Space Tourism

How It Will Change the World

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Space tourism - the concept of tourists flying into space primarily for sheer enjoyment - has been a dream of humankind for millennia. Of late, space tourism has made popular headlines in the news and certainly has grabbed the media's attention.

What's the big deal, one might ask.

This quarter's newsletter explores the importance of space tourism and its implications for space-related activities, and beyond. This is followed by a synopsis of the main barriers that stifle the growth of the industry. First, however, we start from the beginning, with the history of space exploration and an introduction to space tourism.

Space History

FROM SPACE EXPLORATION TO SPACE TOURISM

The era known as the Space Race (1957 – 1975) marked the beginnings of humankind's venture into the final frontier, a dream which has lingered for generations past. During this period, the United States and the Soviet Union were in the midst of the Cold War, where accomplishments in space exploration represented a source of power and pride. From a military standpoint, satellites in space could serve as a vehicle for spying on other countries. At the same time, accomplishments in space demonstrated a country's strength and military potential.[1]

While inspired by war, the Space Race was nonetheless a period full of amazing feats. The first satellite in space, the first man and woman in space, the first space walk, and the first time humankind landed on the moon were all memorable accomplishments. It was certainly an exciting time for space. At this point in time, the idea of private citizens flying into space did not seem far away. Space Tourism was viewed as a near-future possibility. For instance, in the late 1960s, major airlines like Pan Am began taking "reservations" for trips to the Moon ($5 got "passengers" on the waiting list).[2]

However, the public would have to wait. During the Space Race, the 1970's and the 1980's, governments were the main players, and the idea of sending tourists into space was not on the top of their agenda. However, real headway began to take hold in the late 1980's and from the early 1990s onwards, when private interests began to promote space tourism. Literature began to explore the feasibility of space tourism, ideas of space hotels began to appear at important space conferences, and more and more, space tourism began to gain traction.

An important point in the history of space tourism occurred with the launch of the Ansari X-Prize project in 1996. The founders of the $10 million prize hoped to stimulate "the creation of a new generation of launch vehicles designed to carry passengers into space."[3] The idea was inspired by the 1919 Orteig Prize, which awarded $25,000 to the first person to fly solo non-stop from New York to Paris. The feat was achieved by Charles Lindbergh on May 20, 1927, and spurred tremendous growth in the aviation industry, including the three-fold growth in the number of pilots in the U.S. and the 30-fold growth in airline passengers a single year later.[4] X-Prize founders hoped for the X-Prize challenge to be the catalyst for a similar path.

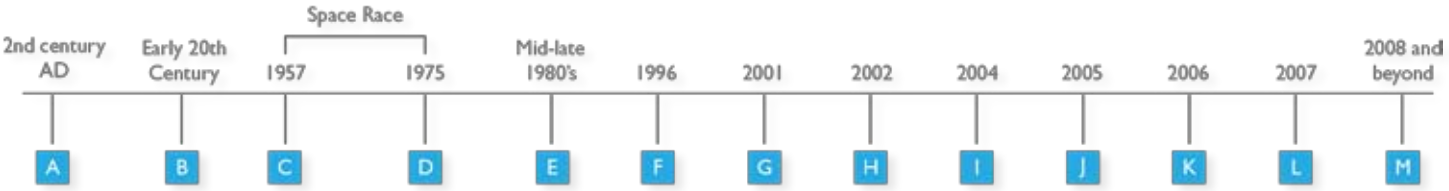
The prize was eventually awarded to Burt Rutan in 2004, who built SpaceShipOne, the first privately funded spacecraft to enter space. Ultimately, it demonstrated that the realm of space was not only a playground for the government. Private players could reach the limits of space, and moreover, could be extremely profitable in doing so.[5]

1 (2008). Space Race. In Wikipedia [Web]. Website: http://en.wikipedia.org/wiki/Space_exploration; http://en.wikipedia.org/wiki/Space_race.
2 Anderson, Eric (2005). The Space Tourist's Handbook. Philadelphia, PA: Quirk Books.
3 Anderson, R. and Peacock, M. (2004). Ansari X-Prize : A Brief History and Background. Web site: http://history.nasa.gov/x-prize.htm
4 Anderson, R. and Peacock, M. (2004). Ansari X-Prize : A Brief History and Background. Web site: http://history.nasa.gov/x-prize.htm
5 Parsons, C.E. (2006). Space Tourism: Regulating Passage to the Happiest Place Off Earth. Chapman Law Review.

Another significant milestone in the history of space tourism occurred on April 28, 2001, when Dennis Tito, a California investment manager who had always dreamed of traveling to space, became the first space tourist. Space Adventures, a private company that provides and organizes access to space for private citizens, worked with Tito and the Russian space program to reserve a seat on the Russian Soyuz rocket. The Soyuz runs routine 8-day "taxi" missions to the International Space Station to rotate staff and deliver new supplies, normally with two cosmonauts and one empty seat.

Albeit that the ticket price was a staggering $20 million, Tito proved that the dream of flying into space by private citizens was no longer just a dream. The rest of the world could experience the final frontier, too.

The past 50 years has been an exciting period for space. Figure 1 provides a timeline that summarizes some of the most significant events in space-related activities - past, present, and future.



A Greek writer Lucian wrote Alethes historia (True History), in which the narrator voyages to the Moon. Similar works, through to the 20th century, seed the idea of space travel in the popular imagination.

B Advent of liquid-fueled rocket engines; spaceflight becomes a practiucal possibility.

C Soviet Union launched Sputnik 1, the first satellite to orbit the Earth; marks the beginning of the Space Race.

D End of the Space Race. Up until the end of the race, there were several accomplishments in space. Examples include the first man and woman in space, the first space walk, and the first moon landing.

E Private interests begin to promote Space Tourism.

F Launch of Ansari X Prize.

G Dennis Tito becomes the first tourist in space (April 28).

H Mark Shuttleworth becomes the 2nd space tourist (April 24).

I Burt Rutan wins X-Prize for SpaceShipOne.

J Gregory Olsen becomes 3rd space tourist (October 1).

K Anousheh Ansari becomes 4th space tourist (September 18).

L American Charles Simonyl becomes 5th space tourist (April 7).

$20 million Google Lunar X Prize launched: challenges teams to compete to successfully launch, land and operate a rover on the moon.

M Private initiatives pursue space tourism and new commercial industries (e.g. Space manufacturing, space mining)

Government initiatives continue to pursue space. NASA: on a mission revisit the moon by 2020, and reach Mars between 2035 and 2037. Other international efforts continue to pursue space as well. Examples include Russia's plans to build a new manned space transport system by 2015 and China's plans to send another rover to the moon in 2012 to survey the moon's surface.

Figure 1. Timeline depicting the significant events in space-related activities

Space Tourism Today

INDUSTRY PLAYERS AND THE PRIVATE SPACE RACE

Today, space tourism is very much in its infancy, with a strong sense of optimism and enthusiasm amongst the pioneers developing the industry. Perhaps the greatest motivation behind the development of the industry is the lure of a potentially large, untapped market. A study performed by Futron Corporation indicated that the market for sub-orbital travel alone could be between 10,000 and 20,000 passengers, bringing in almost $700 million in revenue annually, by 2021.[6] Entrepreneurs are hungry to seize unrealized profits, and a new space race, sometimes referred to as the "Private Space Race", because it takes place primarily amongst private sector organizations and initiatives, has commenced.

More highly publicized efforts to bravely pursue the space tourism industry include undertakings by well known entrepreneurs such as Sir Richard Branson (best known for his Virgin brand), Jeff Bezos (CEO, Amazon), and Elon Musk (Co-founder, PayPal). These entrepreneurs have decided to take the risk of pursuing the space tourism industry, in hopes of realizing potentially large returns. Altogether, however, more than 40 organizations worldwide are attempting to develop the space tourism market, including efforts in the United States, Russia, Canada, Argentina, Australia, China, India, Europe, and Israel.[7] The majority of these organizations are in the business of developing vehicles for space travel, with the intent of operating the vehicles for space tourism. However, there are commercial firms who intend to provide other space tourism products and services, such as space hotels (e.g. Bigelow Aerospace), or creating and developing various space tour experiences (e.g. Space Adventures). Table 1 provides examples of players in the Private Space Race.

Table 1. Examples of players in the Private Space Race[8,9]

Organization	Description
Virgin Galactic	Virgin Galactic, founded by Sir Richard Branson, is perhaps the most visible company in the Private Space Race, attempting to be the first to send tourists into sub-orbit. The company is selling tickets aboard its SpaceShipTwo sub-orbital vehicle for about $200,000, with the first flights expected in 2009. The concept of the spacecraft built by Burt Rutan's company, Scaled Composites (under contract with Virgin Galactic), involves SpaceShipTwo being launched into space from its mother ship, WhiteKnightTwo, after reaching 50,000 feet. Tourists then fly to an altitude of 360,000 feet, at which point passengers experience weightlessness before re-entering into the Earth's atmosphere.
Blue Origin	Amazon.com founder Bezos began building Blue Origin in 2002. The company is developing a vertical take-off, vertical-landing vehicle called the New Shepard that will take tourists into sub-orbit, perhaps as soon as 2010. Blue Origin launched test flights in 2006 and 2007, and intends to continue testing through 2009. Once it begins operating, the company plans as many as 52 launches each year.
Space Exploration Technologies (Space X)	Elon Musk, co-founder of PayPal, founded Space X in 2002. The company was one of two chosen by NASA to develop low cost orbital space vehicles, receiving $500 million to do so. NASA's intent is to use the space craft to service the international space station through to 2010. SpaceX, however, also intends to use their vehicles to launch satellites into space, and eventually, to send tourists into space.
Space Adventures	Space Adventures, formed in the 1990's, has been at the forefront of proving that the space tourism industry exists. The company pioneered the concept that private citizens willing and able to travel to space could in fact do so. The company organizes and sells a range of space experiences. Examples include zero-gravity flight experiences, and trips to the international space station.

6 Futron Corporation. Suborbital Space Tourism Demand. 2006.
7 Pelton, J.N. (2007). Space Planes and Space Tourism: The Industry and the Regulation of its Safety. George Washington University. Website: http://www.spacesafety.org/SpacePlaneTourismStudyMarch07.pdf
8 Olsen, S (2007). Private industry moves to take over space race. Website: http://www.news.com/Private-industry-moves-to-take-over-space-race/2009-11397_3-6210833.html
9 CNET.com, (2007). Major players in private space travel. Website: http://www.news.com/2300-11397_3-6211252-1.html

Bigelow Aerospace	Bigelow Aerospace, founded by hotel mogul Robert Bigelow in 1999, is in the business of developing and (eventually) operating space hotels. In 2006, the company became the first to launch and test an inflatable habitable module, called Genesis I, in orbit. Upon reaching orbit, the module performed as expected - inflating and starting internal systems. A year later, the company launched Genesis II, another test craft identical in size to Genesis I, but with more video cameras, sensors and avionics. The company intends to test and observe the performance of the modules over several years, including testing resistance to radiation and space debris. Bigelow aims to build an operational space hotel by 2015.

Space Tourism Today

OPTIONS FOR ASPIRING SPACE TOURISTS

What can aspiring space tourists experience today? At present, tourists willing and able to pay can experience the joy of space in a variety of ways, from zero-gravity flight to flights to the International Space Station in low earth orbit (LEO) (Table 2 and Figure 2).

Table 2. Current and Near-Future Options for Space Travel[10]

Type	Description	Cost	Experience Time	Training Time
Zero-gravity Flight	A flight on a jet regularly used to train cosmonauts and astronauts, flying in a parabolic flight pattern and taking place within the Earth's atmosphere. Passengers experience weightlessness.	<$10K	1-2 hours	3-5 days
Edge of Space Flight	Passengers travel to the upper edge of the Earth's atmosphere (~25 km), with a view of the curvature of the Earth. The pilot performs combat maneuvers during descent (rolls, dives), and the passenger may also control the vehicle under supervision of the pilot.	$10K - $50K	1 hour	2-3 days
Sub-orbital Flight	A journey that leaves the Earth's atmosphere and enters space (~ 100 km) but does not reach the speeds required for continuous orbit of the planet. Passengers experience 5-15 minutes of weightlessness, and a view of the Earth, the depths of space, and the Moon and stars.	~$200K	1-2 hours	1-2 days
Orbital Flight in Low Earth Orbit (LEO)	Microgravity flights in which one orbits the earth. Tourists experience a rocket-boosted launch into space and life on the International Space Station.	~$20M	10-12 days	4-6 months

10 Anderson, Eric (2005). The Space Tourist's Handbook. Philadelphia, PA: Quirk Books.

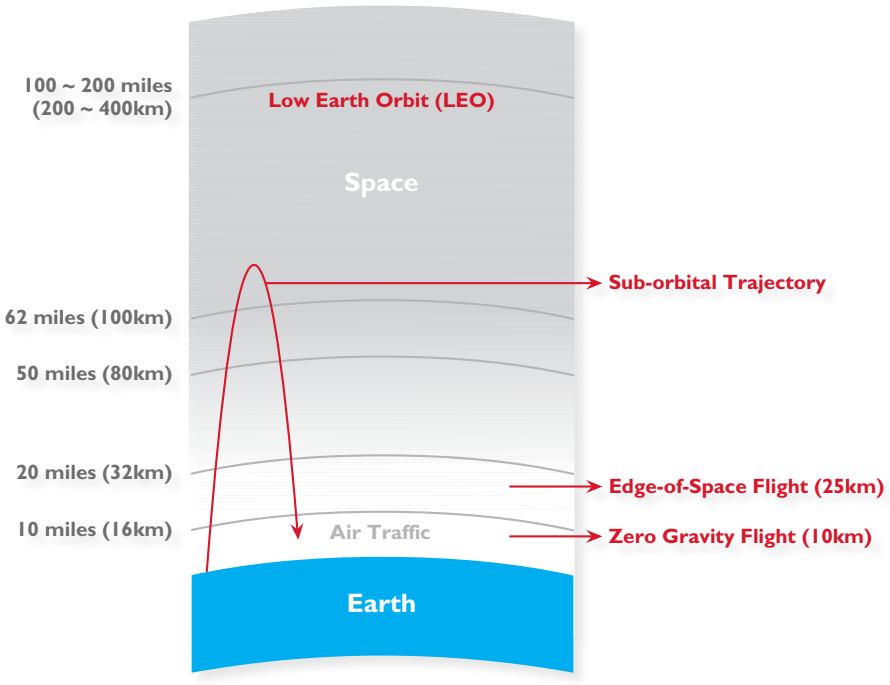


Figure 2. Graphical depiction of zero-gravity flight, edge-of-space flight, sub-orbital flight, and flight in LEO

Orbital trips are still extremely expensive, and available only through government space agency missions.

Hence, before we see passengers staying in space hotels in earth's orbit or on the moon, sub-orbital travel will provide the initial steps to a grander future in space (Figure 3). Players in the private space race are mainly focused on developing vehicles, products, and services for sub-orbital and orbital travel.

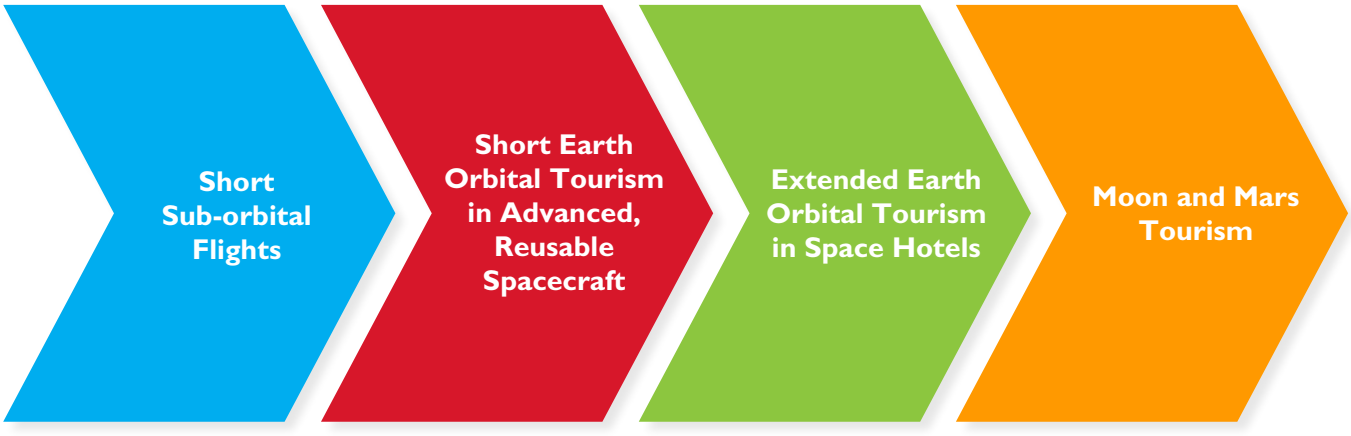


Figure 3. The potential evolution of space tourism[11]

11 Reichert, M (1999). The Future of Space Tourism. Website: http://www.spacefuture.com/archive/the_future_of_space_tourism.shtml

Space Tourism – What's the Big Deal?

FUTURE IMPLICATIONS OF SPACE TOURISM

The competitive spirit of the Space Race between the Soviet Union and the United States spurred tremendous growth and innovation in space-related activities. In the span of just 12 years, the human race progressed from sending the first object in earth's orbit to landing and walking on the first celestial body other than earth – the moon. And that was just the beginning. Satellite radio and television, telemedicine, GPS navigation, and weather and climate monitoring which impact our everyday lives have all developed because of the pioneering work and achievements in early space exploration.[12] In fact, entirely new industries and several important discoveries have stemmed from space exploration, of which was originally inspired by the Space Race (Figure 4).

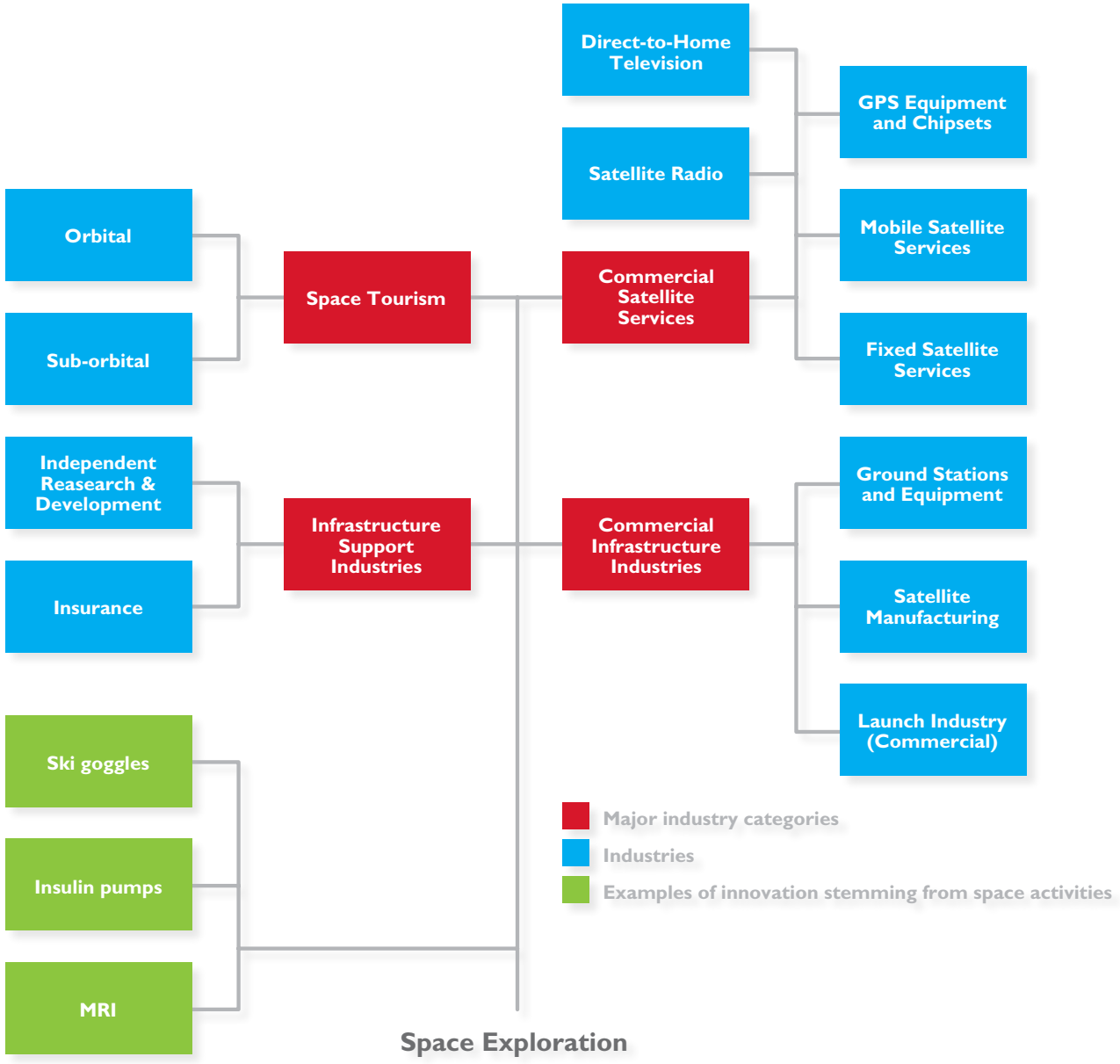


Figure 4. Space Exploration, the beginnings of which were inspired by the Space Race, has resulted in several new industries, and to research discoveries that benefit humankind.

12 Griffin, M (2007). The Space Economy - NASA 50th Anniversary Lecture Series. Website: http://www.spaceref.com/news/viewsr.html?pid=25452

With the dawn of the Private Space Race, where private interests are enthusiastically pursuing the space tourism industry, the competitive spirit in the realm of space has reemerged. This is particularly important for two reasons. First, space tourism will make the dream of spaceflight – one that has lingered for millennia - a reality for our generation. Moreover, the Private Space Race has the potential to spur a similar surge of growth and innovation in space-related activities as was experienced during and after the Space Race. One such scenario is presented in Figure 5, and will be discussed next.

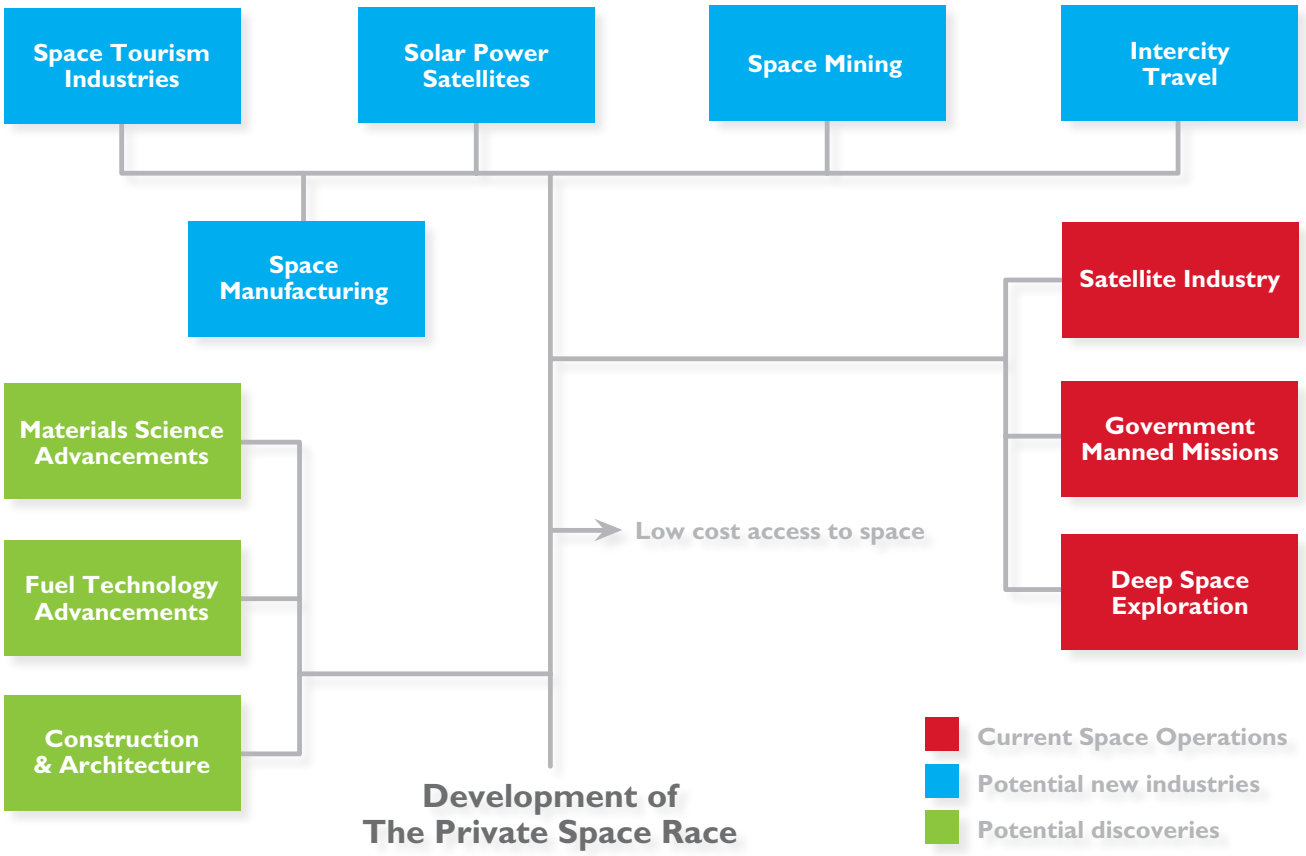


Figure 5. The Private Space Race and the development of the space tourism industry have the potential to spur growth and innovation in space-related activities. New industries (in blue) and discoveries (in green) may result. Additionally, existent space industries and space activities (in red) may benefit from the surge in growth and innovation.

IMPLICATIONS OF LOWER COST ACCESS TO SPACE

Perhaps the most important contribution of the Private Space Race will be lower cost access to space. A $200,000 ticket to space would be considered an expensive vacation for the majority of the world's citizens, and as such, price represents a significant hurdle to space tourism being widely available to the public.

Consequently, a large goal of organizations pursuing space tourism is to develop ways in which to access space at lower costs. Competitors will strive to find innovative designs and methods to build space vehicles at lower cost; they will discover more efficient ways in which to operate their spacecraft and more and more, the cost of space travel will decrease. This, in turn, will slowly open the door to entirely new industries in space. Additionally, industries and governments currently heavily invested in space (i.e. the commercial satellite industry and government space missions, respectively) will benefit from lower cost access to space.[13]

13 Ashford, D.M. (2007). New Commercial Opportunities in Space. Website: http://www.spacefuture.com/archive/new_opportunities_in_commercial_space.shtml

Lower Cost Access to Space will Open Doors to New Space Industries

There are several concepts of new space industries waiting to be developed, many of which are hindered by the high cost of sending materials, objects, or people into space. Lower cost access to space, driven by the pursuit of the space tourism industry, may hold the key to developing these opportunities further.

- **Intercity Sub-orbital Travel:** Imagine flights from Los Angeles to Tokyo in 40 minutes, or from Los Angeles to Paris in 38 minutes. Sub-orbital travel is already capable of flights from one part of the world to another in short periods of time. For instance, Virgin Galactic has mentioned that its' first sub-orbital vehicle could also be used to make super-fast intercity trips.[14] If the cost of sub-orbital flights drop significantly, intercity flight may have potential applications for high urgency cargo flights, urgent military responses, or even business or commercial travel where passengers experience the excitement of space while traveling from continent to continent.[15]

- **Space Manufacturing:** Space manufacturing is the production of manufactured goods in space. As one can imagine, the manufacturing environment in space, which typically includes conditions of microgravity and hard vacuum, is inherently different from earth-based manufacturing environments. This space environment can allow for manufacturing processes that are not possible or cost-effective on earth, or are more effective than earth-based manufacturing processes.[16] For example, a microgravity environment allows for bacteria to build faster and denser, and antibiotics to grow at an "enhanced" level, which can be a large benefit to pharmaceutical companies looking to increase yields and lower costs.[17] Manufacturing in space also minimizes the risk of environmental harm to the Earth or other planets, especially with respect to hazardous processes.[18]

  The energy costs of sending materials required to build manufacturing facilities is a significant barrier to this industry; hence, low cost access to space will greatly contribute to the development of this industry.

- **Space Mining:** Space mining is the mining of astronomical objects in space. Asteroids, meteoroids, the Moon and planets may yield precious metals, water, iron, and perhaps even substances yet to be discovered.[19] Some estimates indicate that Space Mining could be a $10 billion industry by 2030.[20] Lower cost access to space would enable space mining to be a more realistic space activity.

- **Space-based Solar Power Satellites:** Space-based solar power has the potential to supply a significant percentage of the world's electricity demand.[21] In space, the energy from the sun is available at all times. Additionally, satellites in space do not have to contend with clouds and other atmospheric interferences. As a result, satellites in space can collect up to eight times more energy than terrestrial solar cells.[22]

  Delivering hundreds of gigawatts of solar-generated electric power to Earth would require the construction of a system of orbiting satellites, and would therefore also require millions of tons of components in Earth orbit. Therefore, low cost access to space is a requirement for this space industry to become a reality.[23]

14 New Scientist magazine, (2008). Forget the plane, take the intercity spaceship. Web site: http://technology.newscientist.com/article/mg19726415.600-forget-the-plane-take-the-intercity-spaceship.html
15 (2008). Sub-orbital spaceflight. In Wikipedia [Web]. Website: http://en.wikipedia.org/wiki/Sub-orbital_spaceflight#Intercontinental_flights
16 (2007). Space manufacturing. In Wikipedia [Web]. Website: http://en.wikipedia.org/wiki/Space_manufacturing
17 Ma, W (2007). 4 Private Space Businesses That Aren't for Super-Rich Tourists. Web site: http://www.popularmechanics.com/technology/industry/4222134.html?page=1
18 (2007). Space manufacturing. In Wikipedia [Web]. Website: http://en.wikipedia.org/wiki/Space_manufacturing
19 (2007). Space mining. In Wikipedia [Web]. Website: http://en.wikipedia.org/wiki/Space_mining
20 Adolph, J (2006). The Recent Boom in Private Space Development and the Necessity of International Framework Embracing Private Propwerty Rights to Encourage Investment. The International Lawyer.
21 Ashford, D.M. (2007). New Commercial Opportunities in Space. Website: http://www.spacefuture.com/archive/new_opportunities_in_commercial_space.shtml
22 Ma, W (2007). 4 Private Space Businesses That Aren't for Super-Rich Tourists. Web site: http://www.popularmechanics.com/technology/industry/4222134.html?page=1
23 Collins, P. (2004). Synergies Between Solar Power Supply from Space and Passenger Space Travel. Website: http://www.spacefuture.com/archive/synergies_between_solar_power_supply_from_space_and_passenger_space_travel.shtml

- **Space Tourism Industries:** When the space tourism industry is fully developed and the infrastructure for travel beyond sub-orbit is available, the possibilities for the industry will grow immensely. Some forward-thinking entrepreneurs have already commenced preparing for travel to LEO and beyond.

  For example, already in early development is the idea of space hotels, which will provide space tourists with a place to stay. Bigelow Aerospace, led by the hotel owner and entrepreneur American Robert Bigelow, launched the first inflatable habitat module in July 2006. Galactic Suite Limited, a Barcelona-based private company, endeavors to open the first space hotel, "Galactic Suite", in 2012.[24] Other companies, such as Hilton International and Space Island Group have similar plans to develop habitats in space.

  Space hotels provide only one example of the many elements that will comprise the space tourism industry. An entire industry, dedicated to creating the ultimate experience for passengers, is waiting to be built. Ideas of space fashion, space advertising, and theme parks in space are perhaps not completely unfounded considering the current pace of progress in space tourism initiatives.

Lower Cost Access to Space will Benefit Industries and Governments Currently Heavily Invested in Space

In addition to opening the possibilities to new space industries, lower cost access to space – resulting from competition in the Private Space Race - will benefit the already existent satellite industry, as well as government space agency missions.

- **Satellite Industry:** Currently, satellites are launched into space using Expendable Launch Vehicles (ELVs), which are designed to be launched only once. With the advent of lower cost access to space, via Reusable Launch Vehicles (RLVs), satellite manufactures will be able to launch their products into space at much lower costs. With fewer than 100 ELV flights per year, the market for launching satellites is too small to justify the development of low cost vehicles specifically for this purpose. The satellite launching industry will certainly benefit from low cost access to space.[25]

- **Government Manned Missions:** According to the U.S. Space Foundation's 2007 Space Report, the combined international and U.S. budget for space activities is $74.46 billion.[26] A large portion of the budget is used to further International Space Station project goals, as well as preparing for planned future missions to the Moon and eventually to Mars. Low cost access to space will undoubtedly have a positive impact on such government initiatives.[27]

NEW DISCOVERIES IN SPACE WILL BENEFIT US HERE ON EARTH

No one would have predicted that space-related research and activities would lead to the discovery of several products and technologies we take for granted here on earth. MRI technology, which provides doctors with detailed images of the internal structure of the human body, was developed from an image-enhancement technique created to improve the sharpness of moon photographs. The insulin pump, which automatically delivers precise amounts of insulin to diabetics, is based on technology used by the Viking craft that landed on Mars. Ski goggles, which offer fog-free sight, were adapted from astronaut's helmet designs.[28]

24 Thompson, A (2007). Space Hotel Slated to Open in 2012. Website: http://www.space.com/news/070811_space_hotel.html
25 Ashford, D.M. (2007). New Commercial Opportunities in Space. Website: http://www.spacefuture.com/archive/new_opportunities_in_commercial_space.shtml
26 Space Foundation, (2007). The Space Report.
27 Ashford, D.M. (2007). New Commercial Opportunities in Space. Website: http://www.spacefuture.com/archive/new_opportunities_in_commercial_space.shtml
28 The Ultimate Space Place, (2004). NASA Spinoffs: Bringing Space down to Earth. Web site: http://www.thespaceplace.com/nasa/spinoffs.html

What new discoveries will result from the Private Space Race? Perhaps the development of spacecraft for space tourism may lead to new insights in materials science, or contribute to advancements in fuel technology applicable to air and terrestrial transportation vehicles. Perhaps the challenge of designing and constructing hotels in the unique environment in space will provide insights into more effective and efficient ways of designing and constructing buildings, which may then be applied to terrestrial architecture.

While it is quite early to speculate what new products, processes, and technologies might emerge from activities related to the development of the space tourism industry, it is nonetheless worthwhile noting that the implications of space tourism will not be limited to activities in space; our home planet will benefit as well.

Reality Check: Back Down to Earth

BARRIERS TO SPACE TOURISM

While there are critics who have reservations about the future of space tourism, most literature seems to support that the availability of space tourism to the general population is simply a matter of time. Considering the accomplishments of space exploration in just over 50 years, the notion that space tourism will be a flourishing industry is perhaps not so unfathomable. However, early pioneer work is seldom without its challenges. There exist several barriers that stifle growth of the space tourism industry.

High Costs of Development and Operation Translate to High Ticket Prices

The high ticket price for would-be space tourists, resulting from the high costs of developing and operating spacecraft, is considered the main barrier to the widespread availability of space tourism.[29] Near-future flights to sub-orbit are expected to cost passengers approximately $200,000. Comparatively, estimates from market surveys suggest that a ticket price of the order of $50,000 or less is necessary for a space tourism industry to sustain itself.[30] The gap between the current cost of launches and the cost needed to create a self-sustaining space tourism industry must be closed.

Traditionally, expendable launch vehicles (ELVs), which are designed to be launched only once, have been used for space-related activities, such as sending satellites into space. Reusable launch vehicles (RLVs) are designed to be launched more than once. Since RLVs can be used for multiple trips to space, they are the vehicles of choice for space tourism.

Although the use of RLVs rather than ELVs for space tourism is a large step towards lower cost access to space, the development, production, and operational costs of current RLV technology nonetheless make it difficult for space tourism RLV operators to fly customers at the industry-sustaining price point. Table 3 indicates the development, production, and operational costs for representative sub-orbital and orbital RLVs. While these costs will invariably be different for different RLVs, the example in Table 3 demonstrates that with operating costs in the range of $24-30 million per launch, a price point of $50,000 will unfortunately leave commercial space operators unprofitable, even with a vehicle that carries several passengers.

29 Gibson, D (2006). Outer Space Tourism Public Relations Purposes, Practices and Problems. Public Relations Quarterly.
30 ISU Summer Session Students (2000). Dreams and realities: the challenges facing development of space tourism. Space Policy.

Table 3. Development, production and operating costs for representative sub-orbital and low earth orbital reusable launch vehicles.[31]

Vehicle	Phase	Examples of Costs	Cost
Hopper Plus (representative sub-orbital RLV)	Development	▶ Equipment ▶ Engines ▶ Tooling ▶ System integration	$14.7B
	Production (first unit)	▶ Equipment ▶ Engines	$1.2B

	Operation (average)	▶ Variable Direct Operating Costs
		  ▶ Propellant cost
		  ▶ Launch site cost
		  ▶ Public damage insurance cost
		  ▶ Mission abort surcharge cost
		▶ Fixed Direct Operating Costs
		  ▶ Development amortization cost
		  ▶ Launch site support cost
		  ▶ Technical support cost
		▶ Indirect Operating Costs
		  ▶ Administration cost
		  ▶ Fees cost
			$30M/launch

Kankoh Maru Plus (representative low earth orbital RLV)	Development	See Development costs above	$14.2B
	Production (first unit)	See Production costs above	$0.8B
	Operation (average)	See Operation costs above	$24M/launch

Players in the Private Space Race are attempting to develop innovative ways to reduce costs. For instance, propellant represents a significant operational cost, of which the majority is exhausted in order to escape earth's gravitational force. Therefore, engineers have developed concepts such as high-altitude balloons and gliders which carry RLVs to an altitude that largely escapes gravity before the RLV launches into space.[32]

Cost reductions may also be achieved by adopting "Smart Business" strategies, which attempt to eliminate costs caused by high bureaucracy, many design changes, parallel work on identical topics, and other inefficient processes (Table 4). For instance, instead of having several design and technical contractors working in parallel to build an RLV, costs can be reduced by establishing clear-cut prime contractor and subcontractor relationships with well defined responsibilities. When the U.S. Space Shuttle program assigned responsibility to only one prime contractor, for example, annual costs were reduced by 32%. In the paper *Low-Cost Management Aspects for Developing, Producing, and Operating Future Space Transportation Systems*, the authors suggest that several other "Smart Business" strategies can be deployed to achieve significant savings.[33]

31 Goehlich, R.A. (2005). A Ticket pricing strategy for an oligopolistic space tourism market. Space Policy.
32 T. Merali (The International Space School Alumni Association), personal communication, February 21, 2008
33 Goehlich, R.A. and Rucker, U. (2005). Low-cost management aspects for developing, producing, and operating future space transportation vehicles. Acta Astronautica.

Table 4. Development, production and operation costs and savings after implementation of 'Smart Business" processes[34]

Vehicle	Phase	Cost	Cost after implementing "Smart Business" process	Savings
Hopper Plus (representative sub-orbital RLV)	Development	$14.7B	$7.9B	46%
	Production (first unit)	$1.2B	$0.6B	50%
	Operation (average)	$30M/launch	$5.6M/launch	81%
Kankoh Maru Plus (representative low earth orbital RLV)	Development	$14.2B	$9.7B	32%
	Production (first unit)	$0.8B	$0.6B	25%
	Operation (average)	$24M/launch	$2.7M/launch	89%

Further reductions in costs will be realized as the space tourism industry gains more traction. As profits are generated, manufacturers will be able to invest in design enhancements, and contingent on growing success of the industry, the attraction of greater financial investment and human capital will contribute to the cause. Furthermore, supplier costs would be expected to fall as competition increases.

Although an RLV that can support an industry-sustaining price point has yet to be developed, the task is not impossible. The pioneering work has already begun, of which its accomplishments and failures will pave the course of the industry.

The Challenge of Raising Funds

The capital investment required to develop RLV technology for space tourism is significant, as evidenced in Table 3. For venture capitalists and other investors, there are considerable issues that give them cause to hesitate when contemplating investing in space tourism ventures. Investor concerns include high investment and capital costs, management experience and depth in new space ventures (or specifically, a lack thereof), and the high business and political risks associated with the novelty of the industry.[35]

Thus far, only wealthy entrepreneurs and government-backed initiatives have been capable of comprehensively funding commercial space development. Space entrepreneurs that lack significant personal wealth or government-backing will likely need to turn to investors for funding. In order to successfully obtain funding, space ventures must develop skilled management teams that are able to understand and communicate the link between the technical aspects of their venture and its translation to profitable returns. These managers will have to come from other related industries including aerospace, travel-hospitality, among others. Convincing arguments backed by a formidable business and financial plans will be necessary.[36]

34 Goehlich, R.A. and Rucker, U. (2005). Low-cost management aspects for developing, producing, and operating future space transportation vehicles. Acta Astronautica.
35 Livingston, D.M. (2000). Space Tourism and RLVs: You Can't Have One Without the Other!. Web site: http://www.spacetalent.com/archive/space_tourism_and_rlvs_you_cant_have_one_without_the_other.shtml
36 Livingston, D.M. (2000). Space Tourism and RLVs: You Can't Have One Without the Other!. Web site: http://www.spacetalent.com/archive/space_tourism_and_rlvs_you_cant_have_one_without_the_other.shtml

Lack of Applicable Policies and Laws[37]

The United Nations Committee on the Peaceful Uses of Outer Space (COPUOS) is the principal international body involved in the development of international space law. Currently, there are 5 main treaties that have been finalized through COPUOS:

1. Outer Space Treaty
2. Rescue Agreement
3. Liability Convention
4. Registration Agreement
5. Moon Agreement

These laws govern activities in outer space; however, it is clear that, at the time the treaties were finalized, it had not been anticipated that space tourism activities would occur. As a result, current space law does not deal in any specific manner with space tourism activities.

Examples of where gaps occur in current law that do not properly address space tourism include:

- Currently, there is a lack of clarity with respect to what laws apply where. From a strictly legal perspective, there is no clear definition of outer space. Put in another way, the boundary stipulating where air space ends and where outer space begins is not known. Therefore, where commercial aviation law applies and where commercial space law applies is unclear.

- Celestial property rights and laws are undeveloped. Under current space laws, claims of sovereignty in space are not permitted. This implies that outer space, and the property therein, is beyond the jurisdiction of any nation or state. This also implies that ownership can not be currently claimed on any celestial property. As space tourism develops, property rights will need to established; otherwise, development in space will be hindered. For instance, if and when celestial hotels are built, it will be important for the "owner" of such a structure to gain some legal protection in relation to the site of the hotel. Without such protection, the "owner" of such property will be hesitant to establish the property.

- Safety standards and liability policies for space tourists and third parties are not established. If the space tourism industry is to successfully develop, every effort must be taken to ensure the safety of sub-orbital and orbital flights. There must be appropriate safety standards pertaining to the design, construction, and operation of a space tourism launch vehicle. Moreover, a system of responsibility and liability must be established to regulate circumstances where a space tourist suffers injury, loss, or damage, so as to remove uncertainties and ensure proper risk avoidance procedures.

Ultimately, laws at the international level supplemented by laws at the national level will be required to regulate the space tourism industry. Without these widely accepted rules, space tourism activities will be surrounded by uncertainty. The challenge for policy makers will be to create a balance between providing certainty and minimum standards on one hand, while refraining from imposing overly cautious restrictions that may impede innovation.

37 Freeland, S. (2006). Up, Up and…Back: The Emergence of Space Tourism and Its Impact on the International Law of Outer Space. Chicago Journal of International Law.

The Perception of Safety

When it comes to launching craft into space, humankind is improving; however, sending vehicles into space certainly is not a "routine" activity.

From a medical perspective, there are no serious barriers to space tourism. The average civilian can safely travel to space if he/she meets minimal medical selection criteria and receives adequate training and preparation.[38] A more pressing issue is the failure rates of missions. Both the Russian and U.S. governments have invested considerable resources into making their spacecraft as safe as possible and have been unable to achieve safety rates greater than 98%.[39]

This presents an ethical question: What is the acceptable rate of safety for space tourism? And importantly, what will this be in the eyes of the public?

Public relations will play a strong role with respect to this issue, since the public's perception of safety is largely influenced by the media. The role of the media will be of particular importance for disastrous events in space.

According to one space enthusiast - Tahir Merali from the International Space School Alumni Association (ISSA) - space has and will likely continue to experience some setbacks, including disastrous events, especially considering the relative novelty of all space-related activities. While the media may tend to draw attention to these setbacks, it is imperative for the public to remember the significant accomplishments in space in a very short period of time. In the grand scheme of things, space exploration and space tourism is just beginning to evolve.

38 ISU Summer Session Students (2000). Dreams and realities: the challenges facing development of space tourism. Space Policy.
39 Launius, R.D. and Jenkins, D.R. (2006). Is it finally Time for Space Tourism? Astropolitics.

The Accelteon Crystal Ball

The last 50 years of history have been exciting for space. Space tourism, a next step in the evolution of space-related activity, has the potential to be a powerful force driving further growth and innovation. With the likes of savvy entrepreneurs and private interests from excited nations paving the way for the industry, what can we expect?

At Accelteon, we predict the evolution of space tourism as depicted in Figure 6.

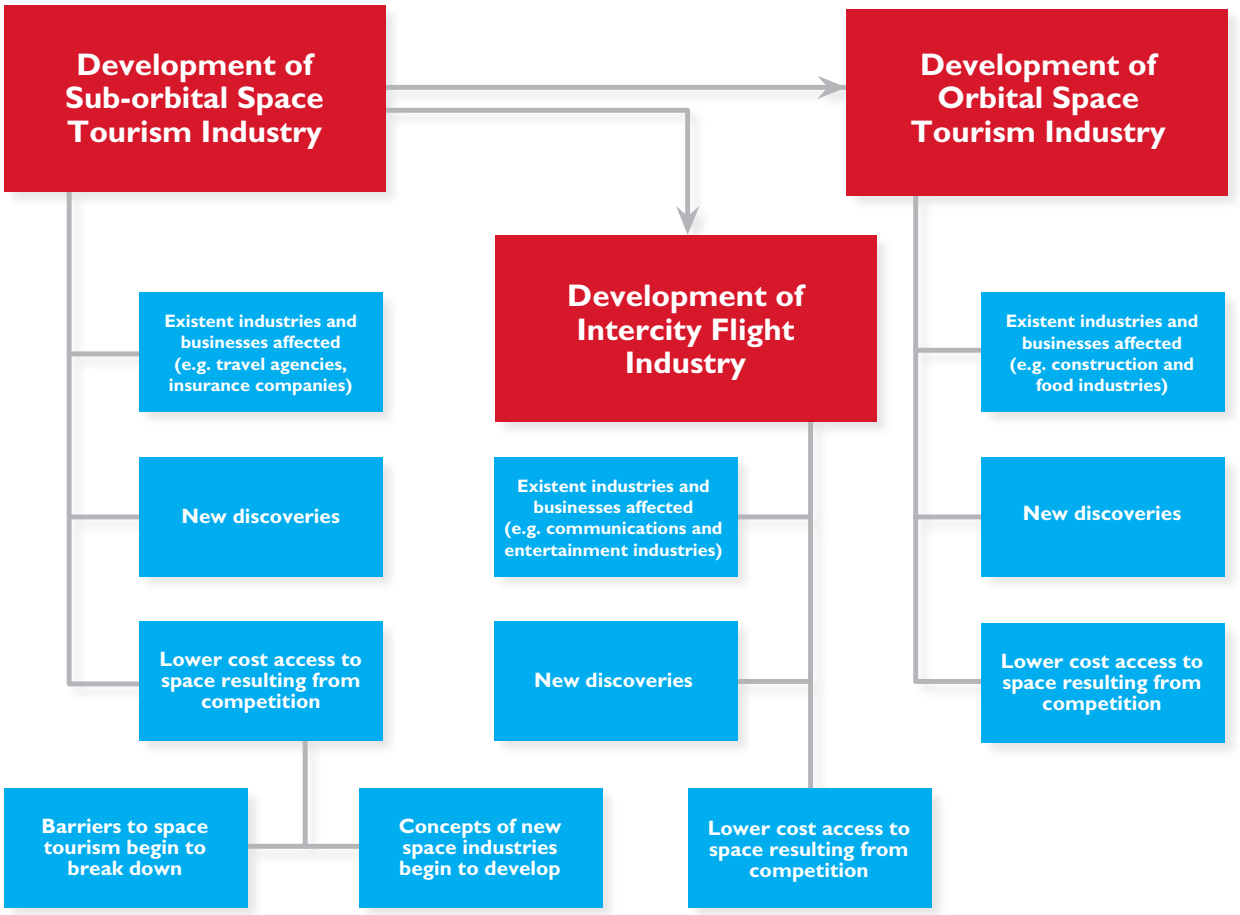


Figure 6. Accelteon's prediction of how the Space Tourism industry might unfold

With the onset of the sub-orbital market, the cost of accessing space will begin to decline as Private Space Race competitors attempt to discover innovative ways to build increasingly inexpensive spacecraft, and as sub-orbital operators find cost efficiencies as more and more launches are completed. As a result, barriers to space tourism will begin to break down. As well, concepts for building new space industries, such as space mining and manufacturing, will begin to develop.

At the same time, existent industries and businesses such as travel agencies, insurance companies, and safety equipment manufacturers will become increasingly involved in the space tourism industry, gaining a new source of revenue. Furthermore, new discoveries, such as advancements in materials sciences and fuel technology may result from sub-orbital RLV development, which might then be applied to earth-based industries, products, and processes.

Success in the sub-orbital market may then lend to intercity travel, where traffic and safety regulators, the communications industry, and the entertainment industry, among others, will be exposed to new revenue opportunities.

As the orbital market becomes more prominent, new space industries will continue to develop. Existent industries and businesses – in addition to those affected by the sub-orbital market – will be touched as well, including the construction industry, the food industry, international and national law, and perhaps even cruise line operators.

We are in the midst of an exciting period in space history. Our generation of entrepreneurs and nations are at the cusp of defining a new space era. Only time will tell if and how space tourism will evolve; however, given the successful record of accomplishments in space thus far, we believe it is only a matter of time.