[title] On To The Lunar Olympics !

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Abstract

Recently announced plans for lunar bases give space agencies scope to perform their traditional role of developing new technologies for use in space. The know-how needed for development of permanent lunar settlements includes materials prospecting, materials processing, and construction. Once these technologies are developed they will be available for companies to use for commercial purposes. One activity that could attract commercial investment is the development of sports events in lunar gravity. Sports on Earth are already a major industry: for example, the Olympic Games nowadays involve budgets of tens of billions of dollars. In lunar gravity both existing sports and new sports, such as bird-like flying, will surely be of great interest to many people. In order to realize the first Lunar Olympics during the 2040s, companies which have not so far been related to the space industry will also participate, bringing new ways of thinking about space activities, and stimulating innovations. For this, "space marketing" will be important to promote space development to the general public by setting exciting and popular goals that will become people's dreams, and also enable them to be achieved.

1 Introduction: Space Tourism Potential

Over the past few years, several countries have announced plans for constructing and operating lunar bases, and have started work to realise them. For example, China has announced that it will build a base at the lunar south pole, as part of its “Space Silk Road” plan, while NASA has announced its “Artemis” project for a base in lunar orbit and another on the lunar surface. Japan’s Toyota motor company is developing a crewed “Lunar Rover” for use on the lunar surface with JAXA from 2029, as part of “Artemis”. Roscosmos is developing a lunar lander, targeting 2029 for its first crewed landing on the Moon, and will collaborate with China in a lunar base. These projects give space agencies scope to perform their traditional role of developing new technologies for use in space, which will then become available for commercial use. Although the great majority of commercial space activities to date have involved information and communications technology (ICT), the potential growth of these activities, and the employment they may generate, are clearly limited. By contrast, as on Earth, a commercial use which has the potential for growth to very large scale is tourism.

Many commentators are very conservative in their expectations for the growth of space tourism, assuming that it will remain limited to small numbers of very rich customers. This may be based on the fact that no fully reusable launch vehicles optimised for carrying passengers to orbit have been developed yet. Nor indeed has there ever been a single detailed design study of such a vehicle, though there have been several paper studies by experienced aerospace engineers that concluded that they are feasible and likely to reduce the cost of flight to low Earth orbit by about 99%. For example, Dr Ivan Bekey, long-term head of NASA’s Advanced Projects Office, concluded that reusable orbital passenger-vehicles could be developed for a cost comparable to the development of a new airliner [Bekey, 1998].

In the absence of any studies contradicting this, the authors take the view that fully-reusable, 2-stage, passenger-carrying, orbital spaceplanes are feasible and, once developed, they will enable traffic to and from facilities in low Earth orbit (LEO) to grow to large scale. With orbiting hotels and sports centres enabling passengers to experience life in weightlessness, costs will fall progressively, and space travel will eventually grow to large-scale like passenger air travel. If so, rocket propulsion will take its place as the seventh great transportation technology, following the six precedents of horse-carriages, sailing-ships, trains, steamships,

cars (and trucks and buses) and aeroplanes. Each of these technologies became so popular that they spread throughout the world, creating some 100 million jobs, and thereby contributed greatly to economic growth.

The fully-reusable, vertical-takeoff-and-landing (VTOL) "Starship" launch-vehicle, which is currently being developed by SpaceX Inc, is scheduled to carry passengers on a return-flight around the Moon within a few years. However, although reusable, "Starship" is designed primarily for travel to Mars, and so it is far from optimal for carrying passengers to LEO, which requires a vehicle with a smaller payload but a larger cabin agreeable for passengers. For this a vehicle more like the Japanese "Kankoh-maru" vehicle, proposed in the 1990s by the Japanese Rocket Society (JRS) to carry 50 passengers to LEO, or a 2-stage spaceplane would be preferable.

The start of space travel services using reusable vehicles was triggered by the successful sub-orbital flights of the "SpaceShipOne" spaceplane in 2004. These led to the development of "SpaceShipTwo", which is expected to operate commercial, sub-orbital space flight services during the 2020s. The VTOL "New Shepard" vehicle is scheduled to start commercial sub-orbital flights in July 2021. JAXA's "RVX" reusable VTOL test-vehicle, which is due to start test-flights in 2021, is a prototype of a sub-orbital VTOL passenger-vehicle. In order to keep these sub-orbital projects in perspective, it is important to remember that the unmanned A-4b sub-orbital rocketplane that was flown in the early 1940s, and was followed by a design study of a piloted version (which was not completed), could have become the basis of sub-orbital passenger flight services during the 1950s – fully 70 years ago – if this had been permitted.

Phase	Year	Travel service	Development /yrs	Investment	Price/person
1	2020s	Sub-orbital	**5 – 10 years**	100s of $M	$ Thousands
2	2030s	Orbital	**15 – 20 years**	$ Billions	10s of $K
3	2040s	Moon surface	**25 – 30 years**	10s of $Billions	100s of $K

Table 1: The first three phases of passenger space travel

The numerical estimates in Table 1 are only "round figures", whereby each successive phase of space tourism costs about ten times the cost of the previous phase. Based on the successful start of sub-orbital space flight services during the 2020s, it seems reasonable to foresee orbital tourism services developing through the 2030s. Although reusable orbital vehicles optimized for passenger travel are still not being developed, orbital hotels are already under development by Bigelow Aerospace Inc, which has a module attached to ISS, and Orion Span Inc which is developing the "Aurora" hotel, among others. Once reusable passenger vehicles are in regular operation, these and other hotels will become profitable, and competition between orbital hotel companies will lead to rapid improvement.

The existence of orbital hotels of different shapes and sizes will help to generate demand for passenger flights to orbit, leading to falling costs and thereby helping the development of a range of business activities in space which are held back today by high transportation costs and resulting low demand. Once there is demand in orbit for water, aluminum, glass and other products that can be made from raw materials from the lunar surface or asteroids, these can become major sources of materials for construction of accommodation and manufacturing facilities in space. New technologies, including robotics and 3-D printing, could be used to make large chambers in orbit for tourist facilities, including hotels, sports centres, factories and others. For example, cylindrical structures are very suitable for automated assembly systems which can be used on larger and larger scale. The success of such developments in Earth orbit will be useful precursors to realising lunar tourism.

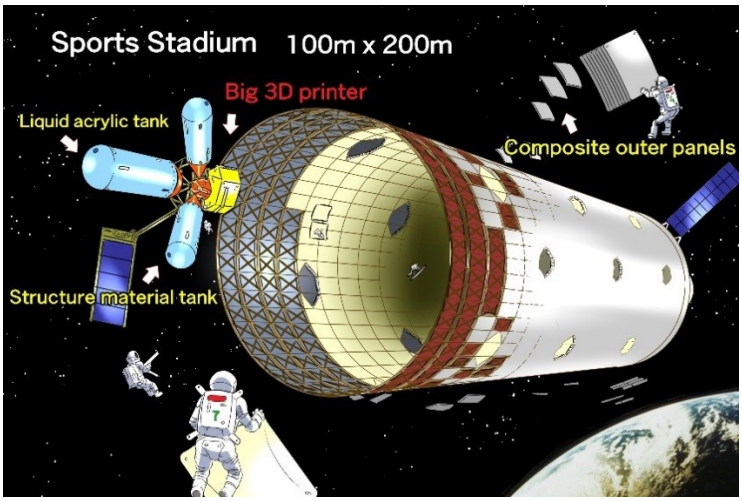

Figure 1: Orbital assembly of large facilities

2 Feasibility of Lunar Tourism

The current “father of space tourism” (so named on the basis of having argued for its importance for nearly half a century) founder of Bristol Spaceplanes Ltd, David Ashford has explained how developing reusable, orbital launch vehicles will, in addition to reducing the cost of passenger travel to and from orbit, also reduce the costs of establishing and operating lunar facilities by 90% by comparison with expendable vehicles [Ashford, 2009]. Hence, once LEO tourism using fully reusable launch-vehicles is under way, the development of lunar facilities and activities will be greatly facilitated.

The aerospace knowhow already accumulated about technology and operations in Earth orbit and near-lunar space enables us to outline the main infrastructure components that need to be developed for lunar tourism. First, the seven components needed to provide regular transportation between the lunar surface and Earth are shown in Figure 2 and listed below:

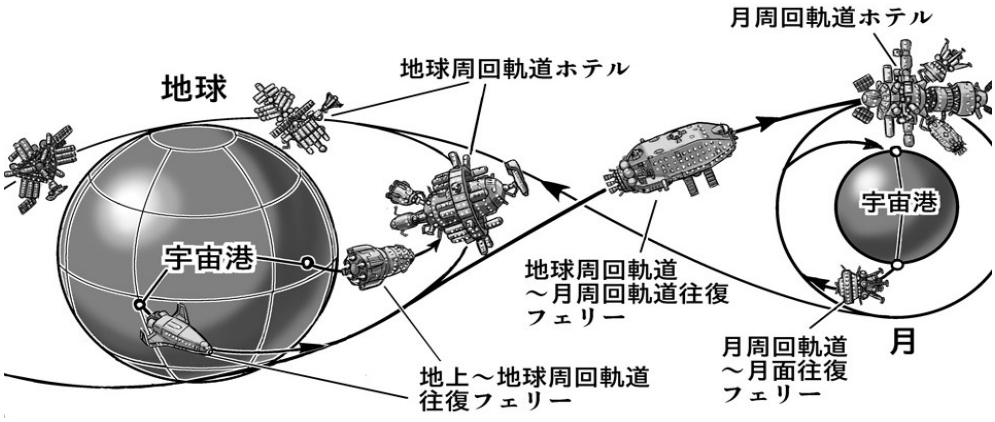

Figure 2: The seven major components of Earth-Moon travel infrastructure

1 Earth surface orbital spaceports
2 Earth surface-to-orbit passenger ferries
3 Low Earth orbit transit-hotels
4 Earth-orbit-to-lunar-orbit spaceliners
5 Lunar orbit transit-hotels

6 Lunar surface-to-orbit passenger ferries

7 Lunar surface orbital spaceports

In addition to these major components, a wide range of related systems will be involved in handling passengers, as well as cargo vehicles, orbital hotels, sports centres, and orbital factories. In order for lunar tourism to grow to large scale, a further range of lunar surface infrastructure will also need to be designed and constructed, including systems and facilities for surface transportation, power generation, accommodation, mining, factories, sports and other functions. The know-how needed for development of these lunar surface activities based on permanent settlements and tourist accommodation includes materials prospecting, materials processing, and construction, which will create opportunities for numerous commercial activities. From the economic point-of-view, tourism is the most promising commercial use of these capabilities, since it has the potential to grow to large scale. Even 10 million passengers per year, (being no more than the daily number of air travel passengers in 2019), will generate Trillion-dollar revenues. Such a prospect will enable companies to invest far more in lunar surface development than government space agencies.

Although the first phase of lunar habitation will use modules produced in factories on Earth, like the international space station (ISS), permanent settlement and large-scale activities will require the development of lunar construction techniques using lunar materials. As on Earth, detailed construction planning will start with study of soil mechanics in the location of the planned buildings. It is widely assumed that the first permanent bases will be built at both the North and South lunar poles, due to the availability of continuous solar energy at these sites, thereby avoiding the two weeks of cold, dark lunar night-time that is experienced each month everywhere else on the Moon. Later bases will surely be built at other sites, but the first generation of tourist facilities seem likely to be polar. Lunar buildings will be pressure-vessels with an air pressure difference of one atmosphere above the vacuum outside, and so many external structures will be partially spherical or cylindrical. Low lunar gravity will make it possible to construct even large domes from aluminium and glass, instead of steel as needed on Earth. For example, a hemi-spherical dome some 500m in diameter would use about 100,000 tons of glass and 20,000 tons of aluminium, which are the typical annual output of modern glass and aluminium factories.

2.1 Role of Lunar Sports

The idea that sports in lunar gravity will be interestingly different from sports on Earth is an old one. Figure 3 is a 2006 illustration published by NASA expressing this: hurdles are about 3 metres high; a diving board is at a height of about 30 metres; the basketball basket is at a height of about 15 metres above the ground, and so on. NB the dome construction illustrated is a very advanced design, comprising very large expanses of glass supported by a small number of slender beams, free-standing in the lunar vacuum. By contrast, a first-generation sports stadium may well be built inside a larger “dome city”, with smaller glass panels, and a much lower ratio of glass area to aluminium beams.

Figure 3: Lunar surface sports stadium

In addition to existing sports, new sports will surely also take advantage of the new environment. The most famous of these is “bird-like” flight, first discussed by Robert Heinlein in his 1957 short story “The Menace from Earth” [Heinlein, 1957], and as seen in the upper right corner of Figure 3. This will surely be of great interest to large numbers of people, both as participants and spectators, and so also for businesses. All lunar sports are likely to be entertaining to watch, due to their novelty, so that broadcasting of sports events and games to audiences on Earth could become popular even in the early days when the number of actual participants is still small.

Hence lunar sports activities and events seem likely to attract substantial commercial investment, once lunar construction techniques are sufficiently developed to build safe lunar accommodation and sports facilities. Sports on Earth are already a major industrial sector, which involves large numbers of participants in every country, and employs large numbers of people in various roles world-wide, including sports facility design, construction and operation, sports event management, coaching for all different sports, management of innumerable teams, sports science and training, dedicated sports media, marketing, insurance and others. As major examples, the Football World Cup and Olympic Games nowadays involve budgets of tens of billions of dollars, and participation from nearly every country in the world.

The participation of large numbers of the general public is a necessary condition for commercial space activities, including lunar development, to grow to large scale. Consequently, it is promising that sports activities in lunar gravity may become sufficiently fascinating to large numbers of the general public in every country, particularly younger generations, that it will be possible for their development to be financed commercially. This will ensure that they grow unstoppably once the infrastructure and technologies needed for their realisation are developed.

3 Lunar Olympic Games

It may seem to be “jumping the gun” to discuss the feasibility of Lunar Olympic Games even before a single person has visited the lunar surface since the 1970s. However, the authors contend that starting already to prepare to hold Olympic Games on the lunar surface during the 2040s will bring many benefits - economic, social, cultural and geopolitical. Table 1 above showed a possible timeline for the development of space tourism services, leading to lunar tourism during the 2040s. If lunar construction technology is developed during the 2030s, this will enable lunar surface development, including sports facilities, to grow through the 2040s. Early outline planning for Lunar Olympics will contribute to guiding the preparatory activities both on Earth and in low Earth orbit that will be needed in order to plan and build needed infrastructure and dedicated lunar sports facilities.

3.1 Participation by Companies New to Space

In order to realize such a special event as Lunar Olympics, for which many people worldwide will have high expectations, many companies which have not so far had any connection to the space industry will surely also participate. In doing so, they will bring new ways of thinking about space activities, and stimulate numerous innovations both in the space-related services available and in the technologies used to supply them. For this purpose, we advocate the importance of "Space Marketing" to promote space development to the general public by planning a series of exciting and popular goals that will become many people's dreams, and also enable them to be achieved.

For example, as tourism services grow to include suborbital space flights during the 2020s, and then travel to and from hotels and sports centres in low Earth orbits during the 2030s, this will involve major roles for travel companies, hotels and restaurants, insurance, marketing and legal services, new types of clothing, sports equipment and other products and services. Entertainment media will also play a role, through the creation of related games, websites, videos, films, television programmes and printed materials. Marketing already plays a major role in planning and accumulating the investment needed for major sports events, including for the leading global sports events, the football World Cup and Olympic Games. It could play a central role in generating the wide public support that will be needed in order to accumulate and manage the large-scale investments required to realise Lunar Olympics.

From this point-of-view, and remembering the marketing saying that “You sell the sizzle not the steak”, the idea of Lunar Olympic Games is so striking and attractive, particularly for younger generations looking for a bright future, that starting to plan the first Lunar Olympics already can be considered an economically and socially strategic initiative.

3.2 Youth Inspiration, Culture and Employment

Hence an important benefit of starting already to plan the first Lunar Olympics is the cultural benefits this will bring. For many young people, spending some years as a dedicated athlete can be valuable preparation for a successful professional career, either within the world of sports, or in other fields of business or public life. This is because serious sports training includes not only disciplined physical and mental training, but also planning campaigns over several years in order to participate in major competitive sports events, such as Olympics. Moreover, different sports are interestingly different: training in a team sport brings many other important lessons, including tactics, leadership, team coaching, training and management. These valuable educational lessons and experiences from serious sports participation contrast with the endless onslaught of trivia which the mass media inflict on young people in order to sell unimportant consumer products and services.

In addition to these cultural values of sports, well-known for thousands of years, the strong attraction of space activities for young people potentially offers many new experiences and commercial opportunities. Consequently, as a new field which promises to grow to large scale, space sports, both in orbit and on the lunar surface, will surely create many new career opportunities. Finally, teaching younger generations these reasons for optimism about their future, instead of the pessimistic vision that much mass media broadcast, is highly desirable.

3.3 Geopolitical Benefits and Beyond

From the point of view of the general public, the most important objective of geopolitics is surely to avoid war – and particularly any more major wars. Unfortunately, as Carrol Quigley discussed in his book "Tragedy and Hope", western economies, most notably the US economy, have a dangerous structural dependency on continuing heavy expenditure on weapons manufacturing and use [Quigley, 1966]. As an example, US federal government funding for military and security services is about $1 Trillion per year – approximately the same as all other countries in the world combined. A major reason why it continues at such a high level is made clear by considering the economic consequences of cutting this budget by, say, 50%. $500 Billion of spending in the US economy would need to be replaced by other business activities in order to avoid a severe recession, possibly leading to depression. Given sufficient time, new business activities could grow to fill this gap, but this would take at least several years, which is too long compared to the electoral cycle for most politicians to support. Consequently, the waste and global threat from massive, unnecessary spending on development of weaponry of every sort continues, stimulating an "arms race" with other countries.

In addition today, rapid technological growth is driving the growth of other new businesses which are expected to reduce employment in many existing fields: robotic factories and warehouses are eliminating much manual work; self-driving trucks are about to displace many millions of drivers; and Blockchain-based AI systems are soon going to reduce the need for millions of white-collar jobs including bankers, lawyers, accountants and bureaucrats. These effects of technological progress greatly increase the potential for productive leisure, but also pose serious challenges to government facing this unprecedented situation.

One hundred years ago, Keynes and other economists suggested that economic growth might end around 2030, due to the lack of new work. We are now reaching that point in human history, and we can see that, if orbital travel services had been developed half a century ago, this could have already created tens of millions of new space-related jobs. Instead, we have experienced decades of growth of ICT, which is eliminating many earlier forms of employment before the cornucopia of potential new jobs that will be created as human civilization spreads out into space in the "5th Industrial Revolution", or "Space Renaissance", and enriches the world economy [Collins & Arai, 2017].

The half-century delay in using rocket propulsion for passenger travel has deprived the world of a much-needed source of large-scale new employment. This is important because of the large amount of employment that is being eliminated by the current "4th Industrial Revolution". In striking contrast to the fields of work about to lose large numbers of jobs due to ICT growth, the many popular consumer services comprising the tourism industry employ very large numbers of people, as the number of tourists grows to include an ever-larger proportion of the population. Space tourism services share this general potential to employ large numbers of people, while adding a wide range of new possibilities. Fortunately there is no known bottleneck to prevent sub-orbital, orbital and lunar tourism from growing like air travel to serve billions of passengers per year, thereby employing tens of millions of people in supplying these new services, in a "5th Industrial Revolution". Safety, energy supply, pollution, shortage of natural resources, orbital debris – none of these is an unsurmountable constraint on the potential growth of passenger space travel to grow as large as air travel.

Moreover, a vitally important benefit is that a substantial proportion of the employment created in realizing space tourism services will be in aerospace engineering and operations, which involve many of the same engineering skills as those used in military equipment production and utilisation. Consequently, a transfer of work from warfare preparations to peaceful space tourism businesses will literally be easy: all that is needed to start the transition of perhaps half the military budgets of OECD countries and their competitors is to invite bids for substantial contracts to start designing and developing the seven key infrastructures needed to enable lunar surface development up to the first Lunar Olympics during the 2040s.

While it is of course necessary for countries to have sufficient defence capabilities, international peace treaties, and confidence-building measures such as mutual inspections and "open skies" agreements can greatly reduce the scale of military budgets needed. Moreover, in the modern world, popular support is a vital aspect of national security, and it is clear that governments of countries that contribute to developing space tourism through its three phases as far as Lunar Olympics will have far more worldwide popular support than a country which did not participate, but concentrated its space development efforts on military projects.

In 1985, NASA was given the additional responsibility " *. . . to seek and encourage, to the maximum extent possible, the fullest commercial use of space*." This was followed by similar requirements being placed on space agencies in Europe, Japan and elsewhere. Tourism is clearly a commercial use of space, and so NASA and other space agencies should have been working to realise space tourism services in order to follow this legal requirement for nearly 40 years. However, they have not done this – despite having spent about $1 Trillion of taxpayers' money during this time. Now is the time to use their huge resources of aerospace knowhow to help "*to the maximum extent possible*" to develop fully-reusable, orbital passenger vehicles so as to achieve airline operations. This will enable newly established "spacelines" to use both space engineering and airline expertise to grow this new industry as fast as possible. The success of the industrial revolution that started in Europe was largely due to free participation by the general public, enabling the endless stream of innovations that have made democratic societies so much more economically productive than authoritarian societies. Space activities are likely to follow the same pattern: once the general public are able to freely travel to space and back, economic growth in space is likely to continue and spread without limit.

4 Summary

Mr Terada, deputy CEO of Toyota Motors, said that his company's new project to develop a "Lunar Rover" in collaboration with JAXA is extremely popular with the company's engineers. The same will surely be true of engineers who work on the design, development, manufacturing, assembly and operation of the innumerable technological systems needed for Lunar Olympics. These include not just the "big seven" major infrastructure systems shown in Figure 2 above, but also such popular projects as sports facilities in low Earth orbit and on the lunar surface – as well as many related systems such as orbital hotel accommodation with capacity for eventually millions of guests. In order to provide a focus for these efforts, the authors suggest that no other project offers a more attractive future vision for the human race than to aim to realise the first Lunar Olympic Games during the 2040s. Among other advantages, the world-wide creation of new businesses needed to achieve this goal promises to create enough new employment to outweigh the threat from the rapid spread of ICT, while substituting for dangerous military expansion.

Those tempted to belittle or criticize the idea of the Lunar Olympic Games as wasteful or even trivial should remember that most economic growth does not arise from producing goods and services that people "need": it arises from supplying goods and services that people **want to buy**. This commercial demand is what drives the growth of all new companies, enabling them to become major employers. Developing sports facilities on the surface of the Moon, with all the related systems needed, will offer numerous fascinating creative challenges for younger generations in many fields, while also creating demand for a wide range of new technology development needed for the 5th Industrial Revolution. As seen in Table 1, the three phases of space tourism will start in succession, but they will each take longer to develop, and so the planning and development of all three phases should start in the near future – including planning of the first Lunar Olympic Games.

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