The Emerging Orbital Space Tourism Industry: New Insight into Demand and Prospects for Success

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The orbital space tourism industry is beginning to gain traction with significant progress made by leading companies such as Space Adventures, Virgin Galactic, Rocketplane-Kistler, Space Exploration Systems (SpaceX), and Bigelow Aerospace. A host of other organizations are seeking to contribute to this future of spaceports, space trips, and space training. However, with a limited number of tourists to date, the orbital space tourism industry is still very much in its embryonic stage, and there is a great deal of uncertainty about the size, composition, and viability of the market. SpaceWorks Engineering, Inc. (SEI) investigated two Low Earth Orbit (LEO) space tourism case studies, space tourism without an orbital hotel destination and space tourism with an orbital hotel destination. An online internet survey of select experts and the general public and a spreadsheet based economic simulation of supply and demand were conducted. The survey posed both qualitative and quantitative questions in an effort to contribute to the current knowledge about demand for orbital tourism. Unique by comparison to surveys of the past, this survey also sought to quantify the uncertainty surrounding this market. Survey participants were asked a series of general questions about orbital space tourism, followed by questions about the expected number of potential customers at price points of $10, $15, and $20 million. Participants were also asked about the degree of certainty they had in their estimates. Modeling and simulation considered both the demand and supply aspects of space tourism to determine the market conditions and price points necessary for an orbital space tourism vehicle operator to be financially successful. The model is unique in that it considers the business case for orbital space tourism, not just a forecast of demand. Both a deterministic and a probabilistic analysis were completed to account for uncertainty in factors such as costs of the orbital space tourism company and growth rate of the market. The results demonstrate that orbital space tourism companies can be successful, measured in terms of net present value (NPV), with a price per passenger in the $12 to $20 million range (FY 2006).

Nomenclature

ABM = Agent-Based Modeling
CABAM = Cost and Business Analysis Module
DDT&E = Design, Development, Testing, and Evaluation
ISS = International Space Station
LCC = Life Cycle Cost
LEO = Low Earth Orbit
LMNOP = Launch Market for Normal Ordinary People
NASA = National Aeronautics and Space Administration
NESC = Nodal Economic Space Commerce tool
NPV = Net Present Value
ROI = Return on Investment
SEI = SpaceWorks Engineering, Inc.
TFU = Theoretical First Unit
VSE = Vision for Space Exploration

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I. Introduction

The space tourism industry continues to progress, driven by the innovation and ambition of entrepreneurs along with investment by private individuals, institutions, and state governments. Furthermore, the Vision for Space Exploration establishes the encouragement of commercial participation as a top-level objective for the National Aeronautics and Space Administration. Many believe space tourism is the primary catalyst for less expensive and more frequent access to space, however, there is much uncertainty surrounding this future market. As with the introduction of any revolutionary product or service, the size of the market in terms of potential customers, the price elasticity, and the factors that influence the purchasing behaviors of potential customers are not completely understood. A company choosing to enter this industry not only faces these demand uncertainties, but also uncertainty surrounding its internal costs, the cost of capital financing, and the forces of competition. In order to appropriately study the future of the space tourism industry, both the supply and demand factors must be taken into consideration.

An investigation of the interaction between supply and demand in the future space tourism industry was conducted by SpaceWorks Engineering, Inc. (SEI) consisting of a survey of select experts and the general public, along with modeling and simulation of the market. Two case studies, or sub-markets, relevant to space tourism specifically were examined. The two case studies were selected based on their credibility as potential, new emerging products and services given commercial activities to date. The case studies and brief support for their selection are:

1. Orbital Tourism:
   This case study involves orbital tourism to Low Earth Orbit (LEO) where passengers orbit the Earth within the spacecraft. Companies such as t/Space and Rocketplane-Kistler envision using their vehicles to support NASA exploration related activities and for orbital tourism.

2. Orbital Tourism with a Destination (Orbital Hotel):
   Space tourism in LEO may include a visit to a destination such as the ISS or a commercially operated space hotel. The company Space Adventures has brokered trips to the ISS for Dennis Tito, Mark Shuttleworth, and Gregory Olsen. The business plan of Bigelow Aerospace involves inflatable modules in LEO. Their goal is to use this platform for tourism and industrial commercial customers.

Modeling and simulation of the space tourism market was accomplished through spreadsheet-based models incorporating data from the survey research and other public resources. The models explore the business case for each of the case studies by simulating the interaction between a fictional but realistic company and realistic demand. The models include product/service costs, market demand estimates, and financing models. The analysis was conducted both deterministically and probabilistically. For example, uncertainty distributions were placed on cost and market demand to yield certainty levels for various output metrics of interest, including Net Present Value (NPV).

Results of both the survey and modeling efforts advance the current level of knowledge about the space tourism industry. The survey data collected by SEI is another data point that helps to define the demand for orbital tourism and the shift in this demand when an orbital destination is offered. Data was also collected concerning the level of confidence people have in estimating this future market. Additional questions targeted issues such as the degree of safety necessary to attract customers and the geographical origins of potential customers. Results of the modeling effort shows the conditions under which a company participating in this market can be successful. Various price points and market risk premiums were considered. A probabilistic analysis allowed for consideration of uncertainty with distributions on cost and other factors. The resulting probability distributions and 90 percent confidence levels give a realistic assessment of the orbital tourism market a representative company in that market.

The activities described herein also provide additional information that will be leveraged in an ongoing effort at SEI to model emerging space markets using agent-based modeling (ABM) techniques as developed in the Nodal Economic Space Commerce (NESC) tool. The suborbital space tourism market and the crew and cargo transportation services for the International Space Station (ISS) market have already been modeled and analyzed by SEI within NESC. The NESC tool utilizes the concept of agent-based modeling, wherein different entities are modeled as “agents”, each with their own characteristics and behaviors. For example, company agents attempt to maximize their profits by offering products to discriminating customer agents. Government agents regulate the marketplace, and may also offer incentives to stimulate the industry or even serve as a customer. This ABM activity provides outputs of use to commercial companies in evaluating different business strategies, and to the government.
in terms of the strength of the industrial economy and potential cost savings. This type of modeling is of higher fidelity than spreadsheet-based modeling and is able to capture unexpected emergent market phenomena that occur as a result of the complex interaction between agents. For more information about ABM efforts at SEI, please see the AIAA papers “Simulating the Dynamic Marketplace: An Introduction to the Nodal Economic Space Commerce (NESC) Model,” “Agent-Based Economic Modeling of Commercial Transportation Services to the International Space Station,” and other related technical papers available in the SEI online library at www.sei.aero.

II. Background

Dennis Tito opened the eyes of world to the idea of orbital space tourism when he became the first private space traveler in 2001. Three years later, the Burt Rutan and Paul Allen led team of Mojave Aerospace Ventures won the Ansari X-Prize by successfully completing two piloted sub-orbital flights of a reusable vehicle to 100 kilometers in altitude within a span of two weeks. This accomplishment demonstrated to the public and government managers the potential for entrepreneurial commercial activities to change the landscape of the space industry. The Vision for Space Exploration (VSE) was announced in the same year, calling for replacement of the Space Shuttle and subsequent human missions to the Moon by the year 2020.

The last stated objective of the National Vision for Space Exploration is interesting in its prominence, a top-level policy directive wherein NASA is tasked to seriously consider commercial involvement in space exploration. A recent proponent of this thesis was the President’s Commission on Implementation of United States Space Exploration Policy, formed to examine the VSE itself. This commission stressed the imperative of commercial involvement as shown in their following recommendation:

“NASA’s relationship to the private sector, its organizational structure, business culture, and management processes – all largely inherited from the Apollo era – must be decisively transformed to implement the new, multi-decadal space exploration vision. The Commission recommends: NASA recognize and implement a far larger presence of private industry in space operations with the specific goal of allowing private industry to assume the primary role of providing services to NASA, and most immediately in accessing low-Earth orbit. In NASA decisions, the preferred choice for operational activities must be competitively awarded contracts with private and non-profit organizations and NASA’s role must be limited to only those areas where there is irrefutable demonstration that only government can perform the proposed activity.”

With low cost access to space as the ultimate enabler for both orbital space tourism and the government’s exploration plans, there is commonality between the objectives of emerging commercial companies and the government. Indeed, many of the companies pursuing the orbital space tourism market are concurrently seeking to offer variants of their products to the government and other commercial customers. There may be potential for the government to leverage current and future commercial developments as well as for commercial industry to benefit from government investment. Within this context, there are multiple activities underway within the emerging commercial space industry:

- Space Adventures has sent paying customers to the International Space Station (ISS) and has proposed in conjunction with Constellation Services International using a modified Soyuz vehicle with a new propulsion stage for a round trip flight to the moon with one crew and two paying passengers for an individual ticket price of $100M per passenger.
- Space Exploration Technologies (SpaceX) is developing new cargo launch vehicles with ambitions for crew launch capability and potentially passenger delivery to LEO. This has included two new engine developments and three new facility developments for under $100M.
- Bigelow Aerospace is developing inflatable habitats based upon modified NASA TransHab technology. The company recently successfully launched Genesis I, a smaller version of their habitats, and is planning at least one additional sub-scale demonstration launch in early 2007. Mr. Bigelow himself has instituted a $50 million prize for companies that can demonstrate delivery to his module by 2010.
- Transformational Space Corporation (t/Space) plans to develop a crew exploration vehicle that would be compatible for NASA’s crew servicing needs and also be able serve the orbital space tourism market. T/Space has successfully completed full-scale drop tests of their capsule concept and is working with partners to attain the capability to launch their vehicle from an airplane.
- In order to serve the sub-orbital space tourism market, Virgin Galactic, in combination with Scaled Composites, is developing a larger follow-on vehicle to the Ansari X-Prize winning SpaceShipOne design. This is in addition to other companies who are developing their own concepts for this market, namely Rocketplane-Kistler, Blue Origin, Xcor Aerospace, and Armadillo Aerospace. Virgin Galactic
and many of these companies have expressed plans to additionally compete in the orbital space tourism market, either with second generation vehicles built upon the suborbital craft or a new vehicle design.

The results of research and modeling by the authors are of use to both commercial companies and the government. Commercial companies gain better insight into the demand for their products and the degree of uncertainty associated with this demand. Commercial companies also gain target prices at which this market can be viable. Depending on the business plan of the company, management may gain a basic justification for their business case, or reason to re-evaluate cost versus benefit. This modeling effort also gives the government better justifications for their investments in emerging commercial space industries. Such investments can stimulate the market with returns that benefit the economy as a whole.

III. Space Tourism Survey

A survey addressing orbital space tourism was administered by SpaceWorks Engineering, Inc. in an effort to contribute additional information to existing data about these emerging markets. The aim of the surveys was to better understand the orbital space tourism market, and quantify the uncertainty surrounding it.

A. Survey Composition and Administration

The survey was administered to two subsets of participants. The first subset consisted of experts in the topic of orbital space tourism, while the second subset consisted of the general public. The internet survey hosting site SurveyMonkey.com was used to administer the surveys. Experts were contacted via email and invited to participate in the online surveys via SurveyMonkey. The general public was notified of the public surveys through a variety of electronic communications designed to particularly target those with an interest in space exploration and development. A link to the survey was posted on the SpaceWorks Engineering website www.sei.aero. Invitations to visit the survey were then posted on forums at spacefellowship.com, nasaspaceflight.com, and the live journal space exploration and astronomy communities at livejournal.com. An unsolicited link appeared on hobbyspace.com. An invitation was also sent to members of the NASA Academy Alumni Association and to subscribers of the National Mars Society email newsletter managed by the Mars Society of San Diego. Finally, emails were sent to the Mars Society, Astronomy Club, and the American Institute of Aeronautics and Astronautics chapter at the Georgia Institute of Technology.

The orbital space tourism survey consisted of an initial set of questions aimed at assessing general aspects of the market such as the nations where tourists will come from, how many companies will participate in the market, and the adoption rate of customers. Following the general questions, survey participants were asked to provide their estimate of the size and price elasticity of two sub-markets. The sub-markets were orbital space tourism without a space hotel destination and orbital space tourism with an orbital space hotel destination. For each of these sub-markets, participants were asked how many potential customers per year exist at the price points of $5 million, $10 million, and $20 million. Participants were also asked about the level of confidence in their answer with three possible choices as their response: within plus or minus 100 percent, within plus or minus 50 percent, or within plus or minus 10 percent. Figure 1 shows screenshots of portions of the survey hosted by SurveyMonkey.
The survey was generally well received according to feedback left by participants in a final question allotted for that purpose. There were six responses to the space tourism survey by invited experts and 99 total responses by the general public. While the low number of responses is not sufficient to make this survey statistically valid, the insight into the market is nevertheless valuable. The responses to each question were evaluated for completeness and rejected from the data set in cases where the question was not answered or was answered obscurely. Table 1 summarizes the administration of the surveys.

In some cases it was possible to determine the location from which the response originated by inspection of the respondent’s Internet Protocol (IP) address. For the public space tourism survey, at least 19 responses originated from a foreign nation including Great Britain, Canada, the Netherlands, Sweden, Finland, Germany, and New Zealand. Other identifiable IP address origins include NASA, several aerospace industry companies, and several American universities.

### Table 1. Surveys Conducted and Number of Responses

<table>
<thead>
<tr>
<th>Survey</th>
<th>Type of Respondents</th>
<th>Date Opened</th>
<th>Date Closed</th>
<th>Number of Responses</th>
</tr>
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<tr>
<td>Orbital Space Tourism</td>
<td>Experts</td>
<td>March 15, 2006</td>
<td>May 6, 2006</td>
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<tr>
<td>Orbital Space Tourism</td>
<td>Public</td>
<td>March 27, 2006</td>
<td>May 6, 2006</td>
<td>99</td>
</tr>
</tbody>
</table>

B. Survey General Results

There was general agreement between the surveyed public and the experts as to the percentage of space tourists that would reside in the United States. Among public survey takers, 41.4% selected “50%” of tourists as their answer. Three of the six surveyed experts also thought that “50%” of space tourists would reside in the US.
The second question of the orbital space tourism survey asked respondents what three countries, other than the United States, have the largest demand for space tourism. The top five answers given are shown in Table 2 below. The experts and the public both agreed that Japan and Great Britain have the first and second largest demand for space tourism. China also appears on both top five lists, albeit at different rankings.

### Table 2. Country Ranking Outputs from Survey: Tourism

<table>
<thead>
<tr>
<th>Country Rank</th>
<th>Expert Opinion</th>
<th>Public Opinion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Japan</td>
<td>Japan</td>
</tr>
<tr>
<td>2</td>
<td>Great Britain</td>
<td>Great Britain</td>
</tr>
<tr>
<td>3</td>
<td>China</td>
<td>Russia</td>
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<tr>
<td>4</td>
<td>India</td>
<td>Germany</td>
</tr>
<tr>
<td>5</td>
<td>Korea</td>
<td>China</td>
</tr>
</tbody>
</table>

Participating in an orbital space tourism experience will involve a certain degree of risk, and has been likened by some to adventure travel. In terms of the safety level required for a company to attract orbital tourism customers, just over 53% of public respondents thought orbital space tourism needs to be safe as a military fighter. Three of the six experts agreed.

![Figure 2. Domestic (US) Space Tourism Results.](image)

The second question of the orbital space tourism survey asked respondents what three countries, other than the United States, have the largest demand for space tourism. The top five answers given are shown in Table 2 below. The experts and the public both agreed that Japan and Great Britain have the first and second largest demand for space tourism. China also appears on both top five lists, albeit at different rankings.

![Figure 3. Safety Required for Space Tourism Vehicles.](image)
The rate at which customers adopt new products once introduced to the market has historically varied from product to product. Some products are immediately widely purchased by a large subset of customers while others do not garner a high volume of sales initially but are adopted by a large number of customers over time. When asked about the adoption rate for the orbital space tourism market, the majority of public survey participants indicated a fast adoption rate with a limited total market size. The next most popular answer with the public was slow adoption with a limited market. The Expert survey participants were split between the same two categories. Two of the six experts indicated fast adoption with a limited market, while two indicated slow adoption with a limited market. The common element of all of the most popular responses was a limited market. The results of the public survey for the topic of adoption rate can be seen in Figure 4.

![Figure 4. Product Adoption by Space Tourism Customers.](image)

For the orbital space hotel sub-market, survey participants were asked how soon orbital space hotels will host the first paying customer. Of the four experts who answered the question, all four thought that the first tourist to visit an orbital space hotel will do so in 10 to 15 years. Roughly one third of the public survey respondents gave the same answer. Figure 5 graphically depicts the public’s opinions about when these events will first occur.

![Figure 5. Date for First Orbital Space Hotel.](image)

Survey participants were polled about the composition of companies that will offer services in the orbital space tourism market. Most respondents believe two or more such companies will exist in the 2006 to 2015 timeframe. Three of the experts predict two companies, while a combined 66 public survey takers predicted either two or three companies. Figure 6 shows the complete results of this question. In addition to the number of companies, participants were asked about the frequency at which an orbital space tourism company will change its prices. With
regard to this question, 41% of the public believe companies will adjust every year, while 37% believe prices will change every 6 months. Three of the experts believe price adjustments will occur every year, while the remaining two believe these will occur every 6 months.

It is likely that orbital space tourism companies will seek revenue streams beyond those of their core product offering space flights. The market has already seen a preview of this with the recent unveiling of Bigelow Aerospace’s “Fly Your Stuff” campaign in which customers can pay to send small items to space aboard an inflatable module and then view pictures of their items via the internet. Masten Space plans a similar campaign while the company Race 2 Space is currently selling advertising space on the side of a rocket. Survey participants were asked what percentage of revenue space tourism companies will generate from offering space flights versus other sources. The results of this question are shown in Figure 7. There is general agreement between the public and the experts that companies will make approximately 50 percent or more of their revenue from space flights.

A picture of the orbital space tourism market can be created by summarizing the most widely held opinions from the general questions of the survey. In this futuristic portrayal of the market, 50 percent of the customers are United States residents, with the majority of other customers residing in Japan or Great Britain. These customers are willing to accept that space flight is not as safe as a commercial airliner, and desire a level of safety for a space tourism vehicle equivalent to that of a military airplane. The broad appeal for orbital space tourism is expected to be
limited perhaps due to high price or lack of interest in adventure activities, and the market may saturate quickly with a rapid adoption rate. Customers will have the option of visiting space hotels as part of their orbital tourism excursion in 10 to 15 years from today. The survey responses also predict a vibrant and dynamic market. Companies will offer a significant amount of additional products with about half of their revenue coming from sources other than space tourism flights trips. There will be at least two of these companies, and they will change their prices every 6 months to a year, perhaps in response to competition or in an attempt to expand the market by making it affordable to a greater number of people.

C. Survey Demand Results

The size of the space tourism market at various price points as predicted by the survey participants was analyzed both as discrete point values and as a probability distribution. Each survey respondent provided an estimate of the number of potential customers for orbital space tourism at a $5 million, $10 million, and $20 million price along with their confidence in this estimate. The point values of the respondents’ estimates, grouped into ranges of 1 to 10 potential customers, 11 to 49 potential customers, 50 to 100 potential customers, and 101 to 1000 potential customers, are shown in Figures 8 through 10.

![Figure 8. Size of the Space Tourism Market at $5 Million Price According to Survey Responses.](image)

![Figure 9. Size of the Space Tourism Market at $10 Million Price According to Survey Responses.](image)
As expected, in both the case of orbital tourism with and without a space hotel destination survey participants indicated a decrease in demand as price increases. There is an increase in demand across the two cases, from the orbital space tourism sub-market to the space hotel sub-market. This suggests that survey participants believe customers will be more likely to participate if a destination is available. Indeed, many survey participants directly commented that a space hotel would attract more customers than orbital tourism alone.

In addition to the point value analysis of respondents’ estimates, a distribution for each individual estimate was created by assuming the confidence levels selected by the respondents are representative of a standard distribution and within 3 standard deviations of the mean. For example, if a participant indicated 30 potential customers at a price of $10 million with a confidence of plus or minus 50%, then 30 was taken as the mean, 45 as plus 3 standard deviations from the mean, and 15 as minus three standard deviations from the mean. These individual distributions were then averaged to obtain an overall distribution for orbital tourism demand. Figure 11 illustrates this process and the resulting aggregate distribution.

An aggregate distribution was obtained for the price points of $5 million, $10 million, and $20 million for each market. The following figures show these results (Figures 12 through 13).
The reduction in number of customers as price increases is apparent again from this presentation of results with confidence levels. It is interesting that the survey respondents had a greater level of confidence in their estimates at the higher price point for each of the three sub-markets. This may be due to reports that space tourists Dennis Tito, Mark Shuttleworth, and Gregory Olsen paid around $20 million for their trips to the International Space Station aboard a Russian Soyuz. From the standard deviations of the distributions, it is also evident that survey participants had a greater amount of confidence in their estimates for the orbital space tourism without a destination case as compared to the space tourism with a destination case.

IV. Market Modeling

The overall goal of this activity was to develop more insight into the demand and supply interaction of the future orbital space tourism market. The process involved development of market demand models from existing data and from the SEI surveys of experts and the public. The second step was to model the financial case of fictional companies to determine the impact on Net Present Value, a financial indicator of whether a project should be initiated. After development of market demand curves and definition of a representative company, financial models were run both deterministically and probabilistically.
A. Modeling Environment

A spreadsheet-based model was used to simulate the future business case for companies engaged in serving the orbital space tourism market. The model contains sections for the cost structure of the program, the actual space tourism market models (elasticities of demand), per year flight calculators, debt financing calculators, equity financing calculators, balance sheet calculations, and overall financial metric calculations including Life Cycle Cost (LCC), Return on Investment (ROI), and Net Present Value.

The user inputs into the model the overall program assumptions (program start year, number of years for development, etc.), cost structure, capital structure, and price (an independent variable for this analysis). The specific cost structure of the company includes Design, Development, Testing, and Evaluation (DDT&E) costs, Theoretical First Unit (TFU) costs, operations costs, etc. The input price is used in combination with the market elasticity curves to obtain the number of passengers per year obtained for the price. In the current model, there is assumed to be no competition and thus at any price the company being modeled captures the entire market.

The output number of passengers per year is used to determine the flight rate and subsequent operations costs per year. The user can define a market growth rate which then increases the baseline captured market on an annual basis. The overall flight program in the model continues until a predetermined program termination date. A balance sheet is then used to determine a discounted cash flow.

The economic model used for this analysis is based upon the Cost and Business Analysis Module (CABAM) and the Launch Marketing for Normal Ordinary People (LMNOP) model, both developed at the Space Systems Design Laboratory at the Georgia Institute of Technology School of Aerospace Engineering and refined at SpaceWorks Engineering, Inc.4,5,6

B. Modeling Demand

Any economic model requires an accurate assessment of demand in order to obtain meaningful results. The most recent publicly available data was used in conjunction with data obtained from SEI’s survey of experts and the general public to develop demand curves. The development of these curves is explained in greater detail in the following sections.

Three categories of data are used in modeling demand for space tourism in the spreadsheet based market model. The first category utilizes available information about the number and composition of wealthy individuals around the world, together with survey information about the preferences of such individuals towards orbital tourism, from a study conducted by the Futron Corporation. The second category uses data from the responses of experts to the space tourism market survey conducted by SpaceWorks Engineering. The third category relies on data collected from responses by the general public to the SEI space tourism market study. These categories are then combined in the form of a weighted average to create an aggregate picture of demand within each sub-market.

Demand at various price points for the first data category is determined using a top down approach, whereby an initial large number of wealthy individuals is reduced to a smaller set of potential customers by applying percentages for factors such as health, interest in orbital tourism, willingness to pay, and so on. This approach is similar to that taken by the Futron Corporation in the 2002 Space Tourism Market Study and relies heavily on information from that study.7 Futron contracted with Zogby International to survey 450 individuals with annual incomes of at least $250,000 or a net worth of at least $1 million. The Futron study provides the best available profiles of those most likely to pay for a space tourism experience because only wealthy individuals were surveyed, and because of questions targeted at ascertaining the characteristics of customers in this market. Information on the number of wealthy individuals in the world was gleaned from two primary sources. The World Wealth Report, compiled yearly by Cap Gemini and Merrill Lynch, provides information on the number of millionaires in the United States and internationally.8,9,10 The report also provides some information on “Ultra High Net Worth Individuals,” or those with net worth greater than $30 million. For information on those in the uppermost echelon of wealth, the Forbes annual list of “The World’s Billionaires” is the best resource.11

Calculation of the number of potential customers that will purchase a space tourism experience in any given year begins with a base population of wealthy individuals and reduces that population based on interest, physical fitness, affordability, and willingness to pay. The base population for a given year is determined by applying a growth rate to the number of Ultra-High Net Worth Individuals in 2005. This growth rate can be set by the user in the spreadsheet. The percent of people interested in participating in an orbital tourism experience, and the percent of people who are physically fit enough to do so, are then multiplied by the base population. Affordability is assessed by calculating the minimum amount of net worth an individual must have in order to afford the ticket price. Within the spreadsheet, the user can select the percentage of net worth that the wealthy individuals would be willing to spend. For example, if the user selects a minimum expenditure level equal to 10% of net worth, then at a price point...
of $20 million, individuals must have a net worth of at least $200 million. The number of individuals that have the requisite net worth is then determined from a curve fit of World Wealth Report Ultra-High Net Worth Individual and Forbes Billionaires List data. Finally, the number of potential customers is further reduced by a “willingness to pay” percentage derived from the Futron market study.

Combination of the three categories of demand is accomplished in a manner similar to that described elsewhere in this report. Each of the three data categories has a mean and standard deviation which is combined by weighted average. The user of the spreadsheet model can input a weighting for each of the data categories. A higher weight for the expert survey, for example, results in a distribution that places more emphasis on that data as opposed to the other two data categories. Figures 14 and 15 show the demand projections for the price points developed in this course of the survey for the two tourism cases.

Figure 14. Demand Curves for LEO Space Tourism with no Destination (Model Settings: Year 2010 demand; 10% of potential customers interested in a tourism experience; 5% net worth expenditure level; Weighted Demand is 50% Futron Derived, 25% SEI Survey Public, and 25% SEI Survey Experts).

Figure 15. Demand Curves for LEO Space Tourism with Hotel Destination (Model Settings: Year 2010 demand; 10% of potential customers interested in a tourism experience; 5% net worth expenditure level; Weighted Demand is 50% Futron Derived, 25% SEI Survey Public, and 25% SEI Survey Experts).
Various reviews of the literature and public data reveal a consensus that there will be some growth to this industry. For deterministic runs of the financial model, the yearly growth rate for these demand curves was set to 6.5%. This value is equivalent to the cumulative average growth rate of millionaires from 2004 to 2005 according to the 2006 World Wealth Report. For probabilistic analysis, this growth rate was varied according to a triangular distribution with minimum of 0%, most likely value of 6.5%, and maximum value of 10%.

C. Modeling Supply

The model simulates the financial case of a potential space tourism business. An implicit assumption in this process, based upon inputs to the model, is that the company is vertically integrated. Thus the company being modeled is developing the vehicle, acquiring the fleet, and performing ground and flight operations to provide consumers with the experience of space tourism. This analysis only examined the space transportation operator. Any space destination/hotel operator was not modeled in terms of a financial analysis. Thus the cost structure and NPV outputs represent the business case of only the launch vehicle provider and not the in-space destination service provider. It was also deemed outside the scope of this analysis to model all the various potential businesses, and their associated financial cases, which would in reality support such a market. These would include such separate businesses as vehicle producers, tour operators, training organizations, etc. If a vertically integrated company could achieve a positive financial return then that would indicate a high likelihood that separate companies providing the same overall service could also achieve positive financial returns.

For the analysis performed here, the Initial Operating Capability (IOC) of the project is assumed to be 2010, with development occurring from 2007 until 2008, fleet acquisition and ground facility development from 2008 until 2009, and 10 years of actual flight operations (ending in 2019). Additional financial assumptions about the program include the following: anticipated future inflation is set to 2.1%, tax rate of 30%, capital on hand at program start is $200M, a debt-to-equity ratio of 3, average nominal interest rate of 7.5%, and SG&A (Selling, General and Administrative) expenses of $3M per year. These assumptions were based upon typical economic modeling guidelines from previous programs or best guesses about potential future space access project economics.

A fictitious cost structure was developed for the company providing the orbital space tourism experience as summarized in Table 3. This cost structure is not directly representative of any particular company. However, it is a proxy for such a company based upon an amalgamation of public data about companies that may be interested in providing such a service. Generally, the assumptions include a high development cost (in the several hundred million dollars) with acquisition cost of between $50-100M. New firms interested in such markets will want to keep operations cost low, but since there are expendable components to their architecture, there is high variable cost. There will be some facilities development that could be offset by government financial investment or other incentives to encourage companies to settle in a particular jurisdiction. There will be a limit to the number of flights possible with such vehicles, based upon refurbishment/turnaround times, facilities limits, and anticipated passengers.

The minimum, most likely, and maximum values for the company cost structure shown in Table 3 define triangular distributions used in probabilistic runs of the financial model. The most likely values were used for deterministic runs.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Minimum</th>
<th>Most Likely</th>
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<td>Fixed Ops Cost / Yr</td>
<td>5</td>
<td>5.75</td>
<td>6.8</td>
</tr>
<tr>
<td>Variable Ops Cost / Flight</td>
<td>5.5</td>
<td>49.6</td>
<td>76</td>
</tr>
<tr>
<td>Facilities Development Cost</td>
<td>30</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>Maximum Number of Flights</td>
<td>5</td>
<td>12.5</td>
<td>30</td>
</tr>
</tbody>
</table>

V. Results

Financial models were run both deterministically and probabilistically. For all simulations, the main scenario that was modeled was one of the financial cases of transportation companies providing this service. A space destination operator was not modeled, but the transportation company providing the service was. For these case studies, a single commercial company was modeled as capturing the entire market for those prices. Parameter sweeps were performed of price and market risk premium to generate surfaces of Net Present Value (NPV). Market risk premium is a value that represents the additional return of an investment required to stakeholders versus a
relatively risk free investment (such as a 30 year government Treasury bond). Market risk premium is used in the calculation of Weighted Average Cost of Capital (WACC), or measure of the overall return on an investment given the various levels of debt and equity within the project. For the Monte Carlo Simulations, distributions were placed on cost parameters (development, acquisition, and operations) as well as on demand forecasts (passengers per year). Each Monte Carlo Simulation consisted of 1000 runs.

A. Deterministic Results

Tables 4 through 5 give the deterministic values of Net Present Value for the space tourism case studies. Sweeps of price and market risk premium were performed. As can be seen, LEO tourism (at high prices, >$10M) did result in positive NPV. A negative value for NPV has no real meaning except that it indicates that the market for orbital space tourism is not viable at this price.

<table>
<thead>
<tr>
<th>Market Risk Premium</th>
<th>Price</th>
<th>$10 M</th>
<th>$15 M</th>
<th>$20 M</th>
</tr>
</thead>
<tbody>
<tr>
<td>5%</td>
<td></td>
<td>-932.21</td>
<td>826.95</td>
<td>990.14</td>
</tr>
<tr>
<td>10%</td>
<td></td>
<td>-842.46</td>
<td>418.39</td>
<td>566.03</td>
</tr>
<tr>
<td>20%</td>
<td></td>
<td>-697.67</td>
<td>17.33</td>
<td>139.46</td>
</tr>
</tbody>
</table>


The lowest price at which a company can succeed in the market can be determined by finding the price at which NPV of the company is equal to zero. This is the breakeven point for a company at which the discounted present value of the amount invested in the undertaking exactly equals the discounted present value of all returns. Table 6 shows the NPV breakeven price for both the case of orbital tourism with a hotel destination and the case of no hotel destination. At the lowest market risk premium in the case of no hotel destination, this price is approximately $11.9 million.

<table>
<thead>
<tr>
<th>Market Risk Premium</th>
<th>Simulation Case</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LEO Tourism without a Hotel Destination</td>
</tr>
<tr>
<td>5%</td>
<td>11.90</td>
</tr>
<tr>
<td>10%</td>
<td>12.66</td>
</tr>
<tr>
<td>20%</td>
<td>14.95</td>
</tr>
</tbody>
</table>

B. Probabilistic Results

Probabilistic NPV results are shown in Tables 7 through 8 and Figures 16 through 17 (mean and 90% certainty values) for the case of LEO tourism without a hotel destination. Generally, the mean values are higher than the deterministic values. To achieve 90 percent certainty of positive NPV, the price charged must be higher and the cost of capital, as measured by market risk premium, lower.
Probability density functions resulting from the 1000 Monte Carlo simulations graphically demonstrate that even though the mean NPV is greater than zero, there is a probability that the company will not be successful. At a $20 million dollar price and 20% market risk premium this probability is about 15%. By contrast, the probability density function for NPV at a $20 million price and a 5% market risk premium is always positive.
Probabilistic results for the case of LEO tourism with a hotel destination are shown in Tables 11 though 12 and Figures 24 through 25 (mean and 90% certainty values). Generally, the mean NPV values are higher than the deterministic values shown in the previous section.

Table 9. LEO Tourism With Destination Net Present Value: Mean ($M FY 2006).

<table>
<thead>
<tr>
<th>Market Risk Premium</th>
<th>Price</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$10 M</td>
<td>$15 M</td>
<td>$20 M</td>
<td></td>
</tr>
<tr>
<td>5%</td>
<td>-472.51</td>
<td>1,512.73</td>
<td>1,630.44</td>
<td></td>
</tr>
<tr>
<td>10%</td>
<td>-530.70</td>
<td>885.93</td>
<td>1,007.53</td>
<td></td>
</tr>
<tr>
<td>20%</td>
<td>-543.21</td>
<td>252.75</td>
<td>368.15</td>
<td></td>
</tr>
</tbody>
</table>

Table 10. LEO Tourism With Destination Net Present Value: ≥90% Certainty ($M FY 2006).

<table>
<thead>
<tr>
<th>Market Risk Premium</th>
<th>Price</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$10 M</td>
<td>$15 M</td>
<td>$20 M</td>
<td></td>
</tr>
<tr>
<td>5%</td>
<td>-3,104.14</td>
<td>125.52</td>
<td>864.21</td>
<td></td>
</tr>
<tr>
<td>10%</td>
<td>-2,346.54</td>
<td>-87.69</td>
<td>471.90</td>
<td></td>
</tr>
<tr>
<td>20%</td>
<td>-1,520.60</td>
<td>-264.44</td>
<td>75.48</td>
<td></td>
</tr>
</tbody>
</table>
VI. Conclusions

After review of all the activities associated with this project several top level conclusions can be drawn:

- Representative single companies existing in the orbital space tourism industry can achieve a positive Net Present Value (NPV).
- The public generally underestimates demand, especially at low price points, as compared to demand estimates derived from wealth data and surveys of actual high net worth individuals. Experts forecast an even lower demand than the public.
- Confidence in forecasting orbital space tourism demand decreases at lower prices for both experts and the public alike.
- Survey respondents believe complementary goods increase the market size, generally forecasting greater demand for orbital tourism with a hotel as opposed to orbital tourism without a hotel at the same price points.
- Modeling shows that given reasonable inputs for company cost structures based upon assumptions of new Earth-to-Orbit vehicles, LEO tourism prices could be below current market prices (i.e. ISS space tourist prices). At these lower prices, a company could still be viable.
- Mean probabilistic NPV output results for most markets turned out to be better than the deterministic NPV values, possibly due to distribution on the growth rate, and skewed cost distributions, thus more significant variables play a part in the analysis.
• Agent-based modeling holds potential for gathering further insight about these markets than can be gained through simplified spreadsheet modeling. Data and allegorical knowledge from other industries exist that make agent-based models feasible.

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References