Academic Research in
The University of Southern California (USC)
Near-Term Lunar Settlement Research Group (N-TLSRG)
and on the Moon

Generating $100 Billion/Year Income from an O'Neill Space Settlement on the Moon

J. Wertz, 4/25/23

The goal of the USC N-TLSRG is to provide the background research and data needed to create near-term, low-cost, profit-making, commercial settlements on the surface of the Moon that, in turn, provide lunar tourism, entertainment and education, scientific research (including the first research into gravitational biology), low cost, clean energy for Earth, and a start for human expansion into the solar system.

Summary

O'Neill Space Settlements were originally intended to be very large colonies (up to 20 miles long) built in space at the Lagrange Points ahead of and trailing the Moon in its orbit about the Earth. Reducing the Space Colonies in size and building them on the surface of the Moon can dramatically reduce the cost to the point where it is readily feasible in the current economy and has multiple other advantages, the most important of which are:

- The use of ^{3}He (available on the Moon, but not on Earth) to generate clean energy on Earth without any radioactive waste
- Generate an enormous amount of previously unavailable scientific data from optical and radio observatories on the far side of the Moon and experiments on the Moon and in space
- Create a literally out-of-this-world tourist attraction and a romantic location in 1/6th g
- Create a near-term profit-making business which can, in less than a decade, generate an income of over $100 Billion/year from a settlement or colony of 1000 people and growing

Because of the generation of a very large, near-term income, the development of a lunar colony or settlement can be done by the commercial community rather than by the government, which further reduces both cost and schedule. Commercial development spreads the cost over multiple organizations and doesn't demand that every element succeed financially. If the Marriott does not succeed, it can be replaced by Motel 1/6th without going through a 1-2 year bidding and award process. In many respects, building the Lunar Settlement is more similar to settling California (including the gold rush) than to building the Space Station.

The extensive work by O'Neill's supporters provides a major step toward creating the Lunar Settlement in that it serves to validate in some detail the technical feasibility of the colony and the methods for building it. Creating a university-based N-TLSRG allows much of the remaining background work to be done quickly and creatively by graduate students here on Earth and who can become some of the first academicians doing work on the Moon itself. This group can also help energize the motion of mankind into the solar system.

Background

In Sept., 1974, Princeton physics professor Gerard K. O'Neill introduced the world to the idea of colonizing space itself, rather than the Moon or planets, in an article in *Physics Today*. O'Neill's approach gathered a large number of professional supporters. O'Neill himself testified before Congress and led a series of professional conferences that explored the technical, economic, and social aspects of colonizing space with large numbers of people located primarily at the L4 and L5 Lagrange Points 60 deg leading and trailing the Moon in its orbit about the Earth. (This led to the L5 Society which eventually became the National Space Society.) Material for constructing the very large cylindrical colonies would be brought primarily from Moon using a mass driver on the Moon's surface, rather than rockets, to overcome the Moon's relatively weak gravity of $1/6^{th}$ g.

In 1999, I began teaching a course at the University of Southern California in the "Design of Low-Cost Space Missions" intended to teach astronautics graduate students about the process of reducing space mission cost by a factor of 5 to 20, based primarily on practical experience with smallsats that were developed and flown for a large number of mission applications, primarily in low Earth orbits. The obvious question generated by the course was whether the techniques developed primarily for smallsats were applicable to large satellites and expensive missions. Consequently, we began spending the last two weeks of the course studying ways to reduce the cost of the most expensive, yet realistic mission that I could think of -- a permanent human settlement on the Moon for 1,000 people. (As one would expect, some of the techniques were applicable and others were not, but by and large it seemed like a workable project with a very large cost savings.)

During course discussions in the Spring, 2021, semester it became clear that what we were discussing was basically an O'Neill Space Colony built on the surface of the Moon. This shift in both perspective and location greatly reduced the cost of the settlement and, equally or more important, provided for very large income generation, estimated at over $100 Billion/yr for a settlement of 1,000 people and growing. It provided very large secondary benefits as well, such as the mining of ^{3}He for clean nuclear energy on Earth, potentially dramatic scientific advances, and a truly unique environment for an unforgettable and romantic vacation in $1/6^{th}$ g.

Perhaps most important, is that changing the perspective from a "large settlement created on the Moon" to a "small version of the O'Neill Colony moved to the Moon" allows us to make use of nearly 20 years of excellent, referried technical work and analyses on how the colony can be implemented and various problems solved. After all, one of the biggest questions has to be, Is it realistically feasible? Can it really be built at a reasonable cost? Is it safe? A Settlement on the Moon is not identical to a colony in space. But it is close enough that we can say, Yes, the lunar settlement is feasible and can be built with today's technology and will be safe for the people living there. We will need to look with care at the basis for the space settlements and determine what is applicable and what is not, but there is no realistic question about whether it can be done. The "looking with care" part is the job of the N-TLSRG.

The Business Case – Making a Very Near-Term Profit from Lunar Colony Development

A key characteristic of the Lunar Settlement is that it is capable of generating a very large income, i.e. reducing cost and generating *external income* = income in excess of the *internal income* needed for sustaining the local population. (Examples of external income would be the cars built in Detroit or the goods from Europe shipped into New York City.) Income generation wants to start as soon as (or even before) the first small settlement starts up on the Moon and, of course, wants to be greater than the cost of creating it.

There are multiple methods of reducing cost. One is reducing transportation cost by using oxygen from the lunar surface for the oxidizer for hydrogen fuel, which could also come from the lunar surface. By far the largest cost saver is doing nearly all of the work inside, rather than outside because this allows us to use normal, everyday equipment, imported from the Earth, rather than specially invented for the Moon. An example of the difference is illustrated in Figs 1 and 2.

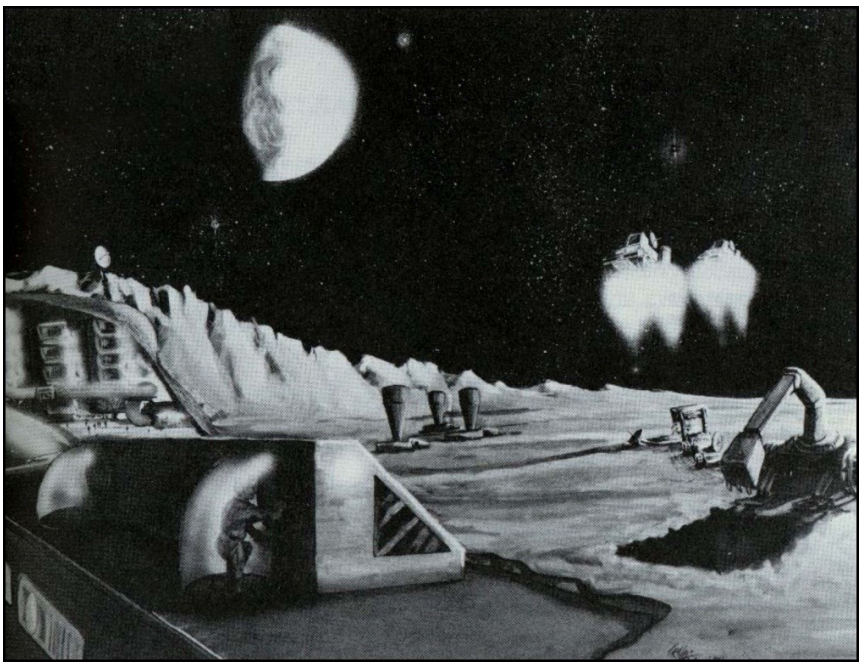

Fig.1. In a traditional lunar colony, nearly all of the work is done outside on the lunar surface. Note in the drawing, the enclosure is so short in height that the crane operator has to kneel for the entire workday.

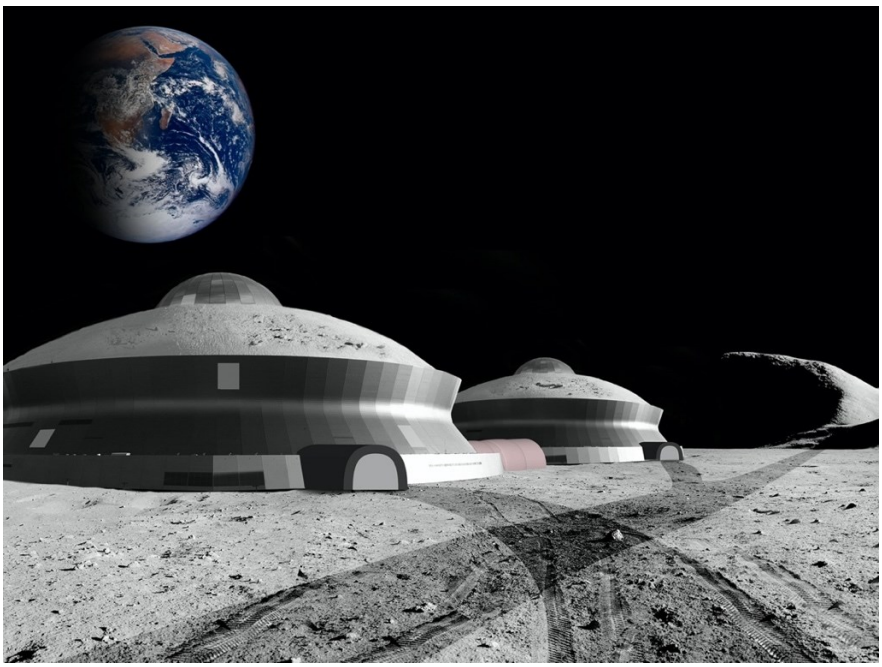

Fig.2. In the proposed lunar settlement nearly all of the work is done indoors. Each of the two domes is about twice the size of a 100,000 seat football stadium and houses the living space and work space for roughly 500 people.

The principal sources of external income for the settlement are summarized in Table 1. Both tourism and space burial will be particularly popular because lunar locations can be seen from anywhere on Earth. (You can stand in downtown Manhattan and point out to your colleague where you stayed and where you visited.) Also, note that Helium-3 is available on the Moon but not on Earth and provides clean nuclear power with no radioactive waste. It can provide clean energy for the entire world with no pollution and no nuclear waste.

Source	Basis (per year)	Annual Income
Tourism	600 tourists/mon = 7,000/year@ $1M–$2M each	$7B–$14B
Space Burial	100,000 to 500,000@$5K–$20K each	$0.5B–$10B
Helium-3	10–30 tons @ $3B/ton	$30B–$90B
Diplomats/National Representatives	200 people $1.0M/person	$0.2B
Entertainment and the Arts	???	$2B–$10B
Mining/Minerals (except ^{3}He)	???	$2B–$10B
Science	Astronomy, Geology, Biology, Physics, Chemistry	$2B–$5B
Solar System Exploration	20% of NASA budget + commercial	$5B
Solar Power Satellites	2–10 @$8.5B each	$17B–$85B
Knowledge Preservation (Lunar Library)	???	$0.5B–$1B
Manufacturing	Low and 0-g manufacturing, structural components for use in space	$2B–$5B
Co-Branding	(Separate estimate available)	$85B–$560B
Total Annual External Income		**$152B–$795B**

Table 1. Principal sources of external income for a lunar Settlement of 1,000 people and growing. Substantially more detail is available on request.

Academic Research in the Near-Term Lunar Settlement Research Group (*N-TLSRG*) and on the Moon Itself

The goal of the N-TLSRG is to provide the background research and data needed to support the building of a real, near-term, growing lunar settlement that is generating an income far greater than its cost. To do this requires creating a detailed model of how such settlements can be built and how they will work. (This does not imply that settlements will necessarily be built this way. Better alternatives may well be found as the process proceeds.) This involves knowledge and research in a great many areas such as astronautics, economics, law, agriculture, space science, energy generation, and social marketing. This, in turn, requires work and background knowledge of multiple individuals and groups, most likely at a large education and research university. Much of the needed knowledge can be obtained by updating and "translating to the Moon" the enormous amount of work done for the O'Neill Settlements. A great deal of this can reasonably be done by graduate students working on either MS or PhD degrees. In any case, the graduate student population is an excellent group for finding an enthusiastic set of people that can support academic, economic, and social objectives and think differently (and near-term) about the problem of expanding mankind onto the Moon and into the solar system.

The most important aspects of this graduate research are:

1. Very diverse range of topics – i.e., it can't realistically be done with expertise from only a single department
2. Some research will be done on Earth and some on the Moon – this implies graduate students on the Moon in the near future
3. Some entirely new fields that haven't realistically been explored at all – gravitational biology
4. Creating and maintaining a clean, closed environment that may be critical to Earth in the future
5. Creating a source of nuclear energy for Earth using He^3 that doesn't leave dangerous radioactive material behind

This leads to an important and exciting set of research topics that will interest potential graduate students from around the world. Representative topics are shown in Table 2.

Area	**Representative Research Topic**	**on Earth or Moon**
Economics	Economic model of cost and income over time and stage of development	Earth
Law	Explore the legality of land and product ownership -- mat be the single biggest impediment to living on the Moon	both
Marketing	How do we sell lunar tourism, sports, and co-branding of Moon products	Earth
Business	Create a business case for multiple lunar businesses	both
Real Estate	How do we build and sell or lease lunar colonies	both
Biology	***Gravitational biology*** is an entirely new field that is critical for the expansion of mankind into the solar system and beyond	Moon
Government	How do we create and build a lunar government that works effectively	both
Astrodynamics	Design and develop supporting infrastructure in low Earth orbit and cislunar space	both

Architecture	How do we create an architecture that reflects the unique properties of the Moon and looks out over the Moon and our outward expansion	both
Education	How do we teach students worldwide about both the Moon and our expansion into the solar system and beyond. This is our new home.	Moon
Geology	New land to explore that is far older than any on Earth, undisturbed by environmental activity, and the size of North and South America combined	Moon
Sports and Entertainment	How do we market these as a part of the new world order	both

Table 2. Representative Research Topics for N-TLSRG. Substantially more detail is available on request.

We would like the N-TLSRG to be a group where individuals, companies, universities, and government organizations can work together to make things happen rapidly and efficiently. Specificially, we have a common goal of making lunar colonization happen for real in the near term and at low cost. We belive that the N-TLSRG, under the auspices of USC is an ideal organization to help make this happen. The opportunity is for the lunar tourism, science, business, and exploration to be available to many of the folks reading this note and not just our kids or grandkids. We would like to have you and your organization join us in a truly "out of this world" expeerience.