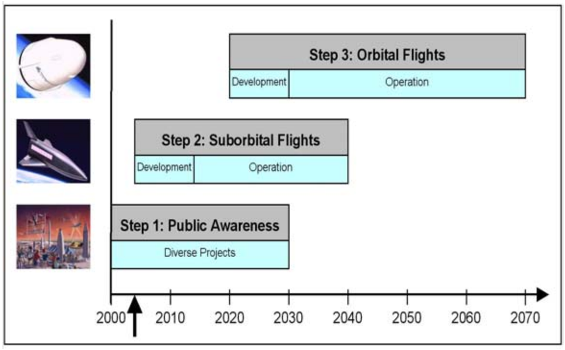

Figure 7: Proposed Life-cycle Scenario for Mass Space Tourism

List of Abbreviations

B$	[-]	Billion US dollars
FY	[-]	Fiscal Year
ISS	[-]	International Space Station
LEO	[-]	Low Earth Orbit
MY	[-]	Man Year
M$	[-]	Million US dollars
NPV	[-]	Net Present Value
pax	[-]	Passenger
RLV	[-]	Reusable Launch Vehicle
ROI	[-]	Return on Investment

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