ORBITAL, LUNAR AND INTERPLANETARY TOURISM
opportunities for different perspectives in star tourism

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By necessity, current star tourism is an outward looking, Earth-bound and geo-centric opportunity with the observer's window to the skies constrained by his/her location. The emergent area of space tourism offers to remove such constraints. Moreover, as it visually and experientially places Earth into the context of other planets, space tourism will provide the tourist with a literally different perspective.

While the proposed sub-orbital (mass) tourism will provide a brief orbital experience, it is still largely focused on weightlessness and the opportunity of seeing Earth from orbit. Despite this, it will offer the tourist brief opportunities for viewing stars from a different point of view. True Space Tourism, be it 'real' (through tourists in space) or virtual (via pay-per-drive remote controlled rovers), moves from a geocentric opportunity spectrum to one that provides views of Earth in space as part of a suite of offerings that encompasses views of planets and stars wholly unencumbered by atmospheric disturbances that plague an observer on Earth, and also unencumbered by constraints of the spatial positioning of the observer in relation to the sector of the universe viewed (as the viewing platform either orbits or is geo-stationary--depending on design intent). Space Tourism will, eventually, also provide access to the lunar and planetary surfaces (eg Mars) providing additional perspectives.

This paper reviews various proposed scenarios of orbital, lunar and interplanetary tourism and examines the opportunity spectra each these provide for star tourism.

Introduction

In late 2002 large numbers of tourists flocked to the small community of Ceduna in South Australia to observe the total solar eclipse of 4 December[9,47], demonstrating the demand for such activities. Likewise, the recent passage of comet McNaught in January 2007 attracted large numbers of star tourists to Southern Hemisphere locations. But star tourism is not a new phenomenon.

Researchers regularly traveled to locations were specific events could be most profitably observed. While Captain James Cook's 1769 voyage from England to Tahiti to observe the transit of Venus[1] is possibly the most famous, the most spectacular is the 1973 observation of the solar eclipse using the fastest commercial plane, the Concorde, flying at Mach 2[41]. While these ventures go out to great lengths to observe the stars, they are not tourism but government and educational sector funded research endeavors.

Star tourism, as perceived for the purposes of this paper, is defined as private individuals traveling to specific locations to satisfy their desire to view planets and stars either unaided ('naked' eye) or with the aim of optical devices (e.g. optical telescopes), but excludes the use of radio-telescopes.

Against a background of terrestrial star tourism and in the context of current developments in the area of space tourism, this paper reviews the various proposed scenarios of orbital, lunar and interplanetary tourism and examines the opportunity spectra each these provide for star tourism.

Current Star Tourism

In the second half of the nineteenth and the first half of the twentieth century there was only limited demand for star tourism. Most major cities in Europe, North America as well as in Australia had an observatory. Some of these observatories conducted research on varied scales, but most were open to the public at regular intervals thus actively engaging the public. The urban night skies changed in the mid-1970s when increased light pollution became an issue, brought about by some aspects of urbanisation, such as suburban sprawl with outside lights; high rises and other office blocks with brightly lit advertising signs and lit roof tops as architectural features; and especially high-lumen street lighting on most inner-urban and all near-urban arterial roads. While some of the observatories are still suitable for viewing the brightest celestial objects, such as the Moon, some planets and a few selected stars, most of these installations have ceased to function effectively and have become heritage places[9,30] or have been transformed into planetaria.

Light pollution has, essentially, given rise to the modern phenomenon of star tourism. In order to experience the night sky and to able to see the fainter stars, the vast majority of urbanized people in the developed countries will have to travel to locations sufficiently far away from the build-up areas. Given the heavy level of urbanization, however, wide-open spaces unaffected by light pollution in the mid-latitudes are no longer common and absent in Central Europe. While there is still a range of research observatories, most are not open to the public for personal use. This limits opportunities for private star tourism.

Ideal locations for the Northern Hemisphere are the Great Plains in North America, the farmlands of Western Russia in Europe, the grasslands in Asia, and most rural areas in the southern and central parts of Australia.

Being continental locations, however, ordinary viewers at such places have to contend with atmospheric variables affecting optical observations[57]; and with climatologic conditions such as localized weather patterns and high-level clouds. Oceanic island locations, such as Mauna Kea (Hawai'i) or La Palma (Tenerife) have no localized issues but are still subject to global weather patterns such as cyclonic systems. An Earth-based location, however, will always have constraints posed by the latitude of the observer that places limits on the sector of the sky s/he can see.

Advantages of space-based star tourism

Given the limitations inherent in Earth-based star tourism, let us now consider the advantages of space-based star observations. These are environmental and conceptual advantages.

The environmental advantages of Space-based star tourism are obvious and quickly summarized. That such an observation location based in Space is preferable to one based on Earth can be easily demonstrated by the quality of images provided by the Hubble Space Telescope launched in 1990 and upgraded as recently as 2002[47]. Any space-based observation platform orbiting Earth or another celestial body such as the Moon or Mars, will have no light pollution, climatic invaguaries (such as a cloudy sky) and no atmospheric distortion to contend with. Very limited atmospheric distortion may occur if an observation platform would be erected on Mars[24], but given the lack of an atmosphere of note, would be near absent, for example, on the surface of the Moon.

The conceptual advantages entail, in a literal and philosophical sense, the point of view. By necessity, astronomy has always been geocentric until the second part of the twentieth century. Although the geocentric view has been obsolete ever since Copernicus' 1543 publication De revolutionibus orbium coelestium[15], it seemed to remain so—at least subconsciously—in many people's minds. The 'blue marble' photograph of a complete and only slightly cloud-covered Earth taken during Apollo XVII in December 1972 has brought home to many a different perspective. It quickly became the icon of Earth in space[45], highlighting our planet's fragility.

Any earth-based star tourism will always be limited in its perspective due to the viewing angle of the location. Moreover, it will be geocentric with a viewer having to rationally assume Earth's position in space. Any space-based star tourism effectively removes this geocentric focus, creating a viewpoint that allows a tourist to personally experience Earth as part of the surrounding universe. Moreover, a space-based viewing platform on the lunar surface will allow tourists to experience a radically different phenomenon: on Earth we are used to sunrise and moonrise, while on the Moon we can experience 'Earthrise,' the moment when Earth comes over the lunar horizon. The power of such shifted points of view must be underrated.

Space tourism

Space tourism is a reality. Apart from official passengers, such as the teacher Christa McAuliffe (1985, perished in Challenger explosion) and journalist Toyohiro Akiyama (1990), paying tourists have flown as part of joint Soviet / United States missions. Paying $20 million for the ultimate joy-ride, Dennis Tito became the first paying space tourist in 2001 (28 April to 5 May) visiting the International Space Station (ISS). The National Aeronautics and Space Agency (NASA) condemned the agreement between Tito and the

Russian space agency at that time, arguing that it endangered the rest of the crew to have an untrained space traveler on board a mission[27,63]. Yet for the Russian Space Industry this was a vital source of income and plans were developed to expand in this market[30,33]. The Russian Soyuz module is rated for three crew, but only requires two for the supply and crew-exchange missions traveling to the ISS twice a year, thus providing capacity for one tourist

Current options

In response, soon after Tito's flight, NASA and its partners in the International Space Station agreed to rules governing who could fly to the outpost as tourists[24,34]. With guidelines firmly set, several more potential space tourists began training in Russia. Since Tito, three other space tourists followed: Mark Shuttleworth (25 April-5 May 2002); Gregory Olsen (October 1-11, 2005); and most recently Anousheh Ansari (September 18- 29, 2006)[36]. Other space tourists are in training with another launch planned for 7 April 2007 taking up Charles Simonyi (flight scheduled to end on 20 April). This tourism venture is a collaboration between Space Adventures Ltd, based in Arlington VA, and the Russian Federal Space Agency (RFSA). With a price tag of US$ 20-25 million and two missions per year the tourism opportunities are currently severely restricted (and soled out until 2009[2]). Plans for budget spaceflight have been revealed across a number of space agencies and aerospace corporations[36,37]. Having won the Ansari X-Prize for successfully having a piloted craft leave atmosphere with SpaceShipOne[68], VirginGalactic, in collaboration with Rutan's Scaled Composites, has plans way to construct and deploy a larger version, SpaceShipTwo, for suborbital flights by late 2008 or early 2009 and has already begun to take bookings[69]. Both VirginGalactic and Space Adventures are developing SpacePorts in New Mexico (USA) and Ras Al-Khaimah (United Arab Emirates) respectively[2].

Future options

Competing with VirginGalactic are Space Adventures who put out a collaborative proposal with a Russian space launch business to conduct tourist orbital flights around the Moon[51,59] with a projected price tag of $100 million for one of two available seats in the first mission[66]. Other companies wanted to send a probe that will crash into the lunar surface, sending live images to be broadcast via the Internet[38,40]. The ambitions of commercial ventures are well beyond orbital tourism. Recent developments have seen a number of proposals emerge for lunar surface tourism[55], including the development of accommodation[55,57], at greatly reduced cost. Ultimately, all of this is a mere matter of time.

Clearly, such tourist ventures to the lunar or Martian surfaces have implications. These have been raised in terms of the management of humanity's cultural heritage on Moon[27,59,61] and Mars[63] as well as the management of space tourists at such sites[59,62], while the possible development impact of human presence on other bodies of our solar system has led to calls for a parks system on Mars[1] as well as the ethical issues surrounding the accidental introduction of contaminating life forms to bodes such as Mars[68].

Demand

In the past decade a number of studies has been carried to assess the market for space tourism in Japan[15,16], the USA[6,17,49], Canada[17], Germany[1], the United Kingdom[2] and more recently Australia[19,20]. The studies demonstrate that interest in space tourism is high, ranging from 34%[49] to over 80%[15], with men being more interested than women. All studies showed that cost was a major factor. The British study, for example, put the costing into the relative spending capacity of the respondents and found hat while 100% would be prepared to spend one month's income on the experience, but only slightly more than 20% would be prepared to spend half their annual income on the experience[2]. Because of the cost factor, the market study carried out by Futron in 2002[6] limited itself to respondents with a net worth (or annual income) exceeding $1 million.

Motivations

The studies also solicited respondents' motivations for the tourism experience, usually in form of multiple choices (or rankings) from a predefined and limited set of options. 'Viewing Earth' ranked highest as motivation in the British[2], German[1], Japanese[15] and US/Canadian surveys[1] The surveys based on the Collins' questionnaire found that between 25 % and 32% of all respondents were interested in making 'astronomical observations.' This option ranked third highest in the Japanese[15] and US/Canadian surveys[1] and fourth highest in the German surveys[1]. The British survey gave respondents the option 'to look deeper into space', which was found to represent the second highest motivation[2].

Realities?

While most of the purely privately-run proposals seem to have faltered (such TransOrbital), and other private projects are facing technological set-backs (Space Exploration Technologies[56]), projects proposed in close collaboration with RFSA or NASA have more chance of success. While the current offerings carry an exorbitant price tag ($25 million) and while projected initial sub-orbital tourist opportunities will also be very expensive ($100,000 and up)[69], there are economic studies that suggest that space tourism is likely become more affordable soon[12,14,49], especially if combined if a mixed market approach (government and private passengers) is espoused[29]. Given the failures of many privately-run proposals, others, however, have argued that space tourism will remain a luxury market for the foreseeable future[7].

Models of space tourism and opportunities for star tourism

Space-based star tourism basically assumes that the observer is located outside the Earth's atmosphere for the duration of the time spent on observing the stars or planets. A range of options either exists or can be conceptualized, ranging from suborbital to stationary locations on the lunar surface. In the remainder of the paper we will review the opportunities for star tourism as the manifest themselves in the various options.

Suborbital

The opportunities for star tourism on such sub-orbital flights are limited as the flights are of short duration (15-20 mins) and the majority of that time the passengers will focus on the novelty feelings of near weightlessness (although mainly strapped into their seats) and will be observing Earth from space. On a technical level, payload space in a suborbital spacecraft will be at a premium, which will limit the nature and size of a telescope that can be carried as such instrumen-tation will compete with the space—and payload weight—of one or two fee-paying passengers. Given the speed of the suborbital plane, a telescope will also require complex tracking mechanisms to stay on target. Finally, actual suborbital flight time in such an experience will be limited and at best one or two people might be able to avail themselves of the opportunity to view stars from (near) space.

Orbital flights

In the orbital tourism model, a crew-rated spacecraft would enter orbit and re-main there anything from a few hours to two days, with the spacecraft circling Earth every 90 min-utes. The tourists would be confined to the spacecraft. Several of the previously stated limitations, especially cabin space, also apply to orbital flights. The opportunity for star tourism will depend on the duration of the flight and the number of orbits. Depending on the configuration of the orbits most of the universe will be visible from an orbiting spacecraft. Despite this, however, the relative closeness to the earth will still provide a limited 'vantage' point. Cost models have shown that or-bital flights may not be significantly more expensive than sub-orbital flights if we disregard the ad-ditional training (and associated costs) required for orbital flights.

Orbital space 'Hotels'

As early as the 1960s the development of on space 'hotels' had been mooted[30] with a range of design proposals on record[7,13,21,52]. The space station or hotel model sees a crew-rated spacecraft docking with on orbiting or geostationary space station, with tourists moving from the ferry craft to the station. At present, the limited number of space tourists enters the ISS. The 'hotel' models either propose a stand-alone commercial space station, or a tourist accommodation module attached to the ISS. Regardless of models, the infrastructure costs associated with commercial space station developments where space tourists can stop over and move from the confines of the spacecraft are several magnitudes larger than 'mere' orbital flights.

Some of these proposed stand-alone hotel developments are projected to provide an artificial level of gravity by having the space station slowly rotate around an axis[27,52]. While this will provide tourists with a viewing experience not unlike a rotating restaurant on a high rise or televi-sion tower, it will hamper serious star tourists as it will limit the time a specific target can be in focus. That limitation can be overcome by positioning the observatories at the endpoints of the rotational axis. Several proposed design concepts, however, use these 'stationary' locations for life-support and docking locations.

Technical considerations aside, the viewing experience from these locations will be more pro-found as tourists have more time and leisure to concentrate on celestial objects of interest. This is counterbalanced by the fact that, apart from arrival and departure only the same surface area of Earth will be visible from the geostationary hotels and that part of the universe will be blocked by Earth.

Inter-lunar space

Additional designs see the placement of such space hotels in the inter-lunar space[12]. The costs involved in both infrastructure development and ongoing maintenance/supply will be a magnitude larger as thrust will be required to leave Earth's gravitational field. From the point of star tourism such hotels will dramatically enhance the tourist experience. The distance to Earth will result in a dramatically enlarge window to most of the universe bar the small segment that is obscured by Earth. The main benefit will be the ability to experience Earth as a 'blue marble' in space and to experience Earth as a planet among others.

Lunar orbit

The next level of space hotel developments sees such installations placed in stationary locations in the Moon's orbit[12]. As before, the level of costs involved in both infrastructure development and ongoing maintenance/supply will be much higher than locations in Earth's orbit but essentially not much more than developments in the inter-lunar space.

From the point of star tourism such hotels would further enhance the tourist experience. In addition to being able to experience Earth as a 'blue marble' in space and to experience Earth as a planet among others, observers will be able to view the far side of the noon, which remains invisible from Earth. Further, tourists will be able to experience the phenomenon of Earthrise. On the downside, the proximity of the Moon itself implies that parts of the universe will be blocked from view.

Ultimately, the design of any of the Earth orbital, inter-lunar and lunar orbital stations is interchangeable. The cost differential will rest in the costs to construct and supply such facilities past the Earth's gravitational field.

Lunar surface

The final options sees developments of facilities on the surface of the Moon. Costs involved with infrastructure development, maintenance and supply, as well as emergency evacuation in case of infrastructure malfunction are several magnitudes higher than in any of the previous options. Plans have been mooted to place a radio telescope on the far side of the moon, thus avoiding interference from radio waves emanating from satellites orbiting earth[26].

From the perspective of star tourism, any observation location on the lunar surface has limitations, as the Moon itself will block much of the universe. The only major advantage is the opportunity for tourists to walk on the lunar surface, thus replicating an experience that has so far been limited to only the dozen astronauts of the Apollo missions.

While any location on the nearside of the Moon will essentially replicate what is already offered by stations in lunar orbit, a station erected on the far side of the Moon will provide tourists with advantage point that makes them part of space without the reassuring visual presence of their own planet, Earth.

Virtual star tourism

The final option that needs to be canvassed is that of virtual star tourism. This involves the deployment of a version of the Hubble space telescope that is controlled by commercial interests. The telescope can be tasked to view sectors of the universe based and the desires of a fee-paying public, with the images relayed to the viewer via the World-Wide Web (WWW). Such a development is in essence a mere extension of the pay-per-view binoculars and telescopes available at many tourist locations. There are proposals to land one or more remote controlled rovers on the lunar surface that can be 'driven' (i.e. controlled) by fee-paying viewers on Earth such as proposed by the now-defunct LunaCorp Project[45]. Again, viewing occurs through the WWW. Such developments would provide a real low-cost and low-personal risk alternative to real space tourism, but also provide a much-reduced experience.

Discussion

While the general implications of the models for star tourism have been raised as part of the discussion of the options, there are more attributes that can and need to be considered. Table 1 compares the models for space tourism mentioned above and correlated their potential against a range of attributes: general aspects of star tourism, the tourists themselves, society as a whole, and the probability that such developments will occur in a 5, 10 and 20-year time frame.

The attributes set out in Table 1 were scored on a six-point scale with higher numbers indicating better outcomes. The average scores for the space tourism models by attribute group (Table 2) show that virtual star tourism scored the highest (4.0) followed by the existing Earth-based option (3.5). All space-based options scored similar (3.1 to 3.3). There are, however, substantial differences between the various attribute groups, such as comparing cost vs. experience. The scoring weighted every attribute and very attribute group equal. If we weight the options based on star viewing quality and cost, for example, then the virtual tourism option far outscores all other option. At the same time, that options ranks for far lowest in terms of tourist experience. If we weight for star viewing quality and tourist experience, then the lunar surface option outscores all others, followed by orbital and inter-lunar space options. Such options, however, are also the most costly.

Outlook

We can anticipate market segmentation. At the elitist end of the spectrum we will see a very limited supply of very high cost opportunities to space stations in the interlunar space and on the surfaces of the Moon and eventually on Mars. For the foreseeable future they will be as exclusive at the currently available space travel opportunities to the ISS. The information available on the demand for space tourism (see above) suggests that Space tourism is viable if prices could be lowered to the $50,000 mark. The 'mass tourism' end of the market will focus on suborbital and especially orbital opportunities, while the low-end of the market will avail themselves to the virtual option.

Literature on the motivations of potential space tourists (see above) suggests that viewing Earth from space is the main motivation for the majority of people. Viewing the universe as a whole and its elements (individual stars and planets) is important to a segment of the market, but at present, and in the near future, not sufficiently so to make the industry viable in its own right. Ultimately, star tourism will need to be seen as value

Table 1. Attributes of the Space-based Star Tourism Opportunities compared to Earth-based and Virtual Opportunities.

	Earth-Based	Sub-orbital	Orbital	Orbital Station	Inter-Lunar Space	Lunar Orbit	Lunar Surface	Virtual
Star Viewing Quality								
Light Pollution	Some	None	None	None	None	None	None	None
Exposure of sky	Hemisphere	Limited	Variable	High	High	Variable	Limited [1]	High
Duration of Observation	V. Long	V. Short	Short	Long	Long	Long	Short	V. Long
Atmospheric disturbance	High	Low	None	None	None	None	None	None
Tourist (Experience)								
Quality of Experience	Medium	High	High	V. High	V. High	V. High	Extreme	Low
Sense of Adventure	Low	Medium	High	V. High	V. High	V. High	Extreme	Nil
Exclusivity (early)	Low	V. High	V. High	V. High	V. High	Extreme	Extreme	Nil
Exclusivity (projected)	Low	Medium	Medium	High	High	High	Extreme	Nil
World View	Geocentric	Geocentric	Mixed	Mixed	Universal	Universal	Universal	Universal
Tourist (Costs)								
Financial Cost to Tourist	Low	Medium	High	High	V. High	V. High	Extreme	Very Low
Risk to Tourist	Low	Medium	V. High	V. High	V. High	V. High	V. High	Nil
Tourist Fitness (physical)	V. Low	Low	V. High	V. High	V. High	V. High	V. High	Nil
Tourist Fitness (mental)	V. Low	Low	Medium	High	V. High	V. High	V. High	Nil
Training required	Nil	Short	Long	Long	Long	Long	V. Long	Nil
Capacity (n° of Tourists)	V. High	High	Medium	Medium	Medium	Medium	Low?	Extreme
Society								
Environmental Impact [2]	Low	High	High	High	High	High	V.High	V.Low
Carbon Cost	Low	High	High	High	High	High	High	V.Low
Earth Resource Depletion	Medium	High	High	High	V. High	V.High	V.High	Low
Risk to Others	Low	Medium	Low	Low	Low	Low	Low	Nil[3]
Probability								
In next 5 years	In place	High	Low	V. Low	V. Low	V. Low	V. Low	Medium
In next 10 years	In place	V. High	High	Medium	Medium	Medium	Low	V.High
In next 20 years	In place	V. High	V. High	V. High	High	High	High	V.High
In next 30 years	In place	V. High	V. High	V. High	V.High	V.High	V.High	V.High

[1] Moon shadow; [2] on Earth and on the Moon, but excluding CO_2 cost; [3] after deployment.

Table 2. Average scores for each space tourism model by attribute group. Data from *Table 1* scored 0-6

	Earth-Based	Sub-orbital	Orbital	Orbital Station	Inter-Lunar Space	Lunar Orbit	Lunar Surface	Virtual
Star Viewing Quality	2.8	3.0	4.3	5.0	5.0	5.0	4.3	5.5
Tourist (Experience)	2.2	3.4	3.8	4.4	4.6	4.8	5.6	1.0
Tourist (Costs)	4.8	3.7	2.0	1.8	1.5	1.5	1.0	5.8
Society	3.8	2.3	2.5	2.5	2.3	2.3	2.0	3.5
Probability	6.0	4.8	4.0	3.8	3.3	3.3	3.0	4.5
Total (excl. probability)	3.5	3.2	3.1	3.3	3.2	3.3	3.1	4.0

adding to the space tourism product. It is conceivable that viewing Earth from orbit will one day become a commonplace option and loose its novelty value. Star tourism can then be ready to provide that 'little bit extra.'

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