Comparison of historic exploration with contemporary space policy suggests a retheorisation of settings

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Key words:

Exploration, Terraforming, Roadmap, funding, policy, corporate, government, public-private partnerships

The authors confirm this article contains unpublished, new research, and is being offered exclusively to the *International Journal of Astrobiology*.

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Introduction

Research and writing of this article was completed on the day of the final NASA space shuttle launch, STS-135, Space Shuttle *Atlantis*, from the US Kennedy Space Center, Launch Pad 39A. This event punctuates the shift in international space policy, the background for which has been investigated by the current research team. From now on the accent will shift to the *Commercial Orbital Transportation Services* (COTS) program, the NASA program announced on January 18, 2006 (NASA 2006) with the express purpose of

coordinating the delivery of crew and cargo to the International Space Station by private companies. From an astrobiology and terraforming perspective, it's a big shift.

The Obama Administration through the NASA COTS program has invested in the success of Space X and Orbital Sciences Corporation, private ventures that the US government supports for the post space-shuttle era. On December 22, 2008, NASA announced it would discuss the contract selection to provide commercial cargo resupply services for the International Space Station (NASA 2008a), and then at a press conference on December 23, 2008, NASA announced the awarding of contracts to both Space X and Orbital Sciences Corporation (NASA 2008b). The contracts include a minimum of 12 missions for Space X and 8 missions for Orbital Sciences (Morring 2008 n.p.).

In parallel with the above efforts, the space policy of the Obama Administration was announced by the President at a press conference held on April 15, 2010 at Kennedy Space Center (Chang 2010). The President committed to increasing NASA funding by US$6 billion over five years and completing the design of a new heavy-lift launch vehicle by 2015 and to begin construction thereafter. He also predicted a US-crewed orbital Mars mission by the mid-2030s, preceded by an asteroid mission by 2025, making NASA still a major player in the exploration of deep space, but not sub-orbital or low Earth orbit.

As these events and policy directions opened up, the current research team decided to investigate the social, commercial and governmental policy drivers of other major adventurous explorations in human history to see whether these apparently new turns in space exploration history actually sit on a continuum of human exploration, and if so, what implications this has for forming new policy.

The story so far

The *NASA Astrobiology Roadmap* published three years ago 'provides guidance for research and technology development across the NASA enterprises that encompass the space, Earth, and biological sciences' (Des Marais et al, 2008: 715). The authors, and by extension the US space agency itself and its international member associates in the European Exo/Astrobiology Network Association (EANA)[5], say they seek to address the questions 'how does life begin and evolve, does life exist elsewhere in the universe, and what is the future of life on Earth and beyond?' But the *Roadmap* has a deeper meaning and function. It has the hallmarks of a document early in the 'policy cycle' (Bridgman & Davis, 1998:21) of

[5] Austria, Belgium, Denmark, Finland, France, Germany, Hungary, Italy, Portugal, Spain, Sweden, Switzerland, The Netherlands, Poland, Romania, Russia, and The United Kingdom, (c.f. http://astrobiology.nasa.gov/nai/international-partners/active/eana/)

space, prepared by advocates and a special interest group with a certain position not just on ‘what’ should be done, but also ‘how’ and ‘in what order’, effectively setting priorities which will inevitably be operationalised in funding allocations by national governments and public and private corporations. While the *Roadmap* is only one of many proposals seeking to influence what humans should do in space and why they should do it, it carries significant weight. Since that publication, however, a gap has remained in the literature concerning any further theoretical or epistemological discussion of policy issues in the *Roadmap* or its precursor documents. The diversity of the astrobiology community suggests it is unlikely that this gap signals universal acceptance of, or at least acquiescence to, the *Roadmap,* its goals and its fundamental approach, so the current authors have undertaken a review of the document and a retheorisation of the *Roadmap* concept regarding exploration of space.

Deconstructing the *Roadmap*

The *Roadmap* authors (Des Marais et al, 2008) address their three fundamental ‘life’ questions – ‘how does life begin and evolve, does life exist elsewhere in the universe, and what is the future of life on Earth and beyond?’ – by setting what they call ‘seven science goals’: 1. understanding the nature and distribution of habitable environments in the universe; 2. exploring for habitable environments and life in our own Solar System; 3. understanding the emergence of life; 4. determining how early life on Earth interacted and evolved with its changing environment; 5. understanding the evolutionary mechanisms and environmental limits of life; 6. determining the principles that will shape life in the future; and 7. recognizing signatures of life on other worlds and on early Earth. From these seven science goals flow 18 science objectives: 1.1 – Formation and evolution of habitable planets. 1.2 – Indirect and direct astronomical observations of extrasolar habitable planets. 2.1 – Mars exploration. 2.2 – Outer Solar System exploration. 3.1 – Sources of prebiotic materials and catalysts. 3.2 – Origins and evolution of functional biomolecules. 3.3 – Origins of energy transduction. 3.4 – Origins of cellularity and protobiological systems. 4.1 – Earth’s early biosphere. 4.2 – Production of complex life. 4.3 – Effects of extraterrestrial events upon the biosphere. 5.1 – Environment-dependent, molecular evolution in microorganisms. 5.2 – Co-evolution of microbial communities. 5.3 – Biochemical adaptation to extreme environments. 6.1 – Effects of environmental changes on microbial ecosystems. 6.2 – Adaptation and evolution of life beyond Earth. 7.1 – Biosignatures to be sought in Solar System materials. 7.2 – Biosignatures to be sought in nearby planetary systems.

The roadmap suggests four basic principles which its authors say are 'fundamental to the implementation of NASA's astrobiology program' (Des Marais et al, 2008: 716): that astrobiology 1. … is multidisciplinary in its content and interdisciplinary in its execution. Its success depends critically upon the close coordination of diverse scientific disciplines and programs, including space missions; 2. … encourages planetary stewardship through an emphasis on protection against forward and back biological contamination and recognition of ethical issues associated with exploration; 3. … recognises a broad societal interest in its endeavors, especially in areas such as achieving a deeper understanding of life, searching for extraterrestrial biospheres, assessing the societal implications of discovering other examples of life, and envisioning the future of life on Earth and in space; and 4. The intrinsic public interest in astrobiology offers a crucial opportunity to educate and inspire the next generation of scientists, technologists, and informed citizens; thus a strong emphasis upon education and public outreach is essential.

Nowhere in the *Roadmap* document, however, do the authors attempt to resolve the pragmatic question: 'how will the investigation of these questions be enabled?' This is neither surprising nor unusual since even a general understanding of the 'policy cycle' suggests there are 'three primary policy contexts: the context of influence; the context of policy text production; and the context of practice' (Hatcher & Troyna 1994: 196) or more simply, 'politics, policy and administration' (Bridgman & Davis, 1998:22). The *NASA Astrobiology Roadmap* clearly sits in the first stage, the context of those with, or seeking, influence, and the context of political manoeuvring. Here is a group of eminent researchers, and a major US government agency, stating their considered position in an attempt to exert influence on government policy writers, who in turn will produce texts which will need to be put into practice through legislation and budgetary allocation. Essentially, the 'how' question is outside the scope of Des Marais et al (2008). However, it should not be outside the scope of astrobiology scholars. In the second stage of the policy cycle, the text production, policy writers assemble and compare all the submissions from those diverse interested parties, weigh up and prioritise the values they represent, and identify the main drivers and constraints of every proposal. But they do this with a purpose, which is the ultimate adoption of the policy by the decision makers. The ultimate decision makers, politicians, are tasked with adoption, amendment or rejection of each and every policy and if astrobiology policy is to be adopted, these individuals and party organisations need to see clearly how it can be implemented or enabled. No effective policy writer seeks to produce a text which is impossible to implement, so for any given policy, those charged with adopting it, or not, need

to see and understand the means by which it will be implemented. This is especially true for space policy, since, as Bridgman & Davis note (1998:34, citing Cobb & Elder 1972) 'issues have most prospects of attracting the attention of politicians when the topic has mass appeal'. The *Roadmap* itself notes, in Basic Principle Number 4, that space policy has mass appeal – not the least being the excitement of a launch and a possible touch-down on a remote planet. However it also has mass opposition, especially persistent community complaints about the enormous expenditures necessary for research and development and the final implementation of building a space station or financing a long-term exploratory mission.

In political terms, a fundamental driver of all policy implementation is value, while the fundamental constraint is cost, most often determined by the forces of the financial markets (Bridgman & Davis, 1998:33). Value can be an abstract term relating to intangibles such as many people 'value honesty and simplicity … or knowledge', or it can be a highly quantified term use by people when they pay certain amounts for services or commodities. How value is set up, or 'created', is unclear, since as Lepak, Smith & Taylor note (2007:180) 'there is little consensus on what value creation is or on how it can be achieved':

> Although the definition of value creation is common across levels of analysis, the process of value creation will differ based on whether value is created by an individual, an organization, or society.

Value creation is especially difficult on space issues. The possibility of 'extraterrestrial life poses unique challenges to the boundaries, application, and confidence in our knowledge' (Lupisella 2009:186), mainly because humans, insofar as their knowledge of biology is concerned, operate from 'from what is effectively a data set of one' (p.187). This is as true for those who think about space and how to get there as it is for those who think about what might exist there and what to do about it. Some think of the vastness of space as having 'intrinsic value' (p.190) based on the value they ascribe to human life and thus 'all life', while others regard it first as having 'instrumental value' (p.190), something that can have intrinsic value but which also offers values other than itself.

One way of asserting the intrinsic value of space is to adopt a 'cosmocentric ethic' (p. 192) putting space first instead of Earth. But, as Lupisella also notes (p. 193, citing Callicott 1995) 'as with environmental ethics, an important challenge for a cosmocentric ethic is justifying intrinsic value'. The most obvious instrumental value of space is the extension of knowledge, principally scientific knowledge, and this is clearly addressed in the *Roadmap*. Resource exploitation, such as mining for helium 3, is another. There are others, however,

rarely published, such as ‘societal questions (and) cultural implications’ (Dick 2000:649): ‘such study is part of the general need for better dialogue between science and society’. Dick (p. 649, citing Wilson 1998) identifies culture as including all aspects of human existence, such as ‘religion, myths, art, technology, sports and all the other systematic knowledge transmitted across generations … culture is a product …’ He notes (p.650) that the *Roadmap* (he was working from an earlier, 1999, version) gestured towards culture in Part 3 of its definition of astrobiology, which ‘recognises a broad societal interest in its endeavors’ but like the current researchers, suggests that this gesture has been all but lost in the science. Elsewhere, he reminds readers (Dick 2004:6) that another instrumental value of space is as a place to explore, and that this sits on a long continuum in human history: ‘many societies have (decided to explore) in cases such as Columbus, Captain Cook, Lewis and Clark, Darwin and the *Beagle*, the US Exploring Expedition, and by those countries involved in the Space Age to a greater or lesser extent … The motivations have been varied: curiosity and the search for knowledge, the promise of riches, population expansion, and nationalism.’ He continues (p.6): ‘… as a policy issue with many competing interests, the decision (of whether to explore space) must rest with the society and its leadership.’

With these issues in mind, we have formulated a research question: historically, how have societies and their leaders valued exploration of remote sites?

Historical policy settings for exploration

As Dick notes, the anticipated value (‘promise’) of riches, population expansion and nationalism have motivated explorers. But the historical discourse suggests that, of these, the promise of riches, principally from commodity exploitation, has been the fundamental driver, since the riches have enabled population expansion to occur, and have also used nationalism as a screen. ‘Profit and power ought jointly to be considered,’ said Sir Joseph Child centuries ago, governor of the East India Company (Newman 2005:78).

European exploration and colonisation grew parallel with available financial resources and these were more often than not market-based, even if they bore the hallmarks of royalty and nationalism. Exchanges were established, such as the court hall exchanges in Antwerp and Amsterdam, where a ground-floor market was set up for open stands selling goods, and commodity trading stalls were set up on the second floor (Coleman 2006:25). London built its Royal Exchange in 1568 and another went up in Exeter (p.25). A similar but diversified concept sprang up in Italy, London and Paris during the 17th century, when traders such as shops, pubs and coffee shops occupied the first floor of many premises (p.26).

Garraway's Coffee House at No. 3 Exchange Alley, off Cornhill near London's Royal Exchange (Newman 2005:84), was one such place 'where influential citizen's gathered' to trade. Historian Peter Newman (2005:85) records that Garraway's was the site, in 1651, of the first tasting of tea in England, brought by the East India Company. It was also the site, in 1672, of the first auction of Canadian beaver pelts delivered by the Hudson's Bay Company (p.85), using a method which sounds familiar to many modern bidders on the EBay website … auctioning to a time deadline. In this case, as Newman explains (p.85):

> Bidding was 'by candle', in which one of two procedures was used to determine the buyer. A one-inch candle was lit, an upset price of seven shillings was called, and bids were made on separate lots of furs; the highest bidder at the point when the candle guttered out got the goods. Alternatively, a pin was stuck into the tallow and the last bidder before it fell out was declared the purchaser.

The important 'charter' companies, essentially 'joint-stock' arrangements which received royal sanctions in different countries during this period, included: 'the Hudson's Bay Company (in what is now Canada); the East India Company, chartered by Elizabeth I on Dec 31, 1600; the Dutch East India Company (1602); the Danish East India Company (1634); and the French East India Company (1664) … scores of smaller enterprises were chartered to exploit the Antilles, Bermuda, Senegal, the West Indies, Cape Verde, Virginia … (and) the Royal Africa Company' (Newman 2005 pp. 59, 74, 78, 92, 112). Severin (1973:60, 63) notes the key role played by the Royal African Company in exploring and exploiting Gambia. Indeed, some of these companies were used by rulers to subsidise parliaments (Newman p.112) and paid dividends to William III in 1690 (p.92), effectively in return for legislative protection (p.91). England's Prince Rupert effectively founded the Hudson's Bay Company (p.77) by subscribing to 3 percent of its initial capital. Earlier the royal patronage of Prince Henry 'the Navigator' in 1460 and his nephew Alfonso V, as well as the 'great German and Italian banking houses' (p.230) greatly assisted with the commercial arrangements for colonising and exploiting resources in the Cape Verde islands and Sierra Leone, as well as the great vision of the Americas (Parry 1981:107-108).

Travel and the subsequent publication of travel and adventure stories and illustrations also played its hand (Severin 1973:186, 188) with many expeditions receiving advance funds in return for the publication rights for manuscripts, illustrations and articles during the adventure or after it had concluded. Sportsmen read of explorers' exploits in Africa and wanted to copy them and see for themselves, even to hunt the big game which reportedly

roamed there: ‘Darkest Africa, as the blank space was promptly called, was a very obvious target for Victorian energy’ (Severin 1973, p.192). Explorers’ true stories from the space age have consistently sold well as books and movies, such as *The Right Stuff* in 1983 and *Apollo 13* in 1995.

After the Challenger shuttle explosion in 1986 the US cancelled its participation in programs that allowed civilians to participate in space missions, but on April 28, 2001, Dennis Tito became the first paying space tourist, charged US$20 million, launched from the central Asian Baikonur cosmodrome aboard a Russian Soyuz bound for International Space Station Alpha. MirCorp and Space Adventures helped organise the trip with the Russian Aviation and Space Agency. Tito had to undergo intensive training for months before the trip so that he was fit for the experience. He remained on board for eight days and orbited 128 times before returning successfully to earth. Mark Olsen had a similar trip with the Russian Space Agency in 2001. In 2005 Greg Olsen and in 2006 Anousheh Ansari paid similar amounts of money for the privilege. Billionaire software engineer Charles Simonyi became the fifth space tourist in 2007 followed by Richard Garriot in 2008. Charles Simonyi reportedly paid $35 million for his second trip to the Space station in 2009. Such trips have become a popular means of space-travel outside of the larger Government agencies, so popular in fact that the agency worried that it might not be able to grant all requests (Rob 2007).

Websites such as Space.com routinely and legitimately exploit the commercial potential of publishing photographs and first-person narratives from astronauts and space tourists. The time is at hand when private space tourists will routinely bring back and sell their own stories and images to their local news outlets for substantial sums. Perhaps a media company such as an internet service provider or a large publisher will see a profit margin in becoming a hub for such publications, just as book and magazine publishers did out of Darkest Africa.

Space exploration as infrastructure driver

In this sense, then, the first era of space exploration can be seen as only the most recent era of all human exploration, following the continuum established by the earlier sea-and-land ventures. The competitive ‘Space Race’ between the Soviet Union and the United States had all the appearances of exploration driven by nationalism but the reality was much closer to the joint-stock ventures of 500 years before, in pursuit of the promise of riches. Certainly on the United States side, government contractors such as Lockheed, Boeing and

Raytheon – in the light of the above discourse – have displayed most of the features of those chartered monopoly companies established and driven by royalty, peers and banks of the 15th-19th centuries. The nationalistic achievements of the then-Soviet Union fed and nourished state-owned companies, and state workers, at the same time as they passed milestones such as the first human spaceflight (1961), the first spacewalk (1965) and the first space station (1971). The competitive pressure from across the Atlantic drove the program to achieve the first moon landing by the Americans (July, 1969), and the investment of government funds employed at least 400,000 workers (*c.f.* Space 2009). The US government arm of the space exploration project, NASA, immediately established co-operative relations with approved ('chartered') companies rather than conduct all its research and development internally (Boeing, 2009). Over the intervening 40 years the initial apparent competition has been replaced by more tangible co-operation, such that Russia and the US, through their contractors and downstream suppliers, played vital roles in the successful functioning of the International Space Station, and expect to receive dividends in exactly the same way as the princes and monarchs of the past: scientific outcomes, taxation revenue and employment outcomes (which lead in turn to taxation revenue). The Klipper space transport vehicle being developed by the Russian Space Agency uses a design begun by the US in the 1960s (Space, 2009).

Public interest in other aspects of 'going to space as tourism' continued to be large, real and widespread (*CNN* 1998). Barron Hilton of Hilton hotels talked about hotels on the moon after the moon landing in 1969. In 1999 this hotel group hosted a symposium to determine the viability of space hotels. Microsoft has sponsored a student design competition on hotels of the future that included space hotels (*XS4ALL* n.d.). In 1996 the US Association of Collegiate Schools of Architecture (ACSA) conducted a worldwide competition for students to design the 'hotel of the future', specifically in the year 2045, held in conjunction with the firm of architects and planners Wimberly Allison Tong & Goo. Among the entries selected as finalists were two space hotel/resort designs submitted by groups of students at the State University of New York at Buffalo: one would orbit 200-250 miles above the earth's surface, 28.5 degrees from the equator and inside the Van Allen belt (ACSA 1997:56-59); the other would rest on the asteroid named Toutatis 4179 (ACSA 1997:60-63). This event has since developed into an annual competition and part of the business model for those architects (WATG website, 2011, n.p.), to the extent that space station architecture is promoted as one of their ongoing interests. Space settlement design contests are now relatively common around the world. One of the biggest and oldest is the Texas-based

International Space Settlement Design Competition launched in 1994 but with its roots in other smaller US design competitions since 1984 (International Space Settlement Design Competition website 2011, n.p.). This targeted high-school students and has prompted spin-off competitions in Australia, the UK, South America, Eastern Europe, India and Malaysia. In the US, the NASA Ames Research Center and the National Space Society (NSS) sponsor an annual space settlement design contest for 6-12th grade students (NSS website 2011, n.p.). Dutch architect Hans-Jurgen Rombaut has proposed a hotel on the moon called the 'Lunatic'[6] (Albrecht 2002: 83).

The launch and flight mechanisms for space tourism have developed a more or less viable business model. Space Adventures, the company involved with the trips on the Russian Soyuz, has provided zero-gravity flights in Russia since 1994. Between 2000 and 2002, 50 tourists flew to 25km above the Earth. The reported revenue from these flights was US$18.5 million over seven years (Collins 2002). The Tauri Group was commissioned by the Personal Spaceflight Federation to provide a summary of the industry in the USA in 2007 (Tauri Group 2008). At that time the spaceflight industry employed 1,227 employees, with 993 of these involved in hardware sales development and support services, e.g. rocket motors to a military client and small satellite development. Less than 50 were solely in spaceflight services. The revenue from the personal spaceflight industry was $175 million in 2006 and $268 million in 2007, almost a 50% growth. More than 70% of this revenue was accounted for by hardware services. The total investment committed to the personal spaceflight industry was $1.2 billion of which 25% had been spent by the end of 2007. The personal spaceflight service revenue included deposits for future launchers in sub-orbital flights and also orbital services which only accounted for one per year. Entrepreneur Jim Benson said that at the bottom line, his adventures into space travel had to make a profit (Benson 2002).

Virgin Galactic

All of the businesses examined in this current study aim to be profitable, but one enterprise has attempted the elusive combination of 'rich *and* famous': Virgin Galactic, part of the Virgin venture capital group founded in 1970 and led ever since by British adventurer Sir Richard Branson. Our research team arranged to meet and interview the leadership of Virgin Galactic and hear first-hand, unmediated by corporate documents, this company's business drivers.

[6] The design formed part of Rombaut's Master's thesis at the Rotterdam Academy of Architecture (p.83)

Will Whitehorn

On September 21, 2010, our team's lead author met Mr Will Whitehorn, then outgoing President of Virgin Galactic, at the company's London offices at 6 Half Moon Street, Piccadilly. Mr Whitehorn explained the current position of Virgin Galactic's space tourism operations[7].

By mid-2010, about 380 individuals had booked reservations on the company's future space flights, paying deposits of between US$20,000 and US$200,000. Mr Whitehorn said single flight tickets cost US$200,000 each. Total deposits received had just exceeded US$50 million. More than 85,000 people from 125 countries had registered their interest in becoming a Virgin Galactic astronaut[8].

At the time of interview, 38 countries – Andorra, Argentina, Australia, Belgium, Brazil, Chile, Colombia, Croatia, Cyprus, Denmark, Dominican Republic, Finland, Greece, Hong Kong, Italy, Korea, Liechtenstein, Luxembourg, Mexico, Peru, Russia, Sweden, Switzerland, The Netherlands, Ukraine, Austria, Canada, Czech Republic, Germany, India, Israel, Japan, New Zealand, Portugal, Spain, United Arab Emirates, United Kingdom and USA – have been named by Virgin Galactic as sites of ticket booking offices for their space flights[9].

Mr Whitehorn said Australia was in the top echelon of countries for space tourism bookings after the US and UK. He put that down to its huge area and expanse of starry skies. He said that as far back as the Aboriginal heritage and Dreamtime the stars had played a huge part in the Australian experience.

He noted that Virgin Galactic is a US registered company acting under US law and the US regulatory environment. The reason for this is the US is the only country with a regulatory structure which he said 'can cope' with what Virgin Galactic wanted to do, including a framework for citizens to give informed consent to fly into space. This regulatory structure had its basis in the *Commercial Space Launch Amendments Act 2004*.

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[7] For company background see http://www.Virgin Galactic.com/

[8] By time of writing, total bookings had reached 430, according to the website

[9] Since our team is predominantly Australia, we had also investigated the position of local astronauts: An Australian woman from the state of New South Wales had been among those who had booked a fully-paid ticket on the company's 'SpaceShipTwo' and expects to be among the first 100 customers to fly (Spencer & Killeen 2008). Three other tickets had been sold in Australia at time of writing – one each in the mining-boom state capitals of Perth, Western Australia, and Brisbane, Queensland, and a third unidentified at time of writing: these three had booked and paid deposits on tickets further 'down the queue' (with deposits from $US20,000 to $US175,000). At least 13 travel agents in Australia had registered with Virgin Galactic to retail these and more tickets: one agency in Perth, six in New South Wales, five in Queensland and one in Victoria (Virgin Galactic 2008). At least one other Australian is known to have booked with Virgin direct through its website (Killeen 2008).

Mr Whitehorn said the reason that *Act* was amended that year was the Ansari X-Prize, the $10 million prize awarded to aerospace engineer Burt Rutan and his sub-orbital spaceplane SpaceShipOne, for becoming the first privately funded spacecraft to enter the realm of space twice within a two-week period. Mr Rutan's achievements had been backed by Microsoft co-founder Paul Allan with $30 million to spend on his carbon composites-design craft because he believed aluminum would be superseded as the preferred material for spaceflight. That year Virgin Atlantic also flew its *Global Flyer* (with the late adventurer Steve Fossett at the controls) around the world on a single tank of fuel. The Virgin Group's Sir Richard Branson proposed a merging of the programs and bought in. Mr Whitehorn said Mr Rutan was due to retire in 2011.

Virgin wanted to explore the space tourism market and purchased a 2002 report by Futron Research commissioned by NASA to scope the market. The report concluded there was at the time a market for space tourism at and below the US$200,000 mark, rather than the US$20 million being paid by earlier space tourists to fly on a Soyuz rocket to the international space station and act as a crew member. Mr Whitehorn compared this earlier kind of space tourism to the 18th century British naturalist Joseph Banks buying his ticket on Captain James Cook's epic voyage of discovery resulting in the European settlement of New Zealand and Australia. Instead of having to give up a year of your life, learn how to speak Russian and work as a crewmember (like a space explorer) he said the Virgin Galactic experience would be like the scuba-diving of space, where, with two days' preparation, testing to endure some G-force, healthy but not super-fit, tens of thousands rather than tens of people could enjoy the experience. Mr Rutan has written that 'we need affordable space travel to inspire our youth, to let them know that they can experience their dreams, can set significant goals and be in a position to lead all of us to future progress in exploration, discovery and fun' (Virgin Galactic booklet 2010, *Your Journey into Space Starts Here*).

In September 2004 Virgin Galactic bought the rights to commercially exploit the space tourism concept and in 10 months had accumulated $10 million in deposits (all of which are guaranteed returnable if the project does not proceed, Mr Whitehorn said). No government funding had been received by Virgin Galactic for the project.

Mr Whitehorn said Virgin Galactic was looking for what some observers called 'the Netscape moment', a paradigm-shifting point such as the 1993 IPO of the Netscape web browser company. He said he thought it was extremely unlikely that government funding would be the key to advancement into space, and that privately funded ventures such as Virgin Galactic would make the most progress. At the core of the Virgin Galactic business

model is the use of the launch vehicle WhiteKnightTwo, renamed VSS *Eve* after Branson's mother, and the suborbital passenger vehicle SpaceShipTwo, renamed VSS *Enterprise*, to take six paying space tourists – each with two large windows near their seat – and two pilots on short-duration sub-orbital flights.

The company says VSS *Enterprise* is being designed to meet 'safety and comfort levels necessary to enable a wide diversity of passengers to become astronauts without specialist skills or experience. This is the first time that a spaceship has been built with these considerations at the absolute forefront of the design and construction process.'

The company promotional booklet (Virgin Galactic booklet 2010, *Your Journey into Space Starts Here*) describes the experience as follows:

> A climb to 50,000ft before a safe air release. A brief moment of quiet then the rocket engine ignites. With awe-inspiring power, the spaceship accelerates to around 3000mph or nearly 4 times the speed of sound. You are instantly pinned back into your seat, overwhelmed but enthralled by the howl of the rocket motor and the eye-watering acceleration … Outside SpaceShipTwo's windows the soft blue atmosphere melts into the black infinity of space (then) the rocket shuts down. Instant silence. Instant weightlessness. Instant elation. … What's really getting your senses screaming now … is that the gravity which has dominated every movement since the day you were born is not there any more.

All this happens as the space craft flies through what the World Air Sports Federation (Fédération Aéronautique Internationale) describes as the Karman Line, 100km above the surface of the earth. The air release happens at 50,000ft and the maximum planned altitude is 360,000ft, or 109km, before the craft begins its unpowered glide back to Spaceport America in New Mexico. The planned maximum speed is Mach 3.5, around 4200kph (2600mph).

> The G forces quickly ease off and you hear the pilot announce the start of the glide home. You feel the feathered wings of the spacecraft producing a powerful drag as the thickness of the atmosphere increases, although out of the window it still looks like space. Later that evening, after the celebrations and being awarded your astronaut wings, you know that life will never be quite the same again.

Mr Whitehorn said that Virgin Galactic had no competition in this market. In fact, the company has adopted the motto: 'Space is Virgin Territory'. He said there had been no other successful launches and other companies such as Boeing were '5-8 years away' from any significant developments, while another potential competitor, Rocketplane Kistler, Inc. had

on June 15, 2010, filed for Chapter 7 bankruptcy in the Eastern District of Wisconsin in the United States.

Pressed to discuss other possible revenue opportunities, Mr Whitehorn suggested that the company was considering opportunities to conduct sub-orbital life science experiments for NASA, including pharmacy developments, which until now had been conducted mostly using sounding rockets or in experiments on the International Space Station. Some RFPs (Request for Proposals) have been issued by NASA.

He also mentioned the possibility of using SpaceShipTwo as a satellite launch system but said that will require a whole new development process. 'Space is a place we can put server farms and gather solar power. But access is the key,' he said.

Mr Whitehorn was (in September 2010) then about to hand over to new Virgin Galactic President George T. Whitesides. This would coincide with the commissioning in October of the first runway at the New Mexico, US, Spaceport America, near the White Sands Missile Range. The SpacePort is receiving development funding from the US state of New Mexico, and Virgin Galactic has also just signed up as the SpacePort's 'anchor tenant' with a 20-year lease.

George T. Whitesides

It was October 28, 2010: Incoming Virgin Galactic President George T. Whitesides had just witnessed the second glide flight of SpaceShipTwo. Years of preparation and planning were beginning to take material form in the skies above the Mojave Air and Space Port in California. The runway had been inaugurated a week earlier, on October 22, for the glide tests, and Virgin Galactic had also just signed a 20-year anchor tenancy with the space port management. Mr Whitesides was appointed president in May 2010, and was previously chief-of-staff at NASA and a former executive director of the US National Space Society

Our research team wanted to know what the space-port experience would be like for Virgin Galactic's astronaut customers and their families, as well as for the thousands of visitors expected to throng to the desert launch site. After all, visitors are a big part of the launch experience around the Kennedy Space Centre NASA launch site at Cape Canaveral in Florida. And even though this involves space travel not aircraft travel, the Virgin Group offers a consistent customer experience from its airline groups around the world. The revenue models for Virgin airlines in Europe, the US and the Pacific include sale of snacks and drinks and in-flight internet and telephone communications and terminal experiences such as guest

lounges and frequent flyer points. 'What kind of experience would visitors to the Virgin Galactic terminal have?' Mr Whitesides was asked.

'That's a good question and we're thinking about that right now,' he replied. 'There are some RFPs (requests for proposal) out right now on that subject.' *NewSpace Journal* reported on October 22, 2010[10]:

> Rick Homans of the New Mexico Spaceport Authority said that the development of Spaceport America is now in a 'very complex' phase, as it transitions from construction to operations over the next year. The authority will soon issue a series of RFPs for operational-related activities, from security to visitor services, and is actively seeking a deputy director who will be responsible for spaceport operations.

'We're trying to figure out what makes the most sense,' Mr Whitesides said. 'The core experience (the suborbital space travel) will be pretty fabulous but there will probably be an additional something in the terminal. There will be sightseers and tourists and the New Mexico Spaceport Authority (NMSA) is engaging with those issues now. We pay a licence fee to the NMSA and it's for a pretty big area. I imagine there will be a higher level of visitors … quite a lot of people.'

Theme parks and airports have this in common that they are basically shopping centres with attractions or runways attached (Coleman 2006:242) and both kinds of installation routinely sells memorabilia or experience packages[11] such as souvenir pictures and trophies.

Associated revenue models

Revenues from spaceport retailing and ancillary facilities may become important factors in customer and visitor satisfaction as they are developed and put into operation. Depending upon the success of the commercial space tourism industry, the need to find more revenue to invest may lead to an explosion of spaceport retail outlets which cater for space tourists. The retail revolution has been ongoing in the United Kingdom (UK) for the past 10 to 12 years in airports, since the privatisation of the UK's major airports. Investing in new revenue streams may help fund extra capacity which, in turn, may increase customer and visitor numbers and improve the space travellers' experience, thus creating greater revenues and creating more capital to fund spaceport operations.

[10] http://www.newspacejournal.com/
[11] See http://bne.com.au/corporate/brisbane-airport-experience-centre, retrieved Nov 18, 2010

The trend into the future may follow that of major airports worldwide. This trend is towards specially designed shopping malls. No longer will anything be left to chance or retail outlets stuffed into spare corners. This will require a study of every aspect of the retail customer from flow to perceived customer spending ability and be used to facilitate the development of retail concessions. The importance of retailing at the Spaceport Visitor Center will be of significant importance. For example, one of the major players in airport retailing is the British Airports Authority (BAA), privatised in 1987 by the Thatcher government. It owns seven UK airports, including London's Heathrow, Gatwick and Stansted, and has equity shares and management agreements at airports in the US, Australia, Italy and Hungary. In the UK BAA serves 142 million passengers and another 96 million globally at 11 airports. In 2005 BAA's total revenue (aviation and non-aviation) was $1.7 billion. Over half of this came from airport retailing. To generate money to invest in the business, commercial revenues are vitally important, as will be the case for the Spaceport America Visitor Center and terminal building. How effectively Spaceport America designs and operates these facilities will surely have a major role in the successful operation of Spaceport America.

Constructing the infrastructure

In December 2008, the New Mexico Spaceport Authority received its launch license for vertical and horizontal launches from the Federal Aviation Administration's Office of Commercial Space Transportation (New Mexico Spaceport Authority 2008). As anchor tenant for the hangar facilities (Spaceport America 2010), Virgin Galactic had agreed to pay US$1 million per year for the first five years, as well as payments on a tiered scale, based on the number of launches the company achieves. As of February 2010 the budgetary estimate for completion was US$198 million.

The Spaceport America site consists of an area of approximately 670,000sq.ft., with the terminal and hangar facility consisting of approximately 110,152sq.ft. The western zone of the spaceport (approximately 25,597sq.ft.) houses support and administrative facilities for Virgin Galactic and the New Mexico Spaceport Authority. The central zone includes a double-height hangar (47,000sq.ft.) to store the spacecraft. The eastern zone (29,419sq.ft.) includes the principal operational training area, departure lounge, spacesuit dressing rooms, and celebration areas. There is an onsite restaurant and mission control rooms that have direct easterly views across the apron, runway and landscape beyond. A visitor centre is planned in

downtown the closest town, named Truth or Consequences, and will provide shuttle bus services to and from the Spaceport.

When Spaceport America opens for business, up to one launch is planned per week, progressing to daily liftoffs. Virgin Galactic will have primary access to the 10,000ft (3000m) runway. From here, Virgin will operate approximately 2-3 hour commercial flights on an on-going basis. Customers will take part in 3 days pre-flight preparation, bonding, and training at the spaceport before their planned departure.

Track record

Of particular note in this study is that many of the entrepreneur/investors in prominent companies involved in commercial space travel and tourism have previously made fortunes in areas other than space travel. Jim Benson (Benson AeroSpace and Space Dev) pioneered computer mainframes, Elon Musk (Space X) started PayPal, Jeff Bezos (Blue Origin) began Amazon.com. Richard Branson (Virgin Galactic) heads the Virgin Group of companies, while Jim Bigelow (Bigelow Aerospace) made his fortune in real estate. Jim Benson believed that private companies were the most efficient way to advance the area of space travel (Benson 2002). He believed in the survival of the fittest and that only the better ideas would succeed. Elon Musk started SpaceX because he wanted to help reduce the cost of space transportation so it would be feasible to establish life on another planet. SpaceX optimises not only the launch costs but also the cost of developing and manufacturing rockets (Chafkin 2007). The space tourism companies are interested in a venture that is profitable.

Summary

The preceding case studies suggest a strong and clear correlation between contemporary space exploration and the historical revenue models for large-scale adventurous exploration projects: investment from institutions such as banks, corporations and individuals seeking to exploit the outputs of explorations (tangible commodities such as spices, slaves, coffee and fibres), intangible commodities such as media products (images, soundtracks, books and articles), hospitality products (tours, accommodation and ancillary services) and finally investment from governments (especially monarchies). The historical record suggests that by providing capital for infrastructure such as vehicles (ships), launch facilities (docks and ports) supplies and equipment, it was the governments which enabled a new business and revenue model to develop for those individuals or organisations (companies) involved in boat building, equipment manufacturing, food and stores

provisioning, and garment manufacture – new revenue opportunities that were directly related to the process of exploration.

We have developed the following hypothesis from this exploration:

H^1: that government intervention is required for large-scale adventurous exploration to proceed, particularly in the realm of space exploration. We now proceed to test this hypothesis using available financial and qualitative data from 21st century space-involved companies.

Methodology

A desktop and library review was conducted of commercial enterprises involved in space flight, space exploration or space component or services development. Data was drawn from a range of space-focussed sources (books, magazines, websites, articles and 'grey literature'[12]) and the *Google Finance* website in 2009 (http://www.google.com/finance) which reports and aggregates data from significant international stock exchanges[13]. Search terms were 'space flight' OR 'space exploration' OR 'space company'. Not all space companies were included in our eventual table for reasons such as unclear or inconclusive data, or the company was apparently dormant or winding up. Our research team members made industry- and experience-based assessments in these instances which will clearly have influenced the resulting data set. However, arriving at a definitive data set of this industry at any one time is inherently problematic. Other lists of space exploration companies have been published, and this factor poses a limitation on the current study, as each data set might be more or less reliable. For instance, one list (Snyder 2011) contained 112 names in April 2011. Stock market movements also imposed limitations. Our initial search was conducted in 2009 but a test replication in 2011[14] of the *Google Finance* search discovered 36 entries using the search term 'space flight', 11 using the search term 'space exploration' and 1146 using the search term 'space company'. Another limitation on the data was the different access available for international researchers such as our team to public and private companies in a

[12] Circulating or stored and otherwise unpublished documents, see http://www.une.edu.au/library/eskillsplus/research/grey.php, viewed July 5, 2011

[13] The American Stock Exchange, Australian Stock Exchange, Bank of Canada, Bombay Stock Exchange, Canadian Venture Exchange, Dow Jones Indices, Euronext [Amsterdam, Brussels, Lisbon, Paris], Frankfurt Stock Exchange, FTSE Indices, Hang Seng Indices, Hong Kong Stock Exchange, London Stock Exchange, Milan Stock Exchange, Morningstar (Mutual Fund), NASDAQ Indices, NASDAQ Stock Exchange, National Stock Exchange of India, New York Stock Exchange, New York Stock Exchange Indices, New Zealand Stock Exchange, Nikkei Indices, S&P Indices, Shanghai Stock Exchange, Shenzhen Stock Exchange, Taiwan Stock Exchange, Telekurs, Tokyo Stock Exchange, Toronto Stock Exchange, and the XETRA German Electronic Exchange.

[14] April 5, 2011

range of jurisdictions: the US, the UK, various European and Asian nations, and Australia. Companies involved with private space travel are based primarily in the US, with the exception of the Russian-based S.P. Korolev Rocket and Space Corporation, 'Energia', described by *Google Finance*, as

> … a Russia-based company active within the rocket and space industry. The company's operations are divided into such segments as manned space systems, unmanned space systems, rocket systems, advanced programs and provision of services. It is the prime contractor for manned space stations and cosmonautics, rocket systems, manned spacecraft and unmanned space systems. In addition, the Company is involved in the production and sale of non-space products such as modules, assemblies and parts for prosthetic-orthopedic products, sophisticated electronic household appliances, electric transport facilities and others. It has 11 subsidiaries and seven affiliated companies. The Company is in 38.22% owned by Federal Agency for Federal Property Management (*Google Finance* 2011).

The data we selected is presented in Appendix Tables 1-3 and summarised and analysed in the Findings section.

Approach

A qualitative approach was adopted as the primary method to provide an enhanced level of insight into the data, which may be of value in understanding the underlying nature of the information, which a statistical analysis alone does not reveal. Trochim (2001) notes that qualitative research has special value for investigating complex and sensitive issues such as human sexuality or gun control or where a quantitative approach would only serve to summarize the key positions on the issue. The general list of space-involved companies was divided into companies: (a) mainly concerned with space vehicles and space flight (end-users); and those (b) mainly concerned with components (innovators) and infrastructure. Where available, we correlated these with company financial details.

> The detail in most qualitative research enables you to describe the phenomena of interest with great richness, in the original language of the research' (Trochim 2001: 152-153).

This is a particular strength of the qualitative approach. It can be extremely useful when the researcher is seeking to understand the historical drivers of the companies being studied. Qualitative studies have a number of aspects related to the nature of the data being analyzed. The quality of the data available itself, the nature of the study environment and

population studied, geographic issues, and related bias and development of all aspects related to the data itself (Trochim, 2001).

As an auxiliary and complementary resource we also conducted analysis using the Wordle Tag-Cloud generator[15], supported as a research tool 'that can allow researchers to quickly visualize some general patterns in text … The visualization allow researchers to grasp the common themes in the text, and sometimes even to find out main differences between sets of responses' (McNaught & Lam 2010:641). This online 'visualisation engine' uses an algorithm to weight and then sort and display words in an analysed passage of text to show which words are used most often and most powerfully (see Viegas, Fernanda; Wattenberg, Martin; & Feinberg, Jonathan 2009:1144 for technical explanation). Overall, Wordle has limited but effective use provided this use is rigorously circumscribed: 'word clouds can be a useful tool for preliminary analysis and for validation of previous findings' (McNaught & Lam 2010:642). The text we analysed was the various descriptions about each company which we collected from the wide-ranging books, journals and grey-literature search conducted in 2009. The built-in limitation of this approach is acknowledged: while the descriptions were collected from a range of authors, a degree of summarising by the researchers has inevitably taken place, so the texts are in no-way verbatim documents from outside sources. McNaught and Lam (2010:641) note that 'the (Wordle) strategy works best for analyzing text in which the full text of each informant's speech is preserved':

> In other words, it is less meaningful to input researchers' minutes or summaries of a focus-group meeting into the system as the frequencies of the words used will be changed.

Findings

The desktop and library review of books, magazines, websites, articles and 'grey literature' returned a total of 23 companies or other organisations in business of space exploration, development, manufacture or tourism. These companies were filtered into Appendix Tables 1 and 2. The Google Finance survey returned a total of 29 corporations where financial data was publicly available. There is some overlap between these data sets, which has not been addressed in this study. These are contained in Appendix Table 3.

[15] http://www.wordle.net/, accessed on July 4, 2011

The desktop literature study

The 23 organisations were filtered into Tables 1 and 2 on the basis of whether the company/organisational description suggested it was mainly concerned with manufacturing space vehicles and space flight (in our typology, manufacturing for 'end-users' in the space business), or mainly concerned with components, innovations and infrastructure such as space ports (in our typology, manufacturing as part of the space supply chain). Seventeen organisations were grouped in Table 1, and six in Table 2. We were able to review that decision using the images generated in Wordle. The visualisation of Table 1 is shown here, as Figure 1. This suggests to us a strong textual emphasis on commercial development of 'space', focussing on flight, tourism, and enabling technologies. Deeper analysis of these terms suggests a concentration on the motivations for such work, and focussing on the perceived intrinsic value of space flight and exploration.

Figure 1: Wordle visualisation of Appendix Table 1.

The visualisation of Table 2 is shown here, as Figure 2. This suggests to us a strong textual emphasis on commercial development and sale of terrestrial engineering works and products, focussing on who will do the work, how that work will proceed and for what returns on investment. Deeper analysis of these terms suggests a focus on the perceived instrumental value of space flight and exploration as a revenue earner for companies involved in the supply chain.

Figure 2: Wordle visualisation of Appendix Table 2.

The Google Finance study

Numerical analysis of Appendix Table 3 suggests that the best performer in terms of net profit margin is the Guizhou Space Appliance Company, which claims a net profit margin of 22.59%, and the worst performers were Aerosonic Corporation, which showed a net profit margin of -26.05% and Loral Space & Communications, at -22.69%. Four companies dominated the two areas of (1) gross profit and (2) total revenue in 2009, and they dominated in identical order: top of the rankings was United Technology Corporation (which specialises in turbines and space propulsion), followed by Lockheed Martin Corporation (advanced technology systems and products), the Northrop Grumman Corporation (integrated systems and space technology) and Raytheon (space systems). Analysis of the areas of R&D and manufacture also completed agreed, suggesting that involvement in turbines and space propulsion would provide the most reliable business opportunity, followed by advanced technology systems and products, integrated systems and space technology and finally space

systems. The results diverged slightly when net profit margins were considered. The positive range of approximately 7.5% to 8.5% for Raytheon, United Technology and Lockheed Martin weighed against the -3.78% net margin loss for Northrop Grumman in 2009. This might be explained by structural imbalances within space businesses allowing for better profits to be made in turbines and space propulsion, space systems, and advanced technology systems and products, but limiting available profits from integrated systems and space technology. We note that since our data analysis, Northrop Grumman has delivered stronger results (see Northrop Grumman 2010).

The numerical analysis of the *Google Finance* data is supported by the textual analysis through the Wordle visualisation of company descriptions in Table 3, shown here, as Figure 3. This suggests to us a strong textual emphasis on commercial development of systems, products, assemblies and components. Deeper analysis of these terms suggests a focus on the perceived instrumental value of manufacturing for space development, as a revenue earner for companies involved in the supply chain.

Figure 3: Wordle visualisation of Appendix Table 3.

Discussion and conclusions

The pre-existing research of historical case studies suggested that governments were required to enable the business and revenue models for individuals or organisations (companies) to become involved in the transportation building, equipment manufacturing, food and stores provisioning, and garment manufacture to enable the process of exploration. This is supported by the approach that exploration and discovery is valued as an instrumental

good which can be measured in revenue and profit margins accrued by the stakeholders involved. Our contemporary case study research suggests that space exploration is being measured by community stakeholders as an intrinsic good: that space can be valued as a territory to be experienced and enjoyed. However, the same process of experiencing and enjoying the territory of space is driving and enabling other stakeholders to value space as an instrumental good, one which can be used to produce revenue and profits through manufacturing flight components and launch systems.

Policy implications

This is the beginning of the third era of space exploration and our research suggests it is being funded by private, corporate cash rather than by state-funded organisations such as the National Aeronautics and Space Administration (NASA), the European Space Agency (ESA) or the governments of the former Soviet Union. Certainly these agencies, and others like them in China and India, remain in the race. But in the first part of the 21st century, the dominant alternative motivation is profitable business rather than national pride.

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Appendices:

Table 1: Companies mainly concerned with space vehicles and space flight (end-users)

Company name	Summary of activities
1. AirLaunch (LLC, US)	Developed QuickReach a small launch vehicle. This company has had little activity in 2009 due to end of funding (RLV and Space Transport News 2009).
2. Armadillo Aerospace (US)	Founded in 2000, develops reusable rocket-powered vehicles, focussing on VTVL (vertical takeoff, vertical landing) suborbital research and passenger flights, with a view to eventually supplying orbiters. The company has recorded more than 100 flight tests using a dozen different vehicles. Clients have included NASA and the US Air Force. The company has flown vehicles at every X-Prize Cup event (Armadillo website 2011)
3. Bigelow Aerospace (US)	Based in North Las Vegas, Nevada, has successfully launched and deployed two test inflatable spacecraft. It hopes to rent out space on future stations to astronauts of some of the world's space agencies, as well as to companies that wish to carry out research or other activities in space. Bigelow Aerospace intends to spur development of a commercial space vehicle to take people into Earth orbit by offering to sign a contract worth $760 million with any company that can meet their criteria (20). Keen to promote space tourism in low Earth orbit (David 2004).
4. The Benson Space Company (USA)	Provides commercial space travel services. The company is based in Poway, California. The Benson Space Dream Chaser (also called the SpaceDev Dream Chaser) is one of the newest space tourism spacecrafts from Benson Space Company, Near the Dream Chaser launch pad, there will also be first-class hotel accommodation and a launch-viewing lounge for the families to sit in while their family member is making history as one of the first tourists to see the earth from space Benson Space is currently taking reservations for the Dream Chaser flight, which will cost in the neighbourhood of between $200,000 and $300,000. For a fully refundable security deposit of $25,000 you can book your way onto this historic flight today (Space Tourism website 2009).
5. Blue Origin	Privately-funded aerospace company set up by Amazon.com founder Jeff Bezos. Initially focused on sub-orbital spaceflight, the company has built and flown a testbed of its *New Shepard* spacecraft design at their Culberson County, Texas facility. According to company statements, it plans on placing the *New Shepard* in commercial suborbital tourist service in 2010 with flights about once a week It is now confirmed that under the current timetable, Blue Origin will fly unmanned in 2011, and manned in 2012 (David 2008).
6. EADS (European Aeronautic Defence and Space Company) Astrium	Based in Europe and United Kingdom, is a global leader in aerospace, defence and related services. Astrium, a division of European aerospace giant EADS, announced plans for the 'space jet' at the Paris Air Show in 2007, but there had been little visible progress in the vehicle's development since then, beyond some propulsion work, as Astrium tried to raise a significant amount of money, in the order of €1 billion, to proceed with the vehicle's development. According to Coppinger (2009a), Astrium decided in January to put the project on hold, blaming the 'world economic situation' for making it difficult to secure funding. (Astrium, though, has kept the space plane section on its web site.). It was considered that EADS Astrium was looking at other applications for the vehicle such as LOX/methane engines. Astrium was the exception, being a large company in a field dominated by small entrepreneurial firms that believe that they can produce at a fraction of Astrium's estimated cost (Coppinger 2009). EADS Astrium has been developing a sub-orbital space tourism jet. Despite impressive results in the field of propulsion technology the plans were recently shelved. This was a result of the current economic climate where the $ 2 billion needed for further investment was not attractive to investors Coppinger (2009b). Coppinger also cites that the Russian company Myasishchev has shelved its development of a sub-orbital tourism vehicle.
7. Excalibur Almaz,	Based in the United Kingdom, is a private spaceflight company which plans to orbit manned spacecraft, by using modernized TKS space capsules and Almaz space stations, derived from the formerly secret Soviet space program. Excalibur Almaz is based in Douglas, Isle of Man, with offices in Houston and Moscow. The company owns its spacecraft but contracts expert services, including refurbishment, launch, control, and recovery (Manta website 2009).

8. Rocketplane Global, Inc. (USA)	Founded in 2001 as an Oklahoma Corporation with a vision to be a driving force in the future of commercial space flight. Rocketplane opened its first office in Oklahoma City, Oklahoma in May 2004, with three employees and a dialup web connection. In the last five years, RGI has significantly advanced the design of XP suborbital vehicle and has reduced risk in many technological fronts. Rocketplane's vision is to create a series of highly reusable and safe space vehicles to serve the markets in the suborbital, point-to-point, orbital regions and beyond. Their spaceplane designs push the boundaries of conventional aerospace thinking and strive for high reusability and reliability, aircraft-like operations, and flexibility to serve a variety of military and commercial applications (Rocketplane website 2009).
9. Scaled Composites (USA) Burt Rutan	First privately funded supersonic manned flight. In May 2004 the company's SpaceShipOne reached the lower levels of space (64 km above Earth), and in June it reached outer space (100 km). In September 2004 SpaceShipOne repeated the feat with the weight of two additional passengers and in October of that year it successfully completed another flight to space, thus claiming the $10 million Ansari X-Prize, which required that a privately funded three-person craft successfully go 100 km into space and return.
10. Space Adventures (USA) Eric C. Anderson president and CEO	Co-founded in 1998 with several other entrepreneurs from the aerospace, adventure travel and entertainment industries and has managed the company over the past several years, selling more than $170M in space tourist flights. The company's advisory board includes Apollo 11 moonwalker Buzz Aldrin, shuttle astronauts Sam Durrance, Thomas David Jones, Byron Lichtenberg, Norm Thagard, Kathy Thornton, Pierre Thuot, Charles Walker, Skylab/Shuttle astronaut Owen Garriott and Russian cosmonaut Yuri Usachev. Space Adventures' vision is to open spaceflight and the space frontier to private citizens. Over the next decade Space Adventures hope to fly more people to space than have made the journey since the dawn of the Space Age. Their clients will fly on suborbital flights, on voyages to Earth orbit and on historic expeditions that circumnavigate the moon. Space Adventures intend to continue to lead the private spaceflight industry that it begun in 2001 with the flight of the world's first space tourist (Space Adventures website, 2009)
11. SpaceDev (USA), wholly owned subsidiary of Sierra Nevada Corporation (SNC),	An entrepreneurial space systems company that develops high performance, innovative components and systems that are changing how we get to, explore, and use space. Their products range from spacecraft actuators that power the Mars rovers, to hybrid rocket technologies that powered the first commercial astronaut to space, and from microsatellites controlled by the Internet to Dream Chaser™, a winged and piloted orbital commercial spacecraft (SpaceDev website 2009).
12. SpaceX	Established in 2002 by Elon Musk , the founder of PayPal and the Zip2 Corporation. SpaceX has already developed two brand new launch vehicles, established an impressive launch manifest, and been awarded COTS funding by NASA to demonstrate delivery and return of cargo to the International Space Station. Supported by this order book and Mr. Musk's substantial resources, SpaceX is on an extremely sound financial footing as they move towards volume commercial launches(29) SpaceX has raised an additional $15 million in funding through the sale of company stock, part of a planned $60-million round. (SpaceX website 2009)
13. Starchaser (United Kingdom) Industries	Privately held, high technology group of companies that specialises in the development, operation and commercialisation of space related products and services. Starchaser Industries enables new space related business opportunities by providing safe, reliable, affordable and reusable access to space for both the space tourism and micro-satellite launch markets. Starchaser Industries UK has been one of, possibly the only, European space tourism related company to achieve significant private venture investment and significant commercial sponsorship which has funded real development and tests of technology. The frequency of flight for any given capsule or space plane system will typically be about once per week. The fully automatic capsule will employ a single pilot, whereas the space plane will utilise a pilot and co-pilot. (NewSpaceJournal)
14. Thalis Enterprise (Germany)	The German company has had more success developing sub-orbital space vehicles. From the Talis Enterprise website comes news of a joint development agreement between the Germany space tourism company, the Swiss Propulsion Laboratory (SPL), and Space Tourism Society, Malaysian Chapter (STSMC) (Messier 2009)
15. Transformational Space Corporation (USA), known as t/Space,	Advising NASA on the agency's plans for further exploration of the moon and Mars. One of eight winners in a NASA competition to advise the agency on architecture for moon-Mars exploration and design of a crew exploration vehicle, t/Space has received two $3 million contracts from NASA since the company was founded in 2004. t/Space works with several partners such as Burt Rutan's Scaled Composites to develop its proposed technologies. The company is also raising funds to provide spacecraft serving US defence agencies, corporations, other nations, and the space tourism industry (Google Finance 2009)

16. Virgin Galactic	Described as the world's first space line, offering travellers opportunities to become one of the first ever non-professional astronauts. Virgin Galactic owns and operates its privately built spaceships, modelled on the history-making SpaceShipOne. Richard Branson, founder of Virgin Galactic, plans to begin sub-orbital flights by 2011 from a US launch pad and by 2012 from a launch pad in Sweden. The Swedish facility will be linked with the Ice Motel so that friends of the space traveller could entertain themselves with on ground activities. Also the Swedish adventure could involve the Northern lights. (De Selding 2007) Virgin's experience in aviation, adventure, luxury travel and cutting-edge design will be combined with the unique technology developed by Burt Rutan. Branson said that It is these spaceships that will allow affordable sub-orbital space tourism.
17. XCOR Aerospace	Founded in 1999, is a small, privately-held California -Corporation. Their headquarters and development facilities are located at the Mojave Spaceport and Civilian Aerospace Test Center in Mojave, California. XCOR engages in research, development, and production of reusable rocket-powered, horizontal launch vehicles for suborbital, and ultimately, orbital, commercial space industry. They are only the second organization to receive a Reusable Launch Vehicle mission license from the FAA's Office of Commercial Space Transportation (AST), and continue to engage in regulatory review with the FAA. They worked with industry to pass the 2004 Commercial Spaceflight Amendments Act, which provides for a moratorium on safety regulations, offers indemnification, and clarifies regulatory authority for passenger spaceflight. Building on the success of their first and second generation rocket-powered planes, XCOR Aerospace plans to proceed towards a phased development of its next generation vehicle, the suborbital RLV named Lynx, which will take a passenger and a pilot to the edge of space (XCOR website 2009)

Table 2: Companies mainly concerned with components (innovators) and infrastructure

Company/consortium name(s)	**Summary of component / innovation**
1. Joint initiative by the University of Queensland, AIMTEK and funder DARPA, an American aerospace organisation (O'Loan 2007).	Scramjet: atmospheric breathing engine that does not need to carry its own oxygen to catapult craft into the stratosphere.
2. The European firm, EADS-Astrium, in collaboration with the3 Australian National University (ANU) and the Surrey Space Centre at the University of Surrey (UK) are developing a prototype (Cox 2009).	Plasma thrusters
3. Sumio Iijima's discovery of carbon nanotubes (CNTs) in 1990 and Bradley Edward's engineering research in 2001 (Edwards & Westling 2003)	Space elevator
4. Space Island Group (website 2011)	Wants to be the first outer-space developer. Has been in talks with Hilton Hotels to build a resort modelled after the Lunar Hilton in '2001: A Space Odyssey,' The estimated construction cost: $25 billion.
5. The Oklahoma Space and Industry Development Authority has developed the first inland launch site and is the home of Armadillo Aerospace and Rocketplane (Oklahoma Space Industry Development Authority 2009).	Space port
6. The Mojave Air & Space Port , also known as the Civilian Aerospace Test Center, is located in Mojave, California; the first facility to be licensed in the United States for horizontal launches of reusable spacecraft, certified as a spaceport by the Federal Aviation Administration on June 17, 2004. Gerald Martin is the construction management firm overseeing the project. (Mojave Air & Space Port website 2011).	Space port
7. Spaceport America, New Mexico (website 2011)	Space port

Table 3: Company financial details sources from *Google Finance* in 2009

	Company	Description	Country	P/E	Total Revenue Millions USD	Gross Profit Millions USD	Net Profit Margin %
1.	Aerosonic Corporation http://www.aerosonic.com	Aircraft Instruments	Public, AMEX:AIM	1.-	20.45	3.43	-26.05
2.	Alliant Techsystems Inc http://www.atk.com/	Aerospace products: Launch systems. Involved in Atlantis Launches	Public, NYSE:ATK	18.70	4171.73	846.33	5.34
3.	Barnes Group Inc http://www.barnesgroupinc.com/	Precision components for aerospace	Public, NYSE:B	11.35	1,362.09	514.85	7.13
4.	Ducommun Incorporated http://www.ducommun.com	Components, assemblies and services for space programmes	Public, NYSE:DCO)	16.64	403.80	81.90	3.25
5.	Embraer-Empresa Bras. De Aernautica http://www.embraer.com	Landing gears, micro-assemblies with Liebherr Aerospace SAS	Public, NYSE:ERJ	8.17	6,335.20	1,343.50	6.25
6.	Esterline Tecnologies http://www.esterline.com	Thermally engineered components: elastomers and complex materials	Public, NYSE:ESL	8.50	1483.17	490.32	7.68
7.	Goodrich Corporation http://www.goodrich.com/	Aerospace components: landing gear, nacelles, brakes	Public, NYSE:GR	7.93	7,061.70	2155.50	9.54
8.	Guizhou Space Appliance Co http://www.gzhtdq.com.cn	Relay series including temperature, electromagnetic in space	Public, SHE:002025	34.68	-	-	22.59
9.	Hawk Corporation http://www.hawkcorp.com	Friction products: oils for aerospace	Public, AMEX:HWK	7.00	269.65	77.10	8.37
10.	HEICO http://www.heico.com	Electronic, microwave and electro-optical products	Public, NYSE:HEI	14.91	582.35	210.50	11.67
11.	Herley Industries http://www.herley.com/	Microwave systems and assemblies	Public, NASDAQ:HRLY	-	152.51	34.20	-6.78
12.	Hi-Shear Technology http://www.hstc.com/	Pyrotechnic, mechanical and electronic products	Public, AMEX:HSR	10.45	27.65	12.80	12.81
13.	Ladish Co., Inc http://www.ladishco.com	High-strength, high-technology forged, and cast metal components	Public, NASDAQ:LDSH	5.56	469.47	59.30	6.90
14.	LMI Aerospace Inc http://www.lmiaerospace.com	Structural components; engineering	Public, NASDAQ:LMIA	6.18	239.46	61.12	6.38

15. Lockheed Martin Corporation http://www.lockheedmartin.com	Advanced technology systems and products	Public, NYSE:LMT	10.24	42,731	4,649	7.53
16. Long March Lunch Vehicle Technology Co http://www.rocketstock.com.cn	Telemetry and measurement products, including radio telemetry systems for launch vehicles, satellite and spaceship telemetry and control subsystems	Public, SHA:600879	30.07	-	-	10.50
17. Loral Space and Communications http://www.loral.com	Satellite Manufacturing and satellite Services	Public, NASDAQ:LORL	-	869.40	81.64	-22.69
18. Magellan Aerospace corp. http://www.magellan.aero	Components, spare parts, repair	Public, TSE:MAL	1.41	684.44	97.46	1.88
19. Moog Inc http://www.moog.com	Designer, manufacturer and integrator of precision motion and fluid controls and systems	Public, NYSE:MOG.A	9.25	1902.67	609.21	6.25
20. Micropac Industries. http://www.micropac.com	Manufacturer of hybrid microelectronic circuits, solid state relays, power operational amplifiers, and optoelectronic components and assemblies	Public, OTC:MPAD	7.08	20.06	6.71	9.56
21. Northrop Grumman Corporation http://www.northropgrumman.com/	Integrated Systems and Space Technology	Public, NYSE:NOC	-	33,887	6,189	-3.78
22. Orbital Sciences Corporation http://www.orbital.com	Satellites and Space Systems Advanced Space Programs include human-rated space systems	Public, NYSE:ORB	21.00	1,168.63	212.88	3.88
23. Oerlikon Corporation http://www.oerlikon.com	Nanotechnology for space applications	Public, VTX:OERL	-	-	-	-4.36
24. Raytheon http://www.raytheon.com	Space systems	Public, NYSE:RTN	11.13	23,174	4,661	7.22
25. SIFCO Industries Inc. http://www.sifco.com	Aerospace metalwork, electrochemical finishing; turbine engines	Public, AMEX:SIF	7.85	101.39	22.23	5.47

26. Tel- Instruments Electronics Corp http://telinstrument.com	Designer and manufacturer of avionics test and measurement solutions	Public, AMEX:TIK	96.50	11.24	4.80	-2.95
27. TransDigm Group Incorp. http://www.transdigm.com	Magnetos, harnesses, actuators, compressors, pumps through subsidiary companies. Champion Aerospace and Aircraft Parts corporation	Public, NYSE:TDG	11.68	713.7	385.93	18.65
28. Triumph http://www.triumphgroup.com	Design construction of components such as mechanical control systems. Involved in Space Station	Public, NYSE:TGI	6.60	1240.38	151.41	7.89
29. United Technology Corporation http://www.utc.com	Turbines and space propulsion	Public, NYSE:TGI	11	58,681	16,268	8.61

Appendix ends here.